Maiga Chang Rita Kuo
Kinshuk Gwo-Dong Chen
Michitaka Hirose (Eds.)

LNCS 5670

Learning by Playing

Game-based Education System Design and Development

4th International Conference on E-Learning and Games, Edutainment 2009
Banff, Canada, August 2009, Proceedings

Springer

Lecture Notes in Computer Science 5670

Commenced Publication in 1973
Founding and Former Series Editors:
Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

Maiga Chang Rita Kuo Kinshuk
Gwo-Dong Chen Michitaka Hirose (Eds.)

Learning by Playing

Game-based Education System Design and Development

4th International Conference on E-Learning and Games, Edutainment 2009
Banff, Canada, August 9-11, 2009
Proceedings

Springer

Volume Editors

Maiga Chang
Athabasca University, School of Computing and Information Systems
1200 Edmonton, T5J-3S8, Canada
E-mail: maiga@ms2.hinet.net

Rita Kuo
Ming Dao University, Department of Digital Design, 369 ChangHua 52345, Taiwan
E-mail: rita.mcsl@gmail.com

Kinshuk
Athabasca University, School of Computing and Information Systems
Athabasca, AB T9S 3A3 Canada
E-mail: kinshuk@athabascau.ca

Gwo-Dong Chen
National Central University, Department of Computer Science and Information Engineering, Jhongli City, 32001 Taiwan
E-mail: chen@csie.ncu.edu.tw

Michitaka Hirose
The University of Tokyo, Graduate School of Information Science and Technology, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656 Japan
E-mail: hirose@cyber.t.u-tokyo.ac.jp

Library of Congress Control Number: 2009931479

CR Subject Classification (1998): K.3.1, K.3.2, I.2.1, H.5, I.3, I.3.7, K.8

LNCS Sublibrary: SL 3 – Information Systems and Application, incl. Internet/Web and HCI

ISSN 0302-9743
ISBN-10 3-642-03363-6 Springer Berlin Heidelberg New York
ISBN-13 978-3-642-03363-6 Springer Berlin Heidelberg New York

springer.com

Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 12727414 06/3180 5 4 3 2 1 0

Preface

With the widespread interest in digital entertainment and the advances in the technologies of computer graphics, multimedia and virtual reality technologies, the new area of "Edutainment" has been accepted as a union of education and computer entertainment. Edutainment is recognized as an effective way of learning through a medium, such as a computer, software, games or AR/VR applications, that both educates and entertains.

The Edutainment conference series was established and followed as a special event for the new interests in e-learning and digital entertainment. The main purpose of Edutainment conferences is the discussion, presentation, and information exchange of scientific and technological developments in the new community. The Edutainment conference series is a very interesting opportunity for researchers, engineers, and graduate students who wish to communicate at these international annual events. The conference series includes plenary invited talks, workshops, tutorials, paper presentation tracks, and panel discussions. The Edutainment conference series was initiated in Hangzhou, China in 2006. Following the success of the first (Edutainment 2006 in Hangzhou, China), the second (Edutainment 2007 in Hong Kong, China), and the third events (Edutainment 2008 in Nanjing, China), Edutainment 2009 was held August 9–11, 2009 in Banff, Canada.

This year, we received 116 submissions from 25 different countries and regions including Austria, Canada, China, Denmark, Finland, France, Germany, Greece, Hong Kong, Italy, Japan, Korea, Malaysia, Mexico, The Netherlands, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Taiwan, Trinidad and Tobago, UK, and USA. A total of 56 papers were selected, after peer review, for this volume. Three related workshops were also held jointly: Enriching Users' Edutainment Through Embodied Video Interactive Games, Research on Educational Robots of Taiwan e-Learning and Digital Archives Program, and Research on Innovative Design of Learning Software and Content.

Topics of these papers fall into 11 different areas: Interactions in Games, Simulation and Animation, Digital Museums and Digital Heritage, Game Design and Development, Social and Cultural Issues, Storytelling and Narrative in Education, Game-Based Learning/Training, VR-Based Education/Training, Vision and Imaging Technology in Games, Educational Robots, and Toys, and Augmented Reality in Education/Training.

We are grateful to the Program Committee for their great efforts and hard work in getting all the papers reviewed in a short period of time. We are grateful to the Organizing Committee for their support of this event. We would also like to thank the authors and participants for their enthusiasm and contribution to the success of this conference.

The success of Edutainment 2009 was also due to the financial and practical support of various institutions, including:

- Athabasca University
- iCore
- NAIT

We would like to thank all of them for offering the opportunity to organize Edutainment 2009 in a way that provided a diversified scientific and social program. Especially, we would like to thank all members of the Program Committee and Organizing Committee for their great job in defining the conference topics, reviewing the large number of submitted papers, and managing to put all the material together for this great event.

May 2009

Maiga Chang
Rita Kuo
Kinshuk
Gwo-Dong Chen
Michitaka Hirose

Organization

Organizing Committee

Honorary Chairs

Judith Brown	Brown Cunningham Associates, USA
Margaret Haughey	Athabasca University, Canada
Frits Pannekoek	Athabasca University, Canada

Advisory Board

Rory McGreal	Athabasca University, Canada
Kinshuk	Athabasca University, Canada

General Co-chairs

Maiga Chang	Athabasca University, Canada
Gwo-Dong Chen	National Central University, Taiwan
Michitaka Hirose	The University of Tokyo, Japan

Program Co-chairs

Xiaogang Jin	Zhejiang University, China
Oscar Lin	Athabasca University, Canada
Hiroaki Ogata	Tokushima University, Japan

Local Chair

Jill Calliou	Athabasca University, Canada

Publicity Co-chairs

Rafael Bidarra	Delft University of Technology, The Netherlands
Yueh-Min Huang	National Cheng Kung University, Taiwan
Wu-Yuin Hwang	National Central University, Taiwan
Abdennour El Rhalibi	Liverpool John Moores University, UK
Demetrios G. Sampson	University of Piraeus, Greece
Karen Stauffer	Athabasca University, Canada
Qing Tan	Athabasca University, Canada

Workshop Co-chairs

Tzu-Chien Liu	National Central University, Taiwan
Zhuo Zhang	North East Normal University, China

Publication Chair

Rita Kuo	Mingdao University, Taiwan

Executive Committee

Ruth Aylett	Heriot-Watt University, UK
Jim Chen	George Mason University, USA
Adrian David Cheok	Keio University, Japan
Abdennour El Rhalibi	Liverpool John Moores University, UK
Xiaopeng Zhang	CAS Institute of Automation, China
Ryohei Nakatsu	NUS, Japan
Zhigeng Pan	Zhejiang University, China
Hyun-Seung Yang	KAIST, Korea

Programming Committee

Sangchul Ahn	Korea Institute of Science and Technology, South Korea
Isabel Machado Alexandre	University Campus of Lisbon, Portugal
Daniel Aranda	Universitat Oberta de Catalunya, Spain
Dominique Archambault	University Pierre et Marie Curie, France
Ruth Aylett	Heriot-Watt University, UK
Madhumita Bhattacharya	Athabasca University, Canada
Rafael Bidarra	Delft University of Technology, The Netherlands
Paul Brna	University of Glasgow, UK
Judith R. Brown	Brown Cunningham Associates, USA
Amy Bruckman	Georgia Institute of Technology, USA
Martha Burkle	Southern Alberta Institute of Technology, Canada
Eliya Buyukkaya	University of Pierre and Marie Curie (Paris 6), France
Tak-Wai Chan	National Central University, Taiwan
Maiga Chang	Athabasca University, Canada
Yam-San Chee	National Institute of Education, Singapore
Gwo-Dong Chen	National Central University, Taiwan
Adrian D. Cheok	Keio University, Japan
Thomas M. Connolly	University of the West of Scotland, UK
Nuno Correia	New University of Lisbon, Portugal
Jinshi Cui	Peking University, China
Akshay Darbari	Digital Imaging & New Media, India
Stephane Donikian	IRISA, France
Abdennour El Rhalibi	Liverpool John Moores University, UK

Guangzheng Fei	Communication University of China, China
Marco Furini	University of Piemonte Orientale, Italy
Lisa Gjedde	Danish University of Education, Denmark
Michael Haller	Upper Austria University of Applied Sciences, Austria
Jia-Sheng Heh	Chung-Yuan Christian University, Taiwan
Michitaka Hirose	The University of Tokyo, Japan
Yueh-Min Huang	National Cheng Kung University, Taiwan
KinChuen Hui	The Chinese University of Hong Kong, Hong Kong
Wu-Yuin Hwang	National Central University, Taiwan
Marc Jaeger	INRIA, France
Xiaogang Jin	Zhejiang University, China
Bin-Shyan Jong	Chung-Yuan Christian University, Taiwan
Posada Jorge	VICOMTech, Spain
Takayuki Kanda	Advanced Telecommunications Research Institute Int'l, Japan
Börje Karlsson	Pontifical Catholic University of Rio de Janeiro (PUC-Rio), Brazil
Jörg Kienzle	McGill University, Canada
Gerard Jounghyun Kim	Pohang University of Science and Technology, South Korea
Sehwan Kim	University of California, Santa Barbara, USA
Kinshuk	Athabasca University, Canada
Frank Klassner	Villanova University, USA
Chen-Wo Kuo	National Palace Museum, Taiwan
Rita Kuo	Mingdao University, Taiwan
Cecilia Sik Lanyi	University of Pannonia, Hungary
Mona Laroussi	INSAT/USTL, Tunisia
Fong-Lok Lee	The Chinese University of Hong Kong, Hong Kong
Jongweon Lee	Sejong University Seoul, South Korea
Steve Leung	Athabasca University, Canada
James Quo-Ping Lin	National Palace Museum, Taiwan
Oscar Lin	Athabasca University, Canada
Craig Lindley	University of Gotland, Sweden
Eric Zhi-Feng Liu	National Central University, Taiwan
Tzu-Chien Liu	National Central University, Taiwan
Zhenjiang Miao	Beijing Jiaotong University, China
Wolfgang Mueller	University of Education Weingarten, Germany
Ryohei Nakatsu	National University of Singapore, Singapore
Hiroaki Ogata	Tokushima University, Japan
Yoshihiro Okada	Kyushu University, Japan
Amalia Ortiz	VICOMTech, Spain
Zhigeng Pan	Zhejiang University, China
Mingyong Pang	Nanjing Normal University, China
Eva Petersson	Aalborg University, Denmark
Jon A. Preston	Southern Polytechnic State University, USA
Marc Price	BBC Research , UK

Manjunath Ramachandra	Philips Electronics, India
Theresa-Marie Rhyne	North Carolina State University, USA
Tim Roden	Angelo State University, USA
Demetrios G. Sampson	University of Piraeus, Greece
Ulrike Spierling	University of Applied Sciences in Erfurt, Germany
Karen Stauffer	Athabasca University, Canada
Chuen-Tsai Sun	National Chiao Tung University, Taiwan
Mohd Shahrizal Sunar	Universiti Teknologi Malaysia, Malaysia
Ruck Thawonmas	Ritsumeikan University, Japan
Harold Thwaites	Multimedia University, Cyberjaya, Malaysia
Hans Vangheluwe	McGill University, Canada
Clark Verbrugge	McGill University, Canada
Frederic Vexo	Ecoles Polytechniques Fédérale in Lausanne, Switzerland
Charlie Wang	The Chinese University of Hong Kong, Hong Kong
Dai-Yi Wang	Providence University, Taiwan
Yangsheng Wang	CAS Institute of Automation, China
Toyohide Watanabe	Nagoya University, Japan
Dunwei Wen	Athabasca University, Canada
Kok-Wai Wong	Murdoch University, Australia
Woontack Woo	GIST U-VR Lab., South Korea
R. Michael Yang	North Carolina State University, USA
Ruwei Yun	Nanjing Normal University, China
Xiaopeng Zhang	CAS Institute of Automation, China
Zhuo Zhang	North East Normal University, China

Table of Contents

Interactions in Games

Simulation and Animation

Digital Museum and Digital Heritage

Game Design and Development

Social and Cultural Issues

Storytelling and Narrative in Education

Game-Based Learning/Training

VR-Based Education/Training

Vision and Imaging Technology in Games

Educational Robot and Toy

Augmented Reality in Education/Training

Enriching Users' Edutainment through Embodied Video Interactive Games

Researches on Educational Robots of Taiwan e-Learning and Digital Archives Program

Researches on Innovative Design of Learning Software and Content

Gamers against All Odds

Anna-Sofia Alklind Taylor, Per Backlund, Henrik Engström,
Mikael Johannesson, and Mikael Lebram

InGaMe Lab, University of Skövde
Box 408, 541 28 Skövde, Sweden
{anna-sofia.alklind.taylor,per.backlund,henrik.engstrom,
mikael.johannesson,mikael.lebram}@his.se

Abstract. The goal of the project presented in this paper is to enable motor rehabilitation to stroke patients in their home environment and to utilise game enjoyment to achieve frequent training. Stroke patients have an average age above 70 years, which implies that they typically do not belong to a gaming generation. In addition, these patients suffer from motor, and many times cognitive impairments, which make traditional games extremely difficult to use. Nearly all work in this area has been conducted in a clinic environment where it is possible to overcome some of these difficulties by letting professionals assist and guide patients.

In this paper, we present the challenges faced, the system itself and the result from a study where five patients were equipped with a game console in their homes for five weeks. The focus of this paper is on analysing the gaming behaviour of patients, which includes the amount of time they spent, the type of games they selected and their comments on the gaming experience. The conclusion from this analysis is that their behaviour resembles that of gamers. They spent significant voluntary time, and it has been possible for patients, with no prior experience of computer games, to enjoy gaming in their homes where they had no professional assistance.

Keywords: Games as motivation, games for elderly, serious games, virtual stroke rehabilitation.

1 Introduction

The goal of the Elinor project is to provide game-based rehabilitation of coarse motor skills in a home environment. Our hypothesis is that games can work as a motivator to do frequent un-assisted training, even when a patient has no prior experience of computers. The application is the result of a creative and exploratory development project in which researchers in the serious games area and experts in stroke rehabilitation collaborated in order to develop a motivating and easy to use tool for re-learning functions lost due to a stroke. The use of IT-support in rehabilitation is well established at clinics but the use of game-based, self-administrated rehabilitation IT in the patients' homes is, however, novel.

To use games for other purposes than pure entertainment is per definition central in the serious games field [1]. A typical case is to use games as a medium to reach the attention of younger people. For the project presented in this paper, the target group is

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 1–12, 2009.

stroke patients. The average age of this group is high and the label “computer game” is more likely to have a negative connotation than the opposite. Still, we believe that the mechanisms that make gaming enjoyable are not depending on age.

Rehabilitation of coarse motor skills acquires repetitive movements which are typically perceived as monotonous. It is a well known fact for care givers that motivation for training drops rapidly once the patient is discharged from hospital treatment. Elinor is a targeted to be used for rehabilitation of stroke patients in their home environment. Our focus lies on the motivational aspects of Elinor and to examine if and how patients have experienced the joy of gaming. The rehabilitation effect was an important goal which affected the design of the system, but the analysis of rehabilitation effect is outside the scope of this paper.

2 Background

The focus of this paper is on the motivational aspects of computer games in the context of stroke rehabilitation. This is still a wide open area with many possible analytical approaches. In this section, we highlight the concepts of gamer and player enjoyment as we find these useful to understand and analyse the outcome of the study. We also give a brief introduction to stroke rehabilitation and the use of virtual reality technology and games in this field.

2.1 Player Enjoyment in Games

There is no simple answer to the question what makes games enjoyable. There is a wide range of suggestions on how to analyse, understand and create games. There are, for example, approaches that use learning [2], competition [3], heuristics [4], narratology [5], or ludology [6], as basis to understand the "fun" in games.

From a game-designers perspective, the main goal is to create interesting, fun, sellable games. This is a creative process similar to the creation of music, literature, and film. In games, there is a unique *gameplay* component which specifies the rules and model of interaction between player(s) and other elements of the game.

Sweetser & Wyeth [7] present an ambitious attempt to unify aspects of enjoyment of games into one single model, based on the theory of flow. A similar approach based on flow theory is presented in [8].

The *GameFlow* model contains eight elements: concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. The *concentration* element means that a game should capture the player's attention and hold it throughout the whole game. *Challenge* means that a game should have tasks that match the player's skill level. The *player skill* element capture aspects related to how players should learn, develop and master the game skills. This relates to the *control* element which covers aspects such that players should feel a sense of control over the game shell, the characters and the actions they take. It is crucial that players feel that their actions have an impact on the game. The *clear goal* element simply means that the game, as well as sections of the game i.e. levels, should have goals that are made clear to the player. The *feedback* element means that players should get immediate response to their actions and they should be informed on their progress towards a goal. The

immersion element relates to the player's involvement in the game, for example, loss of concern for self and an altered sense of time. Finally, the *social interaction* element means that game should support social interactions through the game, such as competitions, collaboration and social communities inside and outside the game.

One benefit of the GameFlow model is that it is inclusive and captures many of the more specialised theoretical models. Sweetser & Wyeth [7] developed the GameFlow model primarily to analyse games but we believe it forms a basis for evaluating player enjoyment as well. The GameFlow model is *gamer centric* rather than *game centric,* which is appropriate for this study.

2.2 Gamers

The gamer concept is widely used and is commonly understood to represent a person who plays (computer) games [9]. An established distinction [10] is made between *hardcore gamers*, who are dedicated and spend much of their time playing, and *casual gamers* who enjoy gaming, but are less concerned with the type of game and may not be willing to sacrifice too much time on it, at the expense of other activities. In addition to these two, there are additional identified types of gamers, such as power gamers, social gamers, leisure gamers, dormant gamers, cyberathletes, incidental gamers, and occasional gamers to mention a few. Dormant gamers [11] is an interesting subclass as these abstain from playing due to other duties such as family, studies or work. A cyberathlete [12], on the contrary, is a professional gamer who's main motivation to play may be to earn money. Hence, none of these types falls under the description that a gamer "is person who frequently plays computer games for amusement". The average age of gamers is still quite low – in 2005 it was 28 years in the UK according to [9]. The game industry is still young, and most companies have a youthful profile. In addition to cultural differences, there are also generational differences in how to interact with technology. Docampo Rama [13] makes a distinction between the *electro-mechanical generation* (born before 1960) and the *software generation* (born 1960 and after) with respect to user interface experience in the formative period (between the age of 10 and 25). A related distinction is that between digital natives and digital immigrants [14]. Based on such studies there are strong arguments for considering the generational aspects when studying gamers. Finally, there is a gender aspect on gaming. Games are by tradition male-dominated [15] and there is a strong male-oriented norm applied to the classification of gamers.

To summarize, the gamer concept contains aspects of gaming behaviour (e.g. types of games, amount of play), motivations to play (e.g. profit, enjoyment, social interaction) as well as a generational and cultural dimension.

2.3 Stroke Rehabilitation and Games

Stroke is the most significant cause of adult disability in the United States and Europe. During the last decade, there has been an increased interest in virtual reality applications as a tool for therapy and rehabilitation (e.g. [16]). However, much of the research in the area of virtual reality for rehabilitation has, according to Flynn et al. [17], been focused on complex systems providing e.g. visual, sensory and haptical feedback. Generally, such systems are expensive and problematic to manage for

non-experts, and therefore limited to usage at the clinic. Due to factors of cost and manageability, such systems are generally impossible to use in a practical way for rehabilitation at home after discharge from a clinic.

A few studies have been reported in the literature on using games for stroke rehabilitation. Goude et al. [18] applies a game design pattern classification to the field of virtual rehabilitation. They present a mapping between impairments and games. Broeren [19] discuss the use of game-like applications that are simultaneously entertaining for the patient and are beneficial for rehabilitation. Some of these games have been studied in a clinical environment using a haptical feedback system. Wood et al. [20] present a specialized game control to play pong, which has been tested in a clinic environment. Flynn et al. [17] present a study with one subject, where the commercial system Eye Toy has been used for home-based stroke rehabilitation. The subject was a retired professor in physical therapy, which enabled insightful feedback, but can hardly be considered to be representative.

A common denominator for the research in the virtual rehabilitation field is that it is heavily focused on the medical aspects, the disease and the limitations of the target group. IJsselsteijn et al. [21] review literature addressing games for elderly and conclude that most work has been focused on accessibility and usability requirements related to functional limitations. There is a great potential in focusing on providing novel and enjoyable games to elderly.

3 The Problem

The main aim with the project presented in this paper is to enable stroke patients to conduct motor rehabilitation in their homes, by playing computer games. A key problem here is to create a motoric interface to computer games where the patients make non-harmful movements that still give them improved motoric ability and increased quality of life. This problem is mainly within the expertise areas of physical and occupational therapists, and is not a focus in this paper. This constitutes the *serious* part of this serious games project. The *games* part, which is the focus of this paper, is to provide patients with an enjoyable experience that will motivate them to conduct frequent rehabilitation. This is a challenge for a number of reasons. Firstly, the target group should use their affected arm to play the game and, together with the rehabilitation requirements, this may be obstacles to the enjoyment. In addition, stroke typically also affects cognitive functions and patients are many times easily exhausted. A game with a lot of graphic and audio stimuli may be inappropriate, in particular if the gameplay is also demanding. Most stroke patients do not belong to a gaming generation, and may not have played games before the stroke. Finally, the playing should be conducted in the patient's home, which means that they have to be able to manage the game console and games themselves.

It became apparent to us at an early stage that a commercial game system, such as Playstation, would not be a viable solution. Existing games on these platforms target a healthy, relatively young audience. They give rich stimuli in terms of graphics, sound and music and have challenging, high paced gameplay. Most games are too demanding for our target group, even in the introductory levels. The Wii console has an

interesting interaction model, suitable for the problem, but the console is not open for tailoring and prototype development. This led us to the decision that we should develop a tailored system to address the presented problem. This means that we have designed not only the game interaction-model, but also the game console itself, the hardware interface, the software interface and the game content. This system has been used in a study where five stroke patients had a game console in their homes for five weeks.

4 The Study

In this section, we present the Elinor system, the usage context and the setting for the study. Since we are focusing on the motivational aspects of the problem, i.e. gamer behaviour of patients, we want to analyse if the enjoyment of games can be observed. To do this we study their gaming patterns in terms of when they play, what they play and the amount of time they spent. We also analyse how patients describe their gaming experience.

4.1 The Elinor Game Platform

To be able to provide an easy-to-use, motion based game environment, a tailor made game console has been developed (Figure 1).

The user controls all game actions by moving two handles. In addition to these handles, the hardware user interface is composed of a power switch, a USB port, a volume control and one button that the user presses to get to the game selection menu. The only prerequisites to use Elinor are a table and a power outlet. The system is configurable to be used by patients with left or right hemiparesis. The menu selections and most game interaction are conducted with the weak side. To avoid harmful excessive training, there is a mandatory 5-minute pause after 15 minutes of play.

Fig. 1. Elinor in action. The player interacts with the game by moving the yellow handles that are connected to the console. In this way the 3D-position of each hand can be read.

4.2 Game Design

The game content of Elinor in the study consisted of fifteen games. The design process was a collaboration between physical therapists, occupational therapists, a psychologist and computer game researchers with various competences. Some of the games were based on classical game concepts, while others were based on physical movements, suitable for rehabilitation. Concern was taken to have a variation in the interaction model both in terms of how much movement was required of the affected arm, and in terms of synchronisation between arms.

The games in Elinor are portioned to players according to a schedule. This scheme was chosen for two reasons; first it gives players a chance to be gradually introduced to the various game concepts; second, it may give players a feel of progression that they are "awarded" new games. Subjects were, however not explicitly informed on when and how they would get new games.

4.3 Experimental Setup

A study was conducted early summer 2008. A total of eight stroke patients were contacted of which six accepted to participate in the study. One of these did however not meet the inclusion criteria, and was excluded from the study. The five subjects participating in the study are presented in Table 1. All subjects suffered from hemiparesis caused by a stroke, but there were some variation in severity.

Table 1. Subjects in the study

Subject	Age	Sex	Hemiparesis	Computer experience	Computer game experience
A	64	F	Right	Minor	Minor
B	71	F	Left	None	None
C	64	F	Left	Minor	Minor
D	52	F	Left	Minor	Moderate
E	70	M	Left	None	None

After initial tests, and a brief introduction to Elinor, each subject got a console installed in their homes together with a USB stick. To enable relatives and friends to use the system, patients are also equipped with a guest USB stick. Player activity – menu action, game selection, game actions, and handle positions are recorded on the USB stick. They did not get any recommendation on how much to play, but were instructed to decide themselves when to play.

They visited the clinic at four occasions during the five week period (once a week). At these visits they met a physical or occupational therapist and a researcher to discuss previous week's gaming activities, based on the data recorded on the USB stick. The subjects were also asked to play two or three different games, and could get guidance in making correct movements. They were also asked about their gaming experiences, and they could get assistance, if they had any problems with a game. After the five weeks had passed, the motoric ability was tested again, and the subjects were interviewed about how they had experienced the rehabilitation.

5 Results

5.1 Gaming Behaviour

As subjects in the study were not given any recommendations on when to play, what games to play or how much to play, it is possible to analyse subjects' gaming behaviour from the usage pattern. There is obviously a rehabilitation aspect to consider here as well. It is possible that a subject used Elinor only motivated by a desire to get improved motoric ability, or she only wanted the enjoyment of the games, or a combination of both. It is impossible to read this from the usage statistics only, but combined with interviews it is possible to get an indication. A comparison with conventional rehabilitation may also give some guidance. The medical experts expressed an expected, acceptable training amount of 15 minutes a day, five days a week – in total 375 minutes. The outcome was that the subjects spent on average 1324 minutes playing – more than three times than expected. There were however a great variation between subjects, as can be seen in Table 2. The table shows the total time per subject, how many distinct sessions they played, and how many days they played at least one session.

Table 2. Total active play time, number of sessions and days of play

Subject	Play time [min]	Sessions	Days
A	703	40	29/35
B	2187	61	31/35
C	1866	88	33/35*
D	1175	59	26/35
E	691	38	18/35

* Subject C lost one day of play due to a hardware failure.

As can be seen from Table 2, subject E spent less days playing than the expected 25. This subject did also spend the least total time, and in interviews express a relatively negative attitude toward computerized training. All other subjects were very positive to this type of training after five weeks of playing. The number of sessions clearly exceed the number of days for all subjects. This means that subjects many times have decided to play for a second time the same day. Conscientious subjects may decide to play once every day, but when subjects play more than once it is more likely that it is driven by joy.

When summarising the playtime for all players per week of play, some “charm of novelty”-pattern is revealed. The total time per week was 27, 28, 21, 17 and 18 hours respectively. In other words there were more playing in the start of the period. There is however, no steep decline in the amount of time spent playing. The weather was an external factor that affected the behaviour of subjects during the study. There were extremely high temperatures in the region for several weeks, and most subjects made remarks that they preferred to be outside in the nice weather. Subject E suffered from physical problems related to the heat, which made it hard to play. In addition to the time presented here, all subjects did also have a substantial amount of recorded “guest-play” during the period.

There is a great variation in popularity of games. The most popular games, in terms of play-time, were Breakout and Puzzle Bubble with 1300 minutes each. Bike Ride is third with 650 minutes, followed by Snake with 500 minutes. The least popular "game" is Paint with 20 minutes. It is remarkable that the most popular games are all based on well-established game concepts, while the least popular is the activity that has no explicit game element.

One interesting property of the Elinor menu system is that games are arranged according to the number of stars achieved. This implies that the least played games will be presented first in the menu and that subjects have to put some effort to find a favourite game. When analyzing menu selections we noted that subject E, in general, picks games earlier in the list compared to subjects A–D. Thus, a lower degree of enjoyment might lead to a smaller interest in selecting a particular game. That this was the case is also reflected in comments from subject E concerning favourite games and motivation to play. It is, however, important to note that Breakout and Puzzle Bubble were the games subject E spent most time on. These two games were also the most played for the whole group.

5.2 Analysing Player Comments

During the weekly visits at the clinic, subjects were asked open questions on their experience during the previous week. They were asked about games they liked the most and the least. While playing games they were asked to comment their actions. As part of the post-test they were interviewed about their experience of the game-based rehabilitation. These interviews were semi-structured and open focused on the experience of using games for rehabilitation. Some subjects had cognitive and attention problems which made it necessary to reformulate questions.

In this section, we present an analysis of transcribed material from the clinic visits and interviews with respect to the GameFlow elements. The aim is not to analyse whether each game has been enjoyable, but rather whether subjects have expectations and experiences that resembles the elements of GameFlow. This is by no means, a complete analysis tool, but a complement to the behaviour presented above.

Concentration. There are many indications from the subjects that match the concentration element. There is a variation between subjects and between games, to what degree the attention has been caught. Some subjects report that they have been fascinated by the game mechanics of a particular game and that they have been extremely concentrated on achieving some game goal. There are also examples on games that have been outside a subject's motoric, perceptual, cognitive, or memory limits and has thus been abandoned.

Challenge. The subjects were aware of challenges and progress in the games and appreciated it. Subject A states concerning game progression: "... this was a good thing. Otherwise it would have been uninteresting – if it had remained in the same place as it started". The introduction of new games were appreciated: "Exciting! It was a little incentive also to see, what is it today?" (subj. C), "It is fun, so that it is not the same all the time" (subj. E).

The paint game, with no explicit goal, is highlighted by several subjects and they request a challenge for it. Several games in the study were played much more than expected and many subjects had to replay the same level several times. This was

unfortunate in many ways, but it gave us a good confirmation that these subjects expected and wanted to have a progress and challenge. Subject D, for example, commented Breakout: “I was irritated on that Breakout, that it didn't reach a higher level. When you have reached a certain level, it starts all over again”.

Skills. The players were deliberately given very limited instructions to the games in Elinor. During the weekly visits at the clinic the subjects got additional instructions, if necessary. Most subjects got some help each week but there were surprisingly little comments from subjects on the lack of instructions when the game was introduced. The learning of games and the interaction with the console seem to have been relatively frictionless and the skill development happened unconsciously. One interesting indication of this was given when subject B, due to a hardware failure, had to start at the first level in a game at a clinic visit. Then she spontaneously stated “this is far too easy … it was not *this* slow in the beginning when I started to play”.

All subjects appreciated that games were introduced gradually. They would not have liked to have all games from the start. This can be seen as an indication that subjects see the benefit of gradually develop player skills over full freedom of choice.

Control. Subjects express a desire to control their gaming themselves, both with respect to individual games and to the gaming sessions. They give suggestions on how to improve control of games (be able to brake in Bike Ride) and are irritated at the forced pause. Subject D report that she have deliberately varied her style of play with respect to the physical movements and that she appreciated that it was possible “So it is not that rigid. You know you can alter it yourself...”.

Clear goals. There is no overriding goal in Elinor except from collecting as many stars as possible. Subject D formulated her own overall goal for each session – that she should earn one star from each game, before she could “award” herself a Breakout session, which was her favourite game.

Each game has their individual goals, except Paint which has no goal. There are several remarks from subjects on the lack of goals in Paint.

Feedback. The feedback is appreciated by subjects and they make several remarks concerning positive experiences from this feedback; both that the feedback has helped them to solve the task and that they have enjoyed receiving it. In some cases, they focused more on the feedback than the task, for example to shoot gnomes instead of moose because of the funny sound the gnomes make when hit.

There are several remarks made by subjects to the collection of stars and that it motivates them. None of them request scores, or a highscore list. Subject B states: ”... I look at how many stars I have. I like that. I think it is sufficient to me.” It is interesting to note that the number of stars granted to a player is not correlated to the difficulty level she has reached. The difficulty is reduced when there have been a number of consecutive failures. None of the subjects have made any remarks concerning this and they seem to be pleased by receiving continuous rewards rather than having an absolute metric on performance.

Immersion. Subjects give several comments that reflect that they have been immersed while playing. These are some examples:

- “you sit down to play and then you think of nothing but the game … there is no time to think about your affliction, so to say” (subj. A)

- ”… it’s fun, time flies” (subj. B)
- ”I think it has been very fun” (subj. C)
- “you get into the game in some way and the game becomes real, and then you make movements and get training without actually reflecting over it” (subj. D)

It is apparent that subjects report experiences that fit the immersion definition very well. They have experienced and appreciated that they forget about their disease and that they feel that they play rather than performing rehabilitation exercises. They experience an altered sense of time, and they are emotionally involved in games.

Social interaction. Although Elinor is a pure single player game, specialised for stroke subjects, we did encourage subjects to let relatives play and provided a guest USB stick. As reported above, all subjects used this opportunity. They also report positive experiences from this social interaction through the game. Several subjects report that their grand-children have showed interest. Subject B reported that “When I shoot moose they [the grand-children] thought it was big fun. 'Here comes a moose, grandma', they shouted”. She also reported that she enjoyed it very much when the grandchildren tried to play themselves. Subject A reported that she was very pleased when she noted that she was more skilful than her relatives in a particular game. There are also examples of the opposite: the brother of Subject E wanted them to compete while playing. The subject, however, did not like to compete with a “healthy” opponent.

Summary. The comments from subjects on their experience from using Elinor, reflects all elements of the GameFlow model. Some elements, such as immersion, are reflected in an apparent, positive way – the experiences reported by subjects are spot-on to the definition of immersion. Other elements, in particular skill, can more indirectly be mapped to the definition. Still, we find it interesting that a group of five subjects, with limited experience of computer games, express opinions and report experiences that are highly relevant from a computer game design perspective. It is important to note here that the interviews were not oriented towards the elements of the GameFlow model. The clinical visit and the interview were oriented towards rehabilitation and how subjects experienced this type of treatment.

6 Conclusions

The aim of the Elinor project is to provide motor rehabilitation to stroke patients in their home, and to utilise the enjoyment of games as a motivational factor. The focus of this paper is to analyse to what extent it has been possible for patients to have an interesting gaming experience, despite all obstacles. The analysis is based on a study, where five stroke patients were given the opportunity to use Elinor for five weeks in their homes. This situation differs from traditional gaming in a number of ways:

- Players suffer from a brain damage which affects their motoric, as well as their cognitive capacity.
- Games were designed to be controlled mainly with the affected arm. The interaction model was created more based on rehabilitation than entertainment considerations.

- The average age of subjects is 64 years, and none of them belong to a gaming generation. Most of them had very limited experience of computer games and two had not used computers at all.

The analysis presented in this paper is based on the log-data from all game sessions, comments made by patients during weekly visits at a clinic, and an interview in the end of the five week period.

The concluded picture from the analysis is that four out of five patients did have an interesting gaming experience: they spent a lot of time playing; they made active choices of games to play; they reflected over their gaming experiences and reported that they had been immersed and that they enjoyed playing.

One subject was not interested in game-based training. This subject spent the least time and clearly the least number of days playing, partly because of health problems. Despite a limited interest in games, this subject still spend most time on games that were popular among the other patients as well.

The popularity of games based on playtime, and comments from patients, has a remarkable resemblance with the quality of the game design. Games that were based on established game concepts were popular, while games based on interaction movement were less popular. The least popular "game" was one that completely lacked a challenge. We claim this correlation between game design and popularity indicates that patients were more targeted on playing than on training. This fits the goal of the project that the motivational aspects of games should be used to achieve frequent training. The achieved rehabilitation effect is not within the scope of this paper. It is however worth noting that the pre- and post-tests conducted by a physical therapist and an occupational therapists, revealed that one patient had a significant increase in both movement and usage of the affected arm. In addition, several patients reported that they had a perceived improvement. None of patients suffered from negative effects of the training.

This has been an exploratory project where we have produced a new game console, a novel interaction model to a number of games, and a usage context. From our study it is not possible to isolate the key concepts for success or failure. Further work is needed to analyse and refine each component in this rehabilitation concept. In particular, the intersection between game-play and rehabilitation is a complex challenge. The movements used by patients to control the game should give a rehabilitating effect, but they should also be well integrated in the game-play. This is a real challenge.

This study can be characterized as a serious games project, i.e. that computer games have been used for a purpose apart from pure entertainment. The medical aspects of stroke rehabilitation are indeed important and serious. Still, the enjoyment should also be taken seriously. One of the subjects in the study had no previous experience of computers or computer games. Her brain damage affected her motoric and cognitive performance and limited her everyday life. When she was presented to Elinor, she quickly got fascinated and spent a lot of time playing and expresses an obvious joy in it. When the five weeks had passed, she wanted to keep the console for a longer period, arguing that she had missed one day due to a hardware failure. She had become a gamer, against all odds, and to a person who is limited in many other ways, the joy of gaming can be as serious as any possible rehabilitation effect from it.

Acknowledgements. The authors wish to express their gratitude to the patients and stroke rehabilitation experts involved in the project. They would also like to extend their appreciation to Karin Rindevall, Monika Mikucka and Eric Thelander for creating the graphics used in Elinor.

References

1. Michael, D., Chen, S.: Serious games: Games that educate, train, and inform. Thomson Course Technology, Boston (2006)
2. Koster, R.: Theory of fun for game design. Paraglyph, Scottsdale (2004)
3. Vorderer, P., Hartmann, T., Klimmt, C.: Explaining the enjoyment of playing video games: the role of competition. In: Entertainment Comp., pp. 1–9. ACM, Pittsburgh (2003)
4. Desurvire, H., Caplan, M., Toth, J.A.: Using heuristics to evaluate the playability of games. In: CHI 2004, pp. 1509–1512. ACM, New York (2004)
5. Murray, J.H.: Hamlet on the Holodeck: The Future of Narrative in Cyberspace. MIT Press, Cambridge (1998)
6. Eskelinen, M.: The Gaming Situation. Game Studies 1(1) (2001)
7. Sweetser, P., Wyeth, P.: GameFlow: a model for evaluating player enjoyment in games. Computers in Entertainment 3(3) (2005)
8. Salen, K., Zimmerman, E.: Rules of Play: Game Design Fundamentals. MIT Press, Cambridge (2003)
9. British Broadcasting Corporation. Gamers in the UK. BBC survey (2005)
10. Bosser, A.-G., Nakatsu, R.: Hardcore Gamers and Casual Gamers Playing Online Together. In: Harper, R., Rauterberg, M., Combetto, M. (eds.) ICEC 2006. LNCS, vol. 4161, pp. 374–377. Springer, Heidelberg (2006)
11. Parks Associates. Survey Reveals U.S. Gamer Market is Diversifying. Press Release (2006)
12. Wikipedia, `http://en.wikipedia.org/wiki/Gamer`
13. Docampo Rama, M.: Technology Generations Handling Complex User Interfaces. PhD dissertation, Eindhoven University of Technology, Eindhoven, The Netherlands (2001)
14. Prensky, M.: Digital Natives, Digital Immigrants. In: On the Horizon, vol. 9(5). MCB University Press (2001)
15. Bryce, J., Rutter, J.: Killing Like a Girl: Gendered Gaming and Girl Gamers' Visibility. In: Mayra, F. (ed.) Computer Games and Digital Cultures Conference Proceedings, pp. 243–255. Tampere University Press, Finland (2002)
16. Rizzo, A., Kim, G.J.: A SWOT Analysis of the Field of Virtual Reality Rehabilitation and Therapy. Presence 14(2), 119–146 (2005)
17. Flynn, S., Palma, P., Bender, A.: Feasibility of Using the Sony PlayStation 2 Gaming Platform for an Individual Poststroke: A Case Report. Journal of Neurologic Physical Therapy 31(4), 180–189 (2007)
18. Goude, D., Björk, S., Rydmark, M.: Game design in virtual reality systems for stroke rehabilitation. Studies in health technology and informatics 125, 146–148 (2007)
19. Broeren, J.: Virtual Rehabilitation – Implications for Persons with Stroke. Doctoral thesis, The Sahlgrenska Academy at Göteborg University, Sweden (2007)
20. Wood, S.R., Murillo, N., Bach-y-Rita, P., Leder, R.S., Marks, J.T., Page, S.J.: Motivating, Game-Based Stroke Rehabilitation: A Brief Report. Topics in Stroke Rehabilitation 10(2), 134–140 (2003)
21. IJsselsteijn, W., Nap, H.H., de Kort, Y., Poels, K.: Digital game design for elderly users. In: Conference on Future Play, pp. 17–22. ACM, New York (2007)

Matchmaker: Interpersonal Touch in Gaming

Cody Watts[1], Ehud Sharlin[1], and Peter Woytiuk[2]

[1] University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada
{wattsc,ehud}@cpsc.ucalgary.ca
[2] BioWare Corp., Edmonton, Alberta, Canada
woytiuk@bioware.com

Abstract. Acts of interpersonal touch – a touch shared between two people – are used by couples to communicate in a simple and emotionally intimate way. In this paper, we argue that the intimacy afforded by acts of interpersonal touch can be used in computer entertainment to support enjoyable and engaging activities for couples. To support this notion, we have developed *Matchmaker*; a two-player, cooperative tabletop video game based on themes of love and romance. *Matchmaker*'s gameplay is directly controlled by a set of collaborative tabletop interaction techniques, as well as by acts of interpersonal touch between its players. In this paper we present a detailed description of *Matchmaker*'s design and the results of an exploratory user suggesting that *Matchmaker* is enjoyable to play and that its use of interpersonal touch contributes to players' enjoyment.

Keywords: Games, gaming, touch, Matchmaker, tabletop.

1 Introduction

Though mother may be short on arms,
Her skin is full of warmth and charms.
And mother's touch on baby's skin,
Endears the heart that beats within.
--Harry F. Harlow, "The Elephant" [6]

This short poem comes from psychologist Harry Harlow's seminal 1958 paper, "The Nature of Love" [6]. In this paper, Harlow presents the results of a study which investigated the effects of skin-on-skin contact in newborn macaque monkeys. Through his research, Harlow established what has since become common sense: that a touch shared between two people (or in Harlow's study, a baby monkey and a terrycloth doll) can create a meaningful emotional bond.

Touching is one of the most emotionally-significant ways in which social creatures interact. Whether it's a baby kitten nuzzling its sibling, a young couple sharing a hug, or a father resting a reassuring hand on his daughter's shoulder, the merest act of interpersonal touch establishes an emotional connection between its participants. In fact, human beings are so emotionally invested in the act of touch that we have established strict cultural norms that dictate under what circumstances it is socially permissible to touch another person. When an act of touch violates these norms, it can be

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 13–24, 2009.

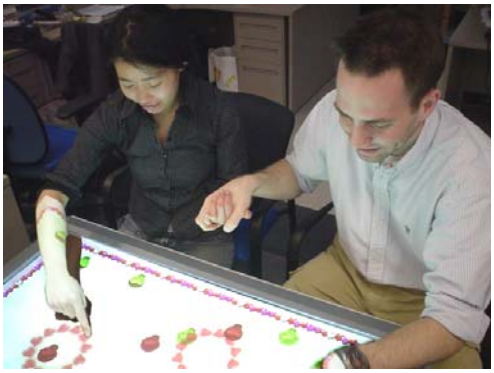


Fig. 1. *Matchmaker*: A two-player tabletop video game utilizing interpersonal touch.

very uncomfortable for those involved. Consequently, the effects of interpersonal touch can run the gamut of human emotions. Depending on the context in which it is delivered, an act of interpersonal touch has the potential to be welcoming and reassuring, or awkward and invasive.

Because of its potential to arouse such unpleasant emotions, interpersonal touch has been largely ignored in the design of human-computer interfaces. But we believe that there are situations in human-computer interaction where interpersonal touch is not only appropriate, but even desirable; it all depends on establishing the proper context. One area where interpersonal touch can be especially appropriate is within the context of a video game. Video games offer consequence-free environments which are capable of evoking strong emotions from their players; by couching interpersonal touch within a game, we can allow the act to remain light-hearted and unthreatening while still retaining it's emotional impact [7]. Games such as *Dance Dance Revolution* and *SingStar* have demonstrated how activities which may otherwise be uncomfortable or embarrassing (such as dancing or singing in front of a crowd) can become a source of amusement when they are integrated into a social game. Similarly, we believe that a well-designed game can cultivate an environment that encourages couples to act affectionately, changing interpersonal touch from an arbitrary and stilted interaction technique to a fun and logical extension of play. To demonstrate these ideas, we have created *Matchmaker*: a cooperative, two-player tabletop video game which utilizes interpersonal touch between players (Figure 1).

2 Related Work

Although *Matchmaker* is the first video game designed around interpersonal touch, it is not the first time that games and touching have ever crossed paths. In her "Intimate Controllers" project, Chowdhury created a set of wearable game controllers for couples: a bra for the woman and a pair of boxer shorts for the man [2]. These special undergarments controlled a collocated game of *Pong* presented on a large screen; as a player touched his partner's left side, his paddle would move to the left and as he touched his partner's right side, his paddle would move right. Though Intimate Controllers has some superficial similarities with *Matchmaker*, these two projects are

actually quite different in their approach. In Intimate Controllers, the focus is very much on overt, sexual intimacy – so much so that players are actually required to disrobe in order to play. Far less importance is placed on the "gaming" aspect of the project (though *Pong* is an iconic game, it is arguably neither exciting, nor intimate, which we feel may make it a lesser choice as a game for couples.) In contrast, our game *Matchmaker* was designed especially for interpersonal interaction. With *Matchmaker*, we attempt to cultivate emotional intimacy in a more subtle way by encouraging teamwork and the pursuit of a shared goal.

Methods for detecting interpersonal touch over tabletop interactions has been previously implemented using the Mitsubishi Electric Research Laboratories (MERL) DiamondTouch. DiamondTouch is a front-projected, touch-sensitive tabletop computing surface which uses an electrical capacitance system to detect touches from up to four unique users simultaneously. [4]. To interact with the DiamondTouch, each user must sit on a conductive pad which is connected to the host PC. When a user touches the table, a circuit is formed between the tabletop, the user's body and the conductive pad. By analyzing the signals coming from its receiver-pads the DiamondTouch software can identify exactly where on the table each user is touching.

Although it was not explicitly designed for the task, the DiamondTouch can be adapted to sense when two users are touching each other quite easily. When two users make skin-on-skin contact, they will begin to conduct electrical signals between themselves. When two users touch each other, and either of them touches a point on the surface of the DiamondTouch, it will appear as though both users are touching that point simultaneously. Such events can easily be as a consequence of interpersonal touch. This technique was first suggested in [4] and is the method we use to detect interpersonal touch in *Matchmaker*.

CollabDraw by Morris et al. is a tabletop drawing application which used the DiamondTouch to allow four people to collaborate simultaneously on a single illustration [9]. As a part of its collaborative toolset, CollabDraw employed "cooperative gestures" which made use of interpersonal touch. Though CollabDraw pioneered the use of interpersonal touch as a human-computer interaction technique, its application was very poorly received by the groups of coworkers who were selected to test the system. Participants complained of "sweaty hands" and the general awkwardness of touching their coworkers. Morris concluded that while interpersonal touch may be unpleasant for formal tasks, the technique may still have use in applications such as computer entrainment.

Zimmerman proposed a novel view of interpersonal touch interaction, by using the human body as a "biological conductor" for the transmission of modulated electric signals produced by on-body devices [10]. In Zimmerman's Personal Area Networks (PANs) signals sent by an emitter on one body can be transmitted through touch to a receiver on another, allowing an exchange of digital data. To demonstrate the PAN concept, a prototype system was created which would allow one person to transmit an electronic business card to another via an ordinary handshake.

Several psychological studies suggest that the mere act of interpersonal touch can create positive emotions in those involved. In [3] an experiment was performed wherein restaurant waitresses would briefly touch the hands of clients as they were returning the clients' change. Their tips were then compared to the tips received by a control group, who did not make physical contact with their clients. The results

showed that diners who made physical contact with their waitress tipped higher than those who had not. The authors concluded that this simple act of touch had increased patrons' satisfaction with their service. A similar result was reported in [5], where library clerks were instructed to subtly touch patrons' hands as they returned the patrons' library cards. After checking out, these patrons were approached by members of the research team (posing as library workers) and asked to fill-out a questionnaire rating their satisfaction with the library and its clerks. This satisfaction data was compared to data for a control group of non-touching clerks. The authors concluded that the addition of touch had significantly increased female patrons' satisfaction ratings, regardless of the gender of the library clerk. Differences in males' responses were less marked, showing only a small increase in satisfaction.

Could the positive effects of interpersonal touch carry over to video games as well? In "Why we play games: Four keys to more emotion without story" Lazzaro presents the results of a study designed to identify and categorize the positive emotions that players experience while playing video games [8]. Lazzaro encapsulated her findings into four keys, which she calls "the four most important pathways to emotion in games." One of these keys is the People Factor – the social interaction between players that occurs in and around games. We believe that encouraging players to interact through the medium of touch can emphasize social connections, thus heightening players' enjoyment via the People Factor.

3 Matchmaker

In designing *Matchmaker*, our goal was straightforward: to create a game which made effective use of interpersonal touch. Hand-holding naturally emerged as the preferred mode of interpersonal touch because it's a simple, cooperative gesture. Because holding hands is most often seen as a sign of affection between couples, we designed *Matchmaker* as a romantically-themed game whose cutsey trappings would complement the tender appearance of its hand-holding players.

Fig. 2. Matchmaker's main game screen

Fig. 3. Two players create a match by dragging their selected Peeps together

Matchmaker's game screen is presented as a window to the world of the Peeps (Figure 2). When the game begins, Peeps will begin to stream into the playing field from off-screen, wandering in and out of the screen in a disorderly, ambling fashion. The players must use these onscreen Peeps to create their matches. Making matches is simple. Players can "grab" a Peep by touching it with their finger as it wanders by. When a Peep has been selected, a colored halo surrounds it, indicating that it is now under the player's control. Selecting a Peep gives the player the power to drag it to any place on the screen. When two players drag their selected Peeps together, a match will be created if the two Peeps are "compatible" (Figure 3). In *Matchmaker*, a Peep is defined by two characteristics: its color (red, orange, yellow, green, blue or purple) and its gender (male or female). Two Peeps are compatible if and only if they have the same colors and opposite genders. Each player is allowed to select only one Peep at a time; this prevents players from being able to match Peeps by themselves and forces them to work together with their partner.

When a match is made a pleasing chime will play, the matched Peeps will disappear from the playing field, and two new Peeps will be created (off-screen) to take their place. If two incompatible Peeps are dragged together, no match will occur. Instead, a buzzer will sound, and the affected Peeps will simply wander away.

If a Peep is not matched up within a certain amount of time it will become lovelorn. When a Peep becomes lovelorn it will start to cry and lose its color, becoming grey (Figure 4). While lovelorn, a Peep cannot be matched up, even with other

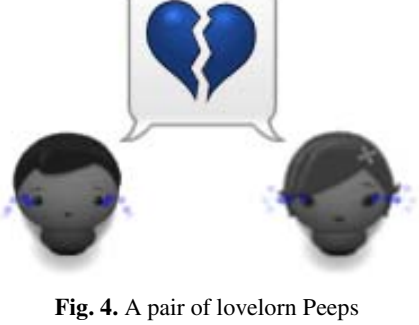


Fig. 4. A pair of lovelorn Peeps

Fig. 5. Touching the table while holding your partner's hand activates the Power of Love

lovelorn Peeps. Although players can temporarily afford to ignore lovelorn Peeps, over time more and more of the Peep population will become lovelorn, making it extremely difficult to create further matches.

The only way to "cure" a lovelorn Peep is through the Power of Love. Players can activate the Power of Love by making physical, skin-on-skin contact with their partner – typically through holding hands – and having either player tap the affected Peep(s) (Figure 5). This will cure the Peep, restoring its original color and permitting it to be matched up once again. Peeps which have been cured in this way are still susceptible to become lovelorn again if enough time elapses.

While players are holding hands, they cannot perform normal operations such as selecting, dragging and matching Peeps; they can only cure lovelorn Peeps through the Power of Love. Though this may seem punitive, we created this limitation in order to give the game strategic depth. If the Power of Love was not mutually exclusive with other game actions, players could simply hold hands with their partner throughout the entire game and in doing so, rob the act of any special significance to gameplay.

Matchmaker is divided into a series of six stages, each of which is more difficult than the last. The goal of each stage is to make a set number of matches within a specified time limit. Players advance through the stages in a linear fashion; when one stage is completed, they move on to the next. If the players fail a stage, they are given the opportunity to restart the game from the beginning of that stage.

As the game introduces more and more colors of Peeps, it becomes increasingly difficult. In the first stage, Peeps come in only two colors: red and green; this ensures that opportunities for matching compatible Peeps are plentiful. However, by the end of the game, there are six distinct colors of Peeps which significantly lowers the likelihood of two compatible Peeps appearing onscreen at once. As opportunities for making matches decrease, partners must learn to work quickly and to coordinate their actions in order to succeed.

In *Matchmaker*, all gameplay functions are performed through the DiamondTouch tabletop; no other peripherals are required to play. Users select Peeps by touching them with their fingers, and drag them by moving their fingers over the surface of the table. As previously stated, *Matchmaker* detects interpersonal touch through the

DiamondTouch using the method first described in [4]. Although the DiamondTouch can only recognize interpersonal touch when at least one participant is touching the surface of the table, this is not problematic for *Matchmaker*, where interpersonal touch is used only to activate the Power of Love.

4 Evaluation

We conducted an experiment in which we invited four couples to play *Matchmaker*. Following these play sessions, questionnaires and interviews were administered to help us understand how players feel about the game.

4.1 Aims

In evaluating *Matchmaker*, we sought to explore two general topics. The first of these topics dealt with *Matchmaker*'s entertainment value, irrespective of its use of interpersonal touch. This required us to ask questions such as: is *Matchmaker* playable? Is it fun? What do players find enjoyable about the game and what about it do they dislike? Though these questions may seem trivial, we believe them to be of the utmost importance; if *Matchmaker* is fundamentally unenjoyable as a video game, then it would make a poor case-study for examining the value of interpersonal touch in games.

Our second area of inquiry was: how does the inclusion of interpersonal touch contribute or detract from the experience of playing *Matchmaker*? Is interpersonal touch a valuable component of *Matchmaker*, or would the game be more enjoyable without it? What specifically about interpersonal touch to players like or dislike?

4.2 Participants

Although *Matchmaker* can be played by anyone, it was designed with couples specifically in mind. So, when it came time to recruit participants for our study, we specifically targeted partners who were dating or married. In total, four couples were recruited; three heterosexual couples, and one homosexual male couple, making for a total of three female and five male participants. Participants were either lab members, or associated with lab members and varied in age from 18 to 37. Seven out of the eight participants could be considered "gamers", each having spent at least one hour playing some form of digital game in the week before the study.

4.3 Procedures

Before starting the experiment, the administrator would introduce himself to the participants and outline the purpose and requirements of the study. Special attention was paid to ensure participants understood that they would be required to hold hands during the experiment. Participants were also informed of their rights, particularly the right to terminate the study at any time if they felt uncomfortable. Participants were then asked to complete a pre-test questionnaire designed to reveal their past experience with the skills they would be using during the experiment – playing video games, interacting with a tabletop computer, and engaging in interpersonal touch.

Once the questionnaires had been completed participants were seated side-by-side in chairs at the head of the DiamondTouch and informed that they would now be playing a game of *Matchmaker*. Participants were instructed to play to the best of their abilities and as though the observer was not present. In order to simulate a natural playing experience, the administrator would not address the participants past this point until the experiment had concluded. Instead, in-game instructions were used to provide players with information on how to play the game and how to proceed. As the participants played through the game, the observer was responsible for noting any interesting occurrences, patterns or behaviors that he witnessed from the players.

As we have mentioned previously, *Matchmaker* is broken into six stages, each of which is more difficult than the last. Participants were asked to play until one of two conditions was met: either all six stages were completed and the game was won or the participants failed to complete a single stage three times in a row.

Once gameplay had concluded, each participant was issued a post-test questionnaire. The purpose of these questionnaires was to determine the participants' feelings towards *Matchmaker* while the experience of playing was still fresh in their minds. Participants were instructed to fill out their post-test questionnaires silently and independently of one another, to protect their responses from possible conformity biases.

Following the post-test questionnaires, the experimenter would conduct a debriefing and an unstructured discussion with the participants in order to explore any questions which arose during the testing period.

5 Results

Having run only eight participants, we must be cautious about drawing any general conclusions; with a sample of this size, we view our study as strictly exploratory. Nevertheless, we were strongly encouraged by the results we obtained.

Observations of our participants' behaviors suggest a favorable impression of *Matchmaker*; smiling, laughing and joking during gameplay was common among all couples. Spontaneous expressions of delight from our participants (such as "oh, wow!") also contributed to our impression of *Matchmaker* as an exciting and engaging game. These positive responses are especially surprising when one considers how few couples made it through the entire game; of our four participating couples, only one managed to complete the entire game.

In fact, the game's difficulty was a popular topic in our players' post-test questionnaires. When asked what he disliked about *Matchmaker*, one male participant wrote: "[It gets] too difficult too quickly." Two players commented that the Peeps moved too fast, while other participants wrote that Peeps became lovelorn too quickly, or that the stages ended too soon.

Our participants' enthusiasm towards *Matchmaker* is likely due in part to *Matchmaker*'s themes and presentation style. Not only did participants agree strongly with the statement "I liked *Matchmaker*'s themes of love and romance" but many participants commented favorably on *Matchmaker*'s polished and "professional" appearance. One participant compared the Peeps to the iconic "Miis" used by the Nintendo Wii, while another praised the game for its "cutsey [sic] feel".

5.1 Tabletop Interaction

Players' feelings towards the DiamondTouch were mixed. On one hand, many participants remarked how easy it was to interact with the touch-sensitive surface. In the words of one male participant: "The multitouch surface made it easy to play; [you] just drag the Peeps together." A female participant commented that *Matchmaker* was very "accessible" because it requires only simple skills like touching and dragging, in contrast to the complex, multi-button control schemes used by many modern games.

However, *Matchmaker*'s tabletop interaction also came with a very tangible drawback; two of our eight participants wrote that playing *Matchmaker* had hurt their fingers. The cause of this pain was apparent from observation; many players were "stabbing" the tabletop with their fingers as they played. This phenomenon is likely related to the Peeps' excessive movement speed – players would often lunge with their fingers to grab important Peeps before they could escape off-screen. Although a firm touch is no more accurate than a soft touch, most participants did not seem to recognize this and, in their excitement to grab Peeps, they were prone to these painful stabbing gestures.

5.2 Interpersonal Touch

Of all the Likert-scale statements we posed to participants, "I feel that *Matchmaker* made use of interpersonal touch in a significant way (i.e. the game would not be the same without it)" received the most highly varied responses; on the whole, our participants tended to agree, but the couples who responded most favorably were those that had progressed farthest into the game. We suspect that players became more appreciative towards the importance of interpersonal touch as they spent more time using it within the game.

When asked how the use of interpersonal touch affected their perceptions of *Matchmaker*, participants were largely positive in their responses. In the words of one participant: "I felt like I was sharing my love in a [silly] but fun way." Another participant responded: "[Interpersonal touch] really made the game more collaborative. Both players really needed to work together to be successful."

However, the use of interpersonal touch in *Matchmaker* was not an unqualified success. One couple did not immediately understand that matches could not be made during periods of interpersonal touch. A member of this couple conveyed his displeasure in the post-test questionnaire, saying: "It's counter-intuitive to have to let go [of my partner's hand] to match up couples." Another couple experienced a similar problem; in this case, the female participant would often touch her partner without any forewarning, preventing him from selecting Peeps until she let go. In his post-test questionnaire, he expressed his dissatisfaction when he wrote: "It was frustrating trying to coordinate touches when you notice a pair [of compatible Peeps] and your partner doesn't."

Although we are mindful of such concerns, this is one aspect of *Matchmaker* which we are not likely to change. Cooperating with your partner is crucial to succeeding at *Matchmaker* and learning to communicate when and how interpersonal touch should be used is a significant part of this cooperation. In the words of one insightful participant: "[Interpersonal touch] made the game more challenging in an interesting way. It was less about the actual act of contact, and more about the coordination challenge."

6 Discussion

Since *Matchmaker* was first developed, it has been demonstrated to literally hundreds of people. Watching these new players' first reactions has shaped our understanding of how potential users relate to *Matchmaker*, and exactly how, where, and with whom *Matchmaker* is most effective.

Games have long been used as a method of breaking the tension in new or awkward situations, and *Matchmaker* is no exception. The quintessential example of *Matchmaker* acting as an ice-breaker occurred during a tour of our laboratory by an official review committee. A group of serious and formally dressed officials had gathered around the DiamondTouch table when our demonstrator asked for players. Two distinguished men volunteered and as they sat, our demonstrator briefed them on the game: "At certain points, this game will require you to briefly hold hands with your partner. Are you both okay with that?" A quiet hush fell over the attending crowd. How would these professional men handle this distinctly unprofessional situation? After a second of silence, one man grinned broadly, turned to the other, and said: "I'm game if you are, Tom" From that point on, the table was all smiles; from the observers to the players themselves, everyone laughed and cracked jokes and they enjoyed the absurdity of the two platonic business associates playing this romantic game together.

Although *Matchmaker* was designed to evoke images of love and romance, we never imagined that it could be used to woo potential romantic partners. Yet, since the game was developed, no less than two members of our group have brought their partners to the lab for exactly this purpose – to play *Matchmaker* with their romantic interest before they began dating. Although this behavior does not ascribe *Matchmaker* with any intrinsic worth, it does suggest that *Matchmaker* is a nonthreatening way to demonstrate playful affection and to introduce physical intimacy to new couples.

Anecdotes such as these reveal *Matchmaker* as an innocuous way to break the ice and to introduce touching into a relationship where participants may be afraid to make more overt romantic gestures. With this in mind, we feel that *Matchmaker* installations could be very popular in locations frequented by younger couples, such as movie theatres and arcades. One can easily imagine a young couple agreeing to play "that silly match-making game" with the ostensible purpose of killing time before their movie, yet with each partner fully expecting guiltless physical contact in the guise of a simple game.

We suspect that *Matchmaker* would also work quite well in situations where individuals are actively seeking to cultivate new romantic relationships, such as bars and singles-events. *Matchmaker* is short, fun and non-committing, making a quick round of *Matchmaker* an ideal "litmus test" for screening potential partners, similar to the practice of speed-dating. If two partners feel a connection while playing, then that's justification enough to continue a dialogue afterwards; after all, a physical connection has already been established. If, however, the players did not connect, then it's easy for their relationship to end with the game; once the round is over, the players can politely part and seek out new partners.

One of *Matchmaker*'s greatest attributes is the way in which it gives interpersonal touch a socially-legitimate pretext; by surrounding the act of touch with a

goal-oriented framework (i.e. a game) we engage players' minds, drawing their attention away from the base physical act and towards an enjoyable cooperative activity that they can share with their partner.

7 Future Work

Both *Matchmaker* and the broader topic of interpersonal-touch-in-games are ripe for future exploration. In the immediate future we intend to revise *Matchmaker* to make it easier for first-time players, in accordance with the feedback we received during our study. Subsequently, we intend to revisit our original study with a greater number of participants so that we can better understand how players feel towards *Matchmaker* and its use of interpersonal touch.

Although the study we have presented here suggests that interpersonal touch has some bearing on a couple's enjoyment of *Matchmaker*, it remains to be seen exactly how important the interpersonal interaction is compared to (say) it's attractive graphical presentation or its romantic theme. To address this issue we may develop an alternate version of *Matchmaker* in which the Power of Love is activated without the use of interpersonal touch. A controlled study comparing these two versions of *Matchmaker* would allow us to quantify how (if at all) the removal of interpersonal touch would affect couples' enjoyment of the game.

8 Conclusions

Interpersonal touch is an extremely potent form of human interaction which has the potential to arouse both pleasant and unpleasant emotions. Many previous investigations into interpersonal touch have failed to consider the contexts in which acts of touch were occurring, and faltered for this very reason. But, by coupling touch-interaction with an unthreatening, consequence-free environment (such as that of a video-game) it is possible to harness the positive powers of touch to bring couples together and to enhance their game-playing experience through cooperation and socialization.

In this paper we have presented *Matchmaker*: a two-player, cooperative tabletop video game which detects and reacts to events of interpersonal touch between its players. *Matchmaker* plays up the positive aspects of touch by using it as a tangible symbol of love and cooperation. These themes are reinforced in-game through the use of cute characters, and heart-iconography.

Data gathered from a controlled study and from numerous demonstrations suggests that *Matchmaker* is an enjoyable game whose use of interpersonal touch contributes strongly to its experience. We believe that *Matchmaker* provides a lighthearted and fun way to overcome awkwardness and to introduce innocent physical contact in new relationships.

Acknowledgements. Thanks to Edward Tse for sharing his expertise on the DiamondTouch and its SDK. Thank you, Daniel Cook of www.lostgarden.com for allowing us to use assets from your "PlanetCute" graphics package in *Matchmaker*. Thanks to Heather Peacock and Matt Klompus for starring in our promotional video. Thanks

to our test participants, whose valuable feedback contributed to the development of *Matchmaker*, to Saul Greenberg and Eva Hornecker for their advice and encouragement, and to all the members of the University of Calgary Interactions Lab for their help. Our work was supported by various grants from NSERC, Alberta Ingenuity, iCORE and the University of Calgary.

References

1. Brave, S., Ishii, H., Dahley, A.: Tangible Interfaces for Remote Collaboration and Communication. In: Proceedings of CSCW 1998, pp. 169–178 (1998)
2. Chowdhury, J.: Intimate Controllers (2007), `http://www.jennylc.com/intimate_controllers/`
3. Crusco, A., Wetzel, C.: The Midas Touch: The Effects of Interpersonal Touch on Restaurant Tipping. Personality and Social Psychology Bulletin 10(4), 512–517 (1984)
4. Dietz, P., Leigh, D.: DiamondTouch: a multi-user touch technology. In: Proceedings of the 14th Annual ACM Symposium on User interface Software and Technology, pp. 219–226 (2001)
5. Fisher, J.D., Rytting, M., Heslin, R.: Hands touching hands: Affective and evaluative effects of an interpersonal touch. Sociometry 39, 416–421 (1976)
6. Harlow, H.: The Nature of Love. American Psychologist 13, 673–685 (1958)
7. Juul, J.: Half-Real: Between Real Rules and Fictional Worlds in Video Games. MIT Press, Cambridge (2006)
8. Lazzaro, N.: Why we play games: Four keys to more emotion without story (2004), `http://www.xeodesign.com/whyweplaygames/xeodesign_whyweplaygames.pdf`
9. Morris, M.R., Huang, A., Paepcke, A., Winograd, T.: Cooperative gestures: multi-user gestural interactions for co-located groupware. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 1201–1210 (2006)
10. Zimmerman, T.G.: Personal area networks: near-field intrabody communication. IBM Systems Journal 35(3-4), 609–661 (1996)

Doing It Right: Combining Edutainment Format Development and Research

Simon Staffans[1], Annika Wiklund-Engblom[1], Marc Hassenzahl[1,2], and Susanne Sperring[1]

[1] MediaCity, Åbo Akademi University, Box 311, 65101 Vaasa, Finland
[2] Folkwang University, Campus Universitat Duisburg-Essen, Universitatstrasse 12, 45141 Essen, Germany
{Simon.Staffans,Annika.Wiklund-Engblom,Susanne.Sperring}@abo.fi, Marc.Hassenzahl@folkwang-hochshule.de

In this paper, we elaborate on the synergy achieved from combining cross media content development and research. We describe the cross media edutainment format "The Space Trainees" (TST), its development, and how we involve research as a tool for assisting the design process. This is the first and foremost aim of the research attempts, in which targets are both usability of the format and user experience (UX). Another aim of involving research is to gain more understanding of the edutainment value this cross media format delivers; i.e. both the value of entertainment and learning. The third aim is to fine-tune research instruments to better target children's UX, with regard to their attitudes, emotions, actions, and reactions.

The Space Trainees has been developed utilizing the principles of bridged cross media, i.e. the development of a storyline that continues in a logical way from one media – the television show – to another- the web portal – and back again. The development work has throughout the process of the project been aimed at producing a viable commercial cross media edutainment format for production and international marketing. The research involved in the development work is conducted in convergence with the design phases, and hence, the aims are always pragmatic (see figure). One crucial factor has been the correct timing of the tests.

The final cross media product is released in the fall of 2009. The final product will be subjected to research targeting its value for learning and entertainment (study IV). The aim of this research is to build know-how for the cross media design team for future edutainment projects, but also to investigate further into the educational perspective on combining learning and play.

During the format development phases of TST research into both usability issues and UX has supported the development work. The first study gave indications that the interactivity was well received by viewers and users. The overall concept also received support. Interactivity via set-top-box, however, brought some negative issues that contributed to the switch to cross media solutions instead. Study two gave much needed information on the set instructions, the games themselves and the collaboration between the children on the television show, and contributed to changes made during the later development phases.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 25, 2009.

Virtual Apple Tree Pruning in Horticultural Education

Ning Xia[1], Ai-Shuang Li[1], and Dan-Feng Huang[2]

[1] Institute of Technology and Information,
Guangdong Agricultural Academy of Sciences, 510640, Guangzhou, China
nxia01@gmail.com
[2] Group of Horticulture, Dept. of Plant Science, School of Agriculture and Biology,
Shanghai Jiaotong University, 200240, Shanghai, China

Abstract. A computer model of branching responses of apple trees (*Malus domestica*) with different levels of pruning schemes is presented. The model simulates the number and distributions of the axillary production along one-year-old parent branches using the Hidden Semi-Markov Chain (HSMC). Results show that (a) simulation system efficiently provides the required information at the desired level of accuracy, and (b) the branch growth model is extremely well calibrated against real apple trees and (c) the system can simulate many interesting growth situations with direct feedback from the different levels of pruning schemes presenting the parent branches' characteristics, such as, location of flower, fruit setting, and so on. The method used in this paper aims at providing a quantitative tool for orchard management in horticultural education, particularly with regard to pruning practices.

Keywords: Apple tree (*Malus domestica*), stochastic process, Markov chain, heading, visualization.

1 Introduction

Over the last four decades in China, the number of intensive apple orchards has been increasing markedly, and the industry is motivated by the desire to produce fruit as early as possible in the life-span of the tree to offset increasing establishment and management costs. In this case, there is a challenge in how to maintain steady cropping, produce high fruit quality and minimize the amount of upright vigorous shoots that produced by effective use of heading treatments (heading refers to the removal of the terminal portion of a 1-year-old shoot) [1], and appropriate agronomic practices such as fertilization, irrigation, pest control, choice of scion variety and rootstock, and so on.

Traditionally, growers have been instructed how to prune at the tree scale on the spot training. Results were usually disappointing because trees had complicated branching structure and grew randomly, which was influenced by internal and external factors. The effect of pruning on branching patterns is generally depicted through reference to empirical data and anecdotal evidence from growers

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 26–37, 2009.

(empirical indices). In addition, researchers evaluating the economic feasibility of new training systems and pruning techniques on diverse cultivars have encountered significant difficulties due to lack of experimental fields, long periods of time from tree planting to maturity, high cost of pruning by hand, and in particular by the length of the delay between pruning and sprouting.

Mathematical modeling has been useful in guiding manipulation of annual plants to improve yields [2]. In contrast, architectural analysis and modeling approach for perennial woody plants, including fruit tree species, has not yet to be adequately developed, probably because of the structural complexity of large woody plants, which increases with their decade- or century-long life span. However, promising advances [3] in modeling the branching patterns have been reported for young fruit trees such as walnut [4], apple [5], kiwifruit [6], [7], apricot [8], pear [9], [10], and peach tree [11], [12], as recently summarized by Costes (2004). Little information on the morphology and architecture of fruit tree influenced by heading treatments has been addressed in the above mentioned literature.

In the present study, a stochastic process model, which deals with plant topology [13], is used to investigate how apple tree responses to heading on branching patterns. The primary aim was to predict the branch development in relation to diverse levels of intensity of pruning that were most commonly used in intensively managed orchards, including light heading, moderate heading, heavy heading, and severe heading as defined below. Another one is to conduct virtual apple tree pruning via simulation. Virtual pruning has the potential to provide a learning environment in horticultural education which the trainees can interact with the tree and which responds in turn to the actions of the trainees.

2 Material and Methods

2.1 Plant Material and Shoot Pruning

One hundred randomly selected apple trees (*Malus domestica* cv 'Fuji') on semi-dwarf rootstocks MM.9 were evaluated. The trees are planted at a spacing of 10 feet $\times$ 7 feet, at densities of about 620 trees per hectares in commercial orchards in East China and Shandong Province. The branches, which had extended in the 2004 growing season, are here referred to as parent branches. Four main types of axillary production could be identified according to their length and development by the end of the 2005 growing season: (i) latent bud, (ii) current-year short shoot ($<$ 5 cm in length) with terminal bud, also called Spur, (iii) medium shoot ($<$ 20 cm) with terminal bud, also called Brindle, and (iv) long shoot with preformed and neoformed part, also called extension shoots.

One-year-old parent branches were shortened to one to twenty-two basal buds. They are designated according to the following pattern: 1-bud-left heading (1blh), 2-bud-left heading (2blh),..., up to 22-bud-left heading (22blh), respectively. By convention, four general levels of intensity of heading treatments are distinguished as follows: three buds and less retained representing severe heading; 4blh to 6blh representing heavy heading; 7blh to 14blh representing moderate

heading; and 15blh to 22blh representing light heading. The number, types, and position of the lateral shoots developing from the retained buds of the parent branches were recorded.

2.2 The Model

A parent branch after being headed back is described as a succession of discrete axillary production associated with each node. A given type of axillary production was represented by a symbol: 0 for a latent bud and/or trace bud, 1 for a short shoot, 2 for a medium shoot, and 3 for a long shoot. The parent branch consists of a succession of differentiated zones. Each zone, representing a state in Markov chain, is characterized by a single or multiple lateral shoots. In this study, we used a Hidden Semi-Markov Chain (HSMC) model to capture the branching structures of heading parent branch [14]. The term hidden characterizes the fact that the branching zones are not always occupied by a single type of axillary production, and therefore could not be observed directly.

A j-state Hidden Semi-Markov Chain is defined by the following parameters:

The initial probability (π_j) is the probability of the proximal bud in each parent branch belongs to a given branching zone j:$\pi_j = P(S_1 = j)$with j = 1,. . . ,J where

$$\sum_{j=1}^{J} \pi_j = 1$$

The transition probability (p_{ij}) is the probability of branching zone transfer from i to j:$p_{ij} = P(S_n = j/S_{n-1} = i)$,with i=1,. . . ,J-1 and j=1,. . . ,J where

$$\forall i \in \{1, \ldots, J-1\}, \sum_{j=1}^{J} p_{ij} = 1$$

The occupancy distribution ($d_j(u)$) is the distribution of length of a given branching zone along the parent branch measured in number of nodes:

$$d_j(u) = P(S_{n+u+1} \neq j, S_{n+u-v} = j, / S_{n+1} = j, S_n \neq j, v = 1, \ldots, u-1), u = 1, 2, \ldots$$

All statistical analyses were performed using Matlab software (version 7.0, The MathWorks, Inc., USA) and AMAPmod statistical software by dynamic programming algorithm and viterbi algorithm.

2.3 Simulation Techniques

In order to obtain 3-D graphs with great fidelity to the branching structures of apple tree, a single theoretical plant axis, called the reference axis, can thus be defined, which successively takes all the possible states of buds according to their physiological age.

The reference axis is simulated by a finite 'left to right automaton', where each state is characterized by three sets of parameters: topological parameters (branching, death laws, number of shoots per node, number of fruits per cluster, number

of inter-nodes per growth unit, etc.), geometric parameters (phyllotaxy, branching angle, length of inter-nodes, organ bending angle, conicity ratio of the shoots, etc.), and parameters of the transition function from one state to another.

The branching order is an important aspect in the description of a branching structure of apple tree. In this context, the first formed axis, issued from the parent branch, is order 1. The shoots that it carries are order 2, and so on.

The control of time in the simulation is assured by a scheduler. The updating of the scheduler involves determining the times of occurrence of the organs and placing them at the appropriate moment in the scheduler. These times of occurrence are calculated according to the endogenous functioning parameters of the organ defined in the reference axis.

3 Simulation Results and Visualization

3.1 Proportion of Budbreak for Retained Axillary Buds

As for a new shoot born in spring, shoot growth after being pruned depends on assimilate availability. Therefore in the case of heavy heading (i.e., heavily reducing potential leaf surface for the following season as well as stored carbohydrate

Table 1. The proportion of long shoots, medium shoots, short shoots, and latent buds per parent branch, according to heading treatments, on 'Fuji' apple trees, and the proportion of retained buds that produced shoots after pruning

Heading treatments	Latent bud	Short shoot	Medium shoot	Long shoot	Budbreak
1 blh	0.00	0.00	0.00	1.00	1.00^a
2 blh	0.00	0.02	0.08	0.90	1.00^a
3 blh	0.33	0.10	0.20	0.37	0.67^b
4 blh	0.40	0.15	0.2	0.25	0.60^b
5 blh	0.42	0.12	0.22	0.24	0.58^b
6 blh	0.47	0.15	0.18	0.20	0.53^c
7 blh	0.46	0.17	0.17	0.20	0.54^c
8 blh	0.46	0.23	0.16	0.15	0.54^c
9 blh	0.49	0.24	0.14	0.12	0.51^c
10 blh	0.54	0.24	0.12	0.10	0.46^c
11 blh	0.48	0.27	0.14	0.11	0.52^c
12 blh	0.47	0.29	0.15	0.09	0.53^c
13 blh	0.47	0.28	0.15	0.11	0.53^c
14 blh	0.46	0.29	0.15	0.10	0.54^c
15 blh	0.51	0.27	0.15	0.08	0.49^c
16 blh	0.54	0.26	0.13	0.08	0.46^c
17 blh	0.54	0.25	0.12	0.08	0.46^c
18 blh	0.52	0.30	0.11	0.07	0.48^c
22 blh	0.50	0.27	0.15	0.08	0.50^c

[a,b,c] Superscript letters indicate significant differences at $P<0.05$, according to a Kruskal-Wallis test.

reserves in the woody tissues), the amount of available assimilates is likely to decrease, leading to reducing the generation of new bearing wood.

Table 1 shows that the proportion of budbreak in heavy heading and severe heading ($P<0.05$) was significantly different from that in light heading ($P<0.05$) and moderate heading($P<0.05$). The proportion of budbreak following moderate heading was not significantly different from that in light heading.

3.2 Comparison of Branching Characteristic of the Headed Parent Branch

In our HSMC model, the zone lengths were reflected in the corresponding occupancy distributions (Fig. 1).

In this context, severe heading parent branch has strong branching capability, which appeared in the higher proportion of long shoots (Table 1). Light heading treatments (15blh to 22blh) had four branching zones of which the non-branching zone was the largest, while heavy heading (4blh to 6blh) had only three branching zones, similar to severe heading. As for moderate heading treatments (7blh to 14blh), the branching zones were divided as follows: the first zone, located on the first 2.2-4.1 nodes from the base on average, corresponding to latent buds; the second zone , located on the 3.7-8.6 nodes from the base on average, consisting of short shoots and latent buds, and was the secondary reproductive branching zone. The next zone, located first 5.8-13.5 nodes, was occupied mainly by short and medium shoots, mixed with latent buds. It is noteworthy that most of the fruits are located within this branching zone in apple trees, that is, it is the primary reproductive branching zone. The last zone, as a vegetative branching zone, was located on the last 1-1.4 nodes around the cut, and was composed of long shoots (Fig. 1).

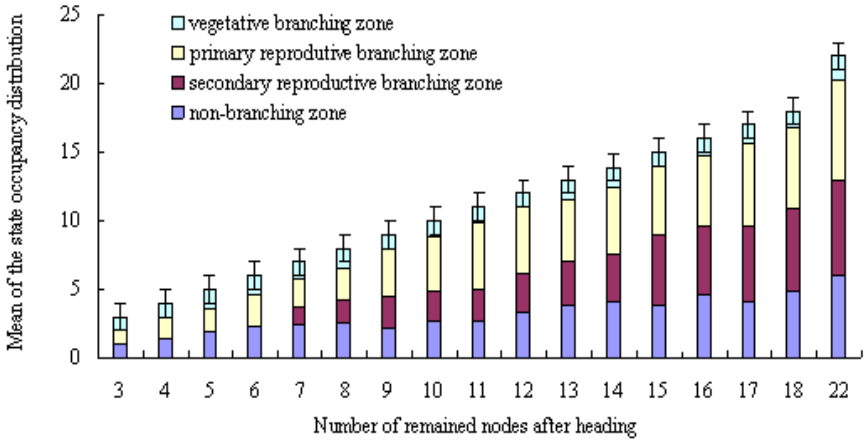


Fig. 1. Mean state occupancy distribution of the Hidden Semi-Markov models corresponding to different heading treatments

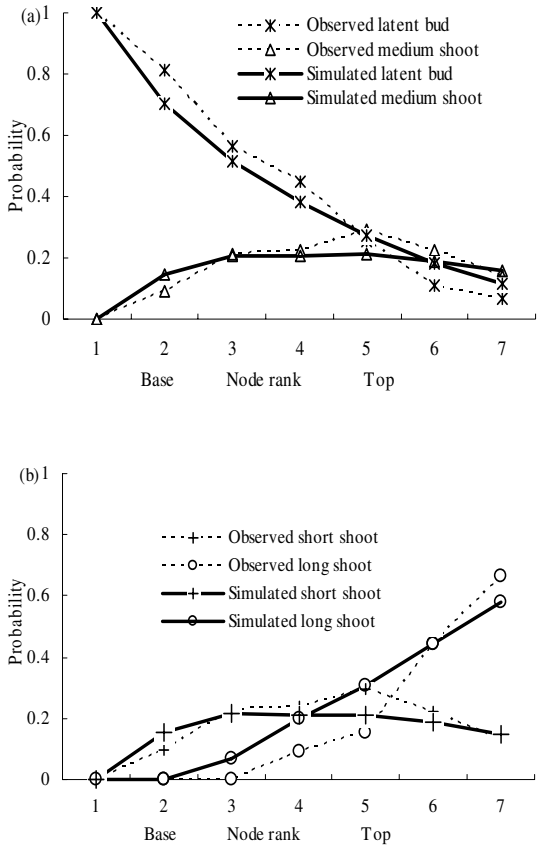


Fig. 2. Comparison between observed and theoretical probabilities of the lateral shoots according to the node rank on 7blh. (a) latent bud and medium shoot; (b) short shoot and long shoot. Dotted lines represent probabilities extracted from the observed data, and solid lines represent simulated probabilities calculated by the Hidden Semi-Markov Chain model.

The accuracy of the entire model was evaluated by comparing the predicted characteristics with those extracted from the observed data of the branching structure (Fig. 1). The results presented here show that the model is largely consistent with observations, although there are some quantitative discrepancies between simulations and observations.

The fruit on the primary reproductive branching zones was the greatest in number, so it is a more important consideration for branch responses to heading. Light heading (15blh to 22blh) was characterized by the same length of secondary and primary reproductive branching zones, the mean state occupancy of vegetative branching zone in 22blh was 6.2 nodes, corresponding to 3.9-4.6 nodes in 15-18blh, it showed that 22blh had a longer vegetative branching zone.

The proportion of primary reproductive branching zones and vegetative branching zones increased from 3blh to 22blh. The mean numbers of fruits set at primary reproductive branching zones were twice as many as in secondary reproductive branching zones [16]. This suggests that the proportion of the two types of branching zones could provide an early evaluation of fruit production. Compared with light heading (15blh to 22blh), moderate heading (7blh to 14blh) had a higher proportion of reproductive branching zones. As the moderate heading treatment is usually considered balancing vegetative and reproductive growth in comparison with the light one, to a certain extent, the moderate one is recommended for heading treatment in the traditional pruning practices to stimulate growth and branching, control the size of trees, encourage fruitfulness, rejuvenate older tree.

3.3 Visualization

We used the software Pruningsim [16], which based on the reference axis technique, to obtain graphic output and coding files of sequences about spatial branching patterns. The simulation software, developed in C language and implemented on Linux workstations, is able to calculate the architecture of any plant by its reference axis parameters.

The variability in the observed branching structure was restored by using a seed i.e. a random number that served to initialize simulation. At the beginning of the simulation cycle, growth is carried out, creating the parent branches, and the subsequent growing shoots along the parent branches. The number and distribution of shoots depends on the HSMC model of the apple tree, which defines its topological structure. The geometry of the branches is computed according to intrinsic geometric parameters in the reference axis.

The simple case of immediate expansion, where organs are created directly with their final size, applies well to apple trees which create their leaves over the course of a few days in the spring. Because plants have self similarity at multiple hierarchical structures (branches, leaves, whole plant), it is possible to approximately represent the geometry of a model using a small number of representative elements (branches, leaves, etc) so that we can build a memory-cheap representation of the plant.

The simulated topological elements are stored in a line tree file. The line tree contains all the information necessary for the representation of organs: transformation matrix, age of tree organs, symbol number, etc. The tree can be visualized by linking the line tree and a 3-D organ shapes (leaves, internodes) on the display.

To give an intuitive interpretation of the pruning response of one year old branches, a detailed and particular description in the following for 7blp was to be used as a reference for comparing other heading treatments (Fig. 3). When all the shoot types in 7blh were considered, 56% of lateral buds developed along the parent branch and the remainder were retained as latent buds. Of the developing buds, approx. 16%, 16%, 14% differentiated into a short shoots, medium shoots, and long shoots, respectively. The distribution of the short shoots highlighted

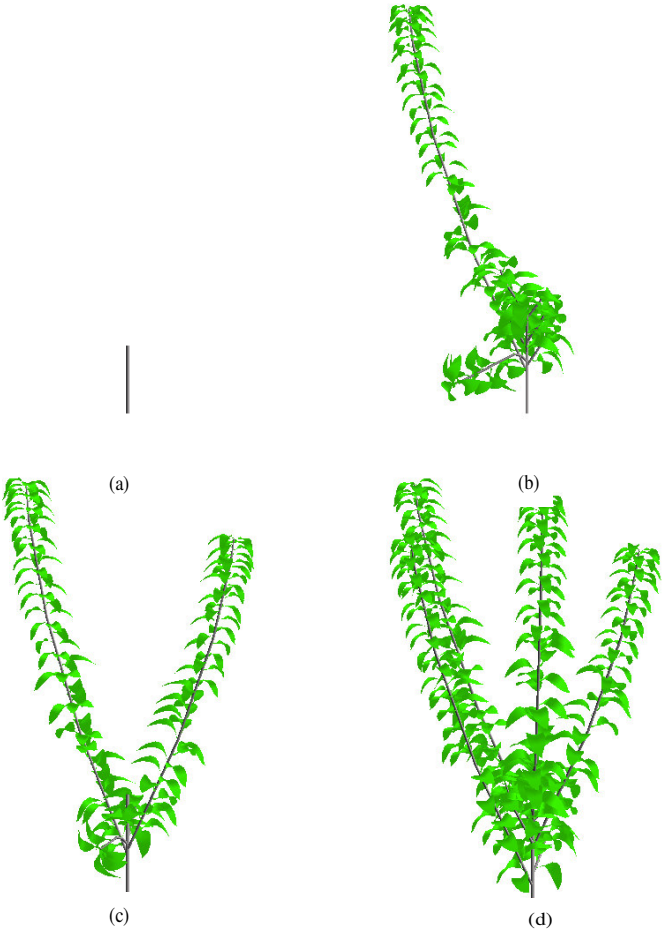


Fig. 3. Simulation results of "7blh". Lateral views of a few examples branching process of the parent branch, (a) represents the headed parent branch, (b)-(d) represents the branching structure of the headed parent branch, respectively.

the isolation along the parent branches since the most number of the successive and transition nodes was one. Similarly, the medium shoots and long shoots were isolated in the same manner as the short shoots.

A set of simulations could restore the variability of the branching pattern in different heading severities well. We compared simulation results with field observations as far as possible. The various simulations described gave a close to picture of reality. The branching patterns of the headed the parent branches were also well characterized.

On Fig. 4, we show some examples of fruit setting under the different level of heading back. Successive images correspond to severe heading (a-c), heavy heading (d-f), moderate heading (g-n), and light heading (o-s). It appears clearly

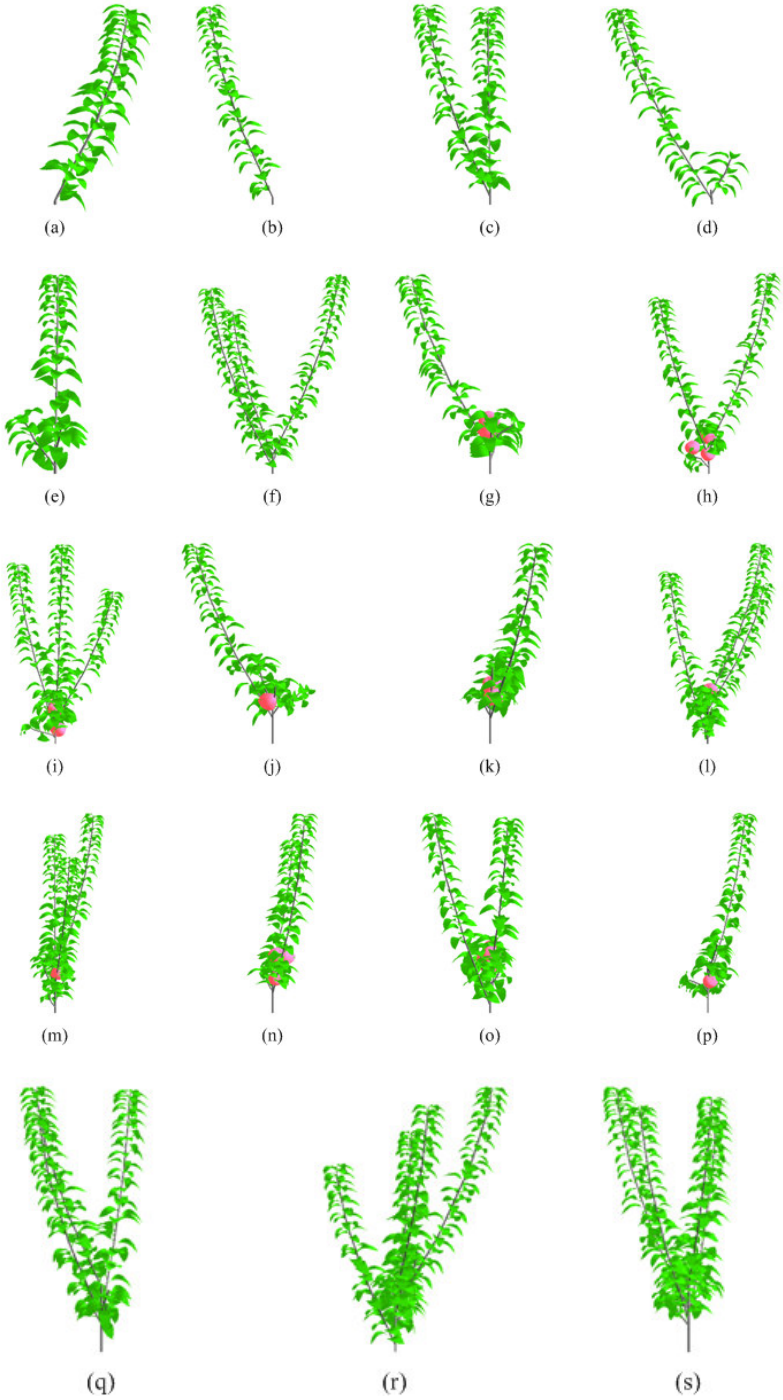


Fig. 4. Compared pruning response of one-year-old parent branches under different heading intensities

along the moderate heading (g-n) parent branch that the overall balance of the vegetative and reproductive growth is influenced by pruning. The first row image of Fig. 4 shows the severe and heavy heading have longer vegetative branching zone. The last row of image shows light heading has more latent bud, less fruit setting than moderate heading.

4 Discussion

Manipulating the vegetative and reproductive growth relationships may be considered as the ultimate goal of fruit tree management. Apple tree productivity is determined by multiple factors, including branching architecture. However, interactions between branching characteristics and pruning are sometimes very difficult to observe and quantify in the field due to the time lag between pruning and regrowth. This delay between cause and effect makes the conventional approach of training students indeed challenge.

"Virtual apple tree pruning" offers realistic significant opportunities for the teaching of pruning techniques in horticultural education. It is possible in theory for a student to prune a virtual parent branch and then observe its regrowth in a few seconds [17]. This is quite helpful tool because it allows student to see how trees react to alternative pruning practices are applied, to avoid mistake using a three-dimensional model where one can both count the topological entities and visualize the resulting geometry. The quantitative aspect of this modeling makes it particularly easy for optimization of training and pruning systems and estimation of crop load taking into account the tree structure development.

A main benefit of this approach is the coupling of cause and effect which allows the student to take a more experimental and interactive approach to learning, helps to reduce time- and labor-consuming investigations. For example, this simulation has shown that heavy and severe heading causes a flush of long shoots, which is a non-fruitful, shade out the interior of tree canopy. Alternatively, moderate heading prevents the formation of an autumn flush with higher ability to set flower buds, which demonstrates great ability to produce more short shoots and medium shoots. This growth pattern leads to higher fruit set. Usually, shortening the parent branches by half to two thirds (7-14blh) to an outward facing bud is required to encourage the production of more fruiting spurs along its length. From these simulation results, students understand that light heading back is not recommended to alleviate shoot crowding, to improve fruit size and quality and to maintain an optimum light exposure on the whole tree canopy, whereas medium heading back can adopt to improve profitability of the orchard. Severe heading back usually recommended on weak ageing trees.

The model was applied to apple tree but there was no restriction concerning its application to other species. Environmental effects like light reception, carbon allocation and so on, were not examined in this work. Future development of the models would include their integration into functional structural models which contain functional as well as structural information to simulate realistic 3D fruit tree development correctly. These works on virtual fruit tree pruning are underway in our laboratory [18].

Acknowledgements

This work was supported by a grant from Guangdong Natural Science Foundation (8151064001000009), Doctoral Start-up Fund of Guangdong Agricultural Academy of Sciences, Key Technologies R & D Program of Guangdong Province of China (58581110304032), and Leading Academic Discipline Project of Shanghai Municipal Education Commission, Project Number: B209.

References

1. Miller, S.A., Broom, F.D., Thorp, T.G., Barnett, A.M.: Effects of Leader Pruning on Vine Architecture, Productivity and Fruit Quality in Kiwifruit (Actinidia deliciosa cv.Hayward). Sci. Hortic. 91, 189–199 (2001)
2. Yin, X., Kropff, M.J., Aggarwal, P.K.: Optimal Preflowering Phenology of Irrigated Rice for High Yield Potential in Three Asian Environments, a Simulation Study. Field Crops Research 51(1/2), 19–27 (1997)
3. Prusinkiewicz, P., Remphrey, W.R., Davidson, C.G., Hammel, M.S.: Modelling the Architecture of Expanding Fraxinus pennsylvanica Shoots Using L-systems. Can. J. Bot. 72, 701–714 (1994)
4. Balandier, P., Lacointe, A., Roux, X.L., Sinoquet, H., Cruiziat, P., Le Dizès, S.: A Structural-Functional Model Simulating Single Walnut Tree Growth in Response to Climate and Pruning. Ann. Forest Sci. 57, 571–585 (2000)
5. Costes, E., Guédon, Y.: Modelling Branching Patterns on 1-year-old Trunks of Six Apple Axillary Flowering Sequences. Ann. Bot. 212, 481–520 (2002)
6. Smith, G.S., Gravett, I.M., Edwards, C.M., Curtis, J.P., Buwalda, J.G.: Spatial Analysis of the Canopy of Kiwifruit Vines as It Relates to the Physical Chemical and Postharvest Attributes of the Fruit. Ann. Bot. 73, 99–111 (1994)
7. Seleznyova, A.N., Greek, D.H.: Effects of Temperature and Leaf Position on Leaf Area Expansion of Kiwifruit (Actinidia deliciosa) Shoots, Development of a Modelling Framework. Ann. Bot. 88, 605–615 (2001)
8. Costes, E., de Reffye, P., Lichou, J., Guedon, Y., Audubert, A., Jay, M.: Stochastic Modelling of Apricot Growth Units and Branching. Acta Hortic. 313, 89–98 (1992)
9. du Plooy, P., Sadie, A., Jacob, G., Cook, N.C.: Branching Habit of 2-year-old Pear Branches Classified on the Basis of Length and Position of 1-year-old Laterals. Sci. Hortic. 95, 193–201 (2002)
10. Costes, E., de Reffye, P., Lichou, J., Guedon, Y., Audubert, A., Jay, M.: Development of Young Pear Tree Architecture and Occurrence of First Flowering, a Varietal Comparison. Hortic. Sci. Biotechnol. 79, 67–74 (2004)
11. Bassi, D., Dima, A., Scorza, R.: Tree Structure and Pruning Response of Six Peach Growth Forms. J. Amer. Soc. Hort. Sci. 119, 378–382 (1994)
12. Weibel, A.R.S., Dejong, T.M.: Comparative Vegetative Growth Responses of Two Peach Cultivars Grown on Size-controlling versus Standard Rootstocks. J. Amer. Soc. Hort. Sci. 128, 463–471 (2003)
13. Godin, C., Guédon, Y., Costes, E.: Exploration of a Plant Architecture Database with the AMAPmod Software Illustrated on an Apple Tree Hybrid Family. Agronomie. 19, 163–184 (1999)
14. Guédon, Y.: Computational Methods for Discrete Hidden Semi-Markov Chains. Appl. Stoch. Model. Bus. Ind. 15, 195–224 (1999)

15. Mauget, J.C., Frizot, N., Guinard, J.: Effect of Time and Position of Summer Pruning on the Release from Inhibition of the Axillary Buds of Walnut Sprouts. International Walnut Meeting (1993)
16. Xia, N., Hu, B.G.: Evaluation of Importance of Pruning on Branching Structures in Nectarine Tree Using the Model of Hidden Semi-Markov Chain. In: The 3rd International Symposium on Intelligent Information Technology in Agriculture (2005)
17. Atkins, T.A., O'Hagan, T.A., Rogers, W.J., Pearson, M.W.E., Cameron, A.: Virtual Reality in Horticulture Education, Pruning Simulated Fruit Trees in a Virtual Environment. Acta Horti. 416, 243–246 (1996)
18. Xia, N.: Modeling Fruit Setting Patterns of the Peach Shoot. In: 2008 International Conference on Cyberworlds. IEEE Computer Society, Los Alamitos (2008)

An Architecture for Flexible Entity Configuration in a Simulation Environment*

Changgu Kang, Yoosoo Oh, and Woontack Woo

GIST U-VR Lab.
Gwangju 500-712, S. Korea
{ckang,yoh,wwoo}@gist.ac.kr

Abstract. Recently, people's interest is on the rise for virtual simulation as witnessed from a large number of applications using virtual space. Especially, simulations for ubiquitous environment focus on generating realistic data, context, contextual interpretation and have characteristics such as systematic testing, detection of rule confliction, and provision of context-aware modules. The previous works only consider systematic functionalities, but do not consider how to easily configure entities in a simulation environment for a user. To make up for these limitations, we propose a system architecture for flexible entity configuration in a simulation environment for smart space. The proposed system architecture removes dependency which is related to a parameter among functions of each entity, and independently interprets and generates context information. An application developer can implement graphical user interface(GUI) of new entities without considering the structural dependency about overall GUI of the system. Therefore, the proposed system architecture is expected to provide flexible simulation environment for an application developer to test an entity by cost effectiveness.

Keywords: Simulator, virtual reality, smart space, context-awareness.

1 Introduction

Recently, virtual space is applied to various domains such as education, entertainment, and medical service according to an increased interest of people on virtual space [1,5,6]. Since using the virtual space in these domains solves limited constraints such as time, technique, and cost, a user is offered with indirect yet increased educational and entertaining experiences [5]. Using virtual space, the works about simulation of smart space are also making progress. These works cover many sensors and actuators, and use acquired data to interpret context information [2,4,8,12].

There are serveral related works, such as CASS [12], CAST [4], UbiREAL [8], and C@SA [2]. Most of these simulators focus on generating realistic data,

* This research is supported by Korea Culture Content Agency(KOCCA) of Ministry of Culture, Sports and Tourism(MCST) in the Culture Technology(CT) Research & Development Program 2009.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 38–48, 2009.

context, and contextual interpretation and have characteristics such as systematic testing, detection of rule confliction, and provision of context-aware modules. Existing simulators only consider systematic functionalities, but do not consider how to easily configure entities in a simulation environment for a user. When there is dependency between entities, an application developer has to spend repetitive effort whenever an entity is removed.

In this paper, we propose a system architecture for independent entity configuration in a simulation environment. First, the proposed architecture removes dependency among entities such as a parameter defined in programming functions . Second, the proposed architecture enables an individual entity to generate and interpret context information. Third, a developer can implement graphical user interface(GUI) of new entities without considering the structural dependency about overall GUI of the system.

The rest of this paper is organized as follows. In section 2, we explain the requirements for the proposed architecture and overall system architecture. In section 3, we describe a scenario-based implementation of simulator following the proposed system architecture. In section 4, we conclude this paper and dicuss the future works.

2 System Architecture

2.1 Requirement and Analysis

In this paper, we have considered the following requirements for the proposed system archtecture.

(1) The entities have their own context-aware module. The shared context-aware module has to confirm with changed status of all entities and generates context information according to those changes. As shown in Fig. 1 (a), the increased number of entities increases complexity and incurs synchronization problem. As shown in Fig. 1 (b), our proposed system architecture assigns context-aware module to each entity. In this approach complexity is kept to minimum and each entity is able to independently interpret and generate context information. Also there is no synchronization problem for entity configuration.

(2) There is no internal data flows between entities. The data generated by an entity are changed into context information through context-aware module. Then, all entities are able to use this context information. If this context information flows internally in a system, the flow of context is complex. Since entities are dependent in programming, a user has to remove all links related to an entity whenever he eliminates this entity. Fig. 2 (a) shows the flow of context information between related entities each other. More the number of entities exist, the complexity of a context flow is going to increase. The data of the proposed architecture flows through network. As shown in Fig. 2 (b), even though the number of entities increases, the flow of context information is kept simple and the dependency on programming is minimized because each entity has to only consider context information from the network.

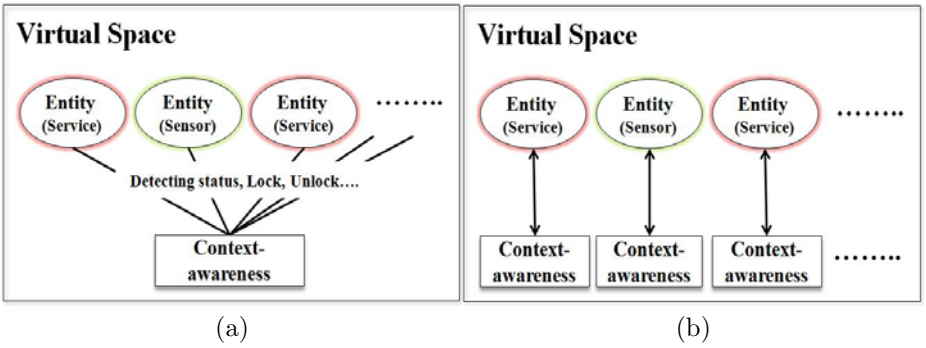


Fig. 1. (a) Shared context-aware module between entities and (b) independent context-aware module for each entity

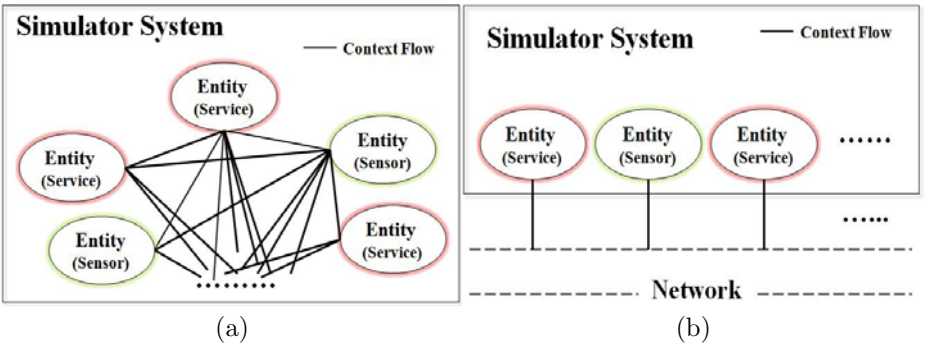


Fig. 2. The context information flows (a) internally in a system as a parameter and (b)externally through network

(3) Each entity holds own GUI. A user composes GUI for the control of entities during simulation. A user is able to implement GUI in a window or compose own GUI for each entity in accordance with the configuration. The GUI implemented in a window has a limit on the number of entities. Therefore, the latter approach is more useful for customized simulator. Fig. 3 (a) shows the window used for GUI configuration. We used this method for 2D simulator in our previous work. However our domain is smart space in ubiquitous computing environment and there are many sensors and services. Therefore, there should be no limit about the number of entities. Since the proposed system architecture provides components for GUI configuration, our architecture can guarantee independent GUI configuration and a developer can implement a new GUI without considering the structural dependency about overall GUI of the system. Fig. 3 (b) shows separate GUI for the entity. As shown in Fig. 3 (b), when a developer selects an entity, GUI for the entity is displayed.

(a) (b)

Fig. 3. GUI configuration (a) using a window and (b) individualized according to each entity

(4) There is a module for configurating indepently existing entities in a simulation space. Requirements (1), (2), and (3) are useful in keeping independency. Also it makes it easier for a developer to add and remove an entity and implement new entity. Although there are independent entities, we simulate these entities in a single simulation space. Therefore, as shown in Fig. 4, there is a module to make the simuation space and configure needed entities in the simulation space.

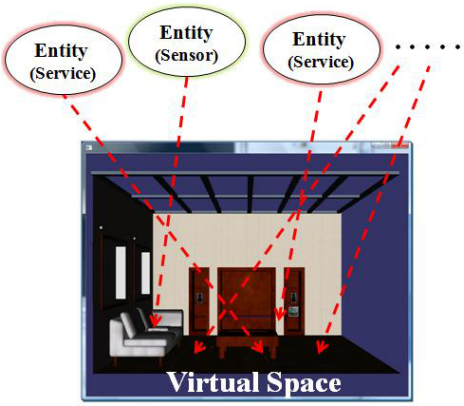


Fig. 4. Entity's configuration in virtual space

2.2 Proposed Architecture

Since the proposed system architecture keeps independency on each entity, a developer can separately implement new entity. And a developer easily add and remove existing entities whenever he organizes simulation environment. Fig. 5 shows the organized system architecture based on previously mentioned requirements. Each entity has its own context-aware module and GUI module, and there is an entity configuration module in a simulation system. Entity configuration

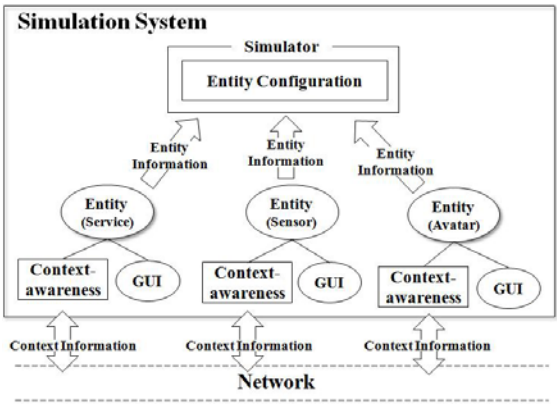


Fig. 5. System architecture

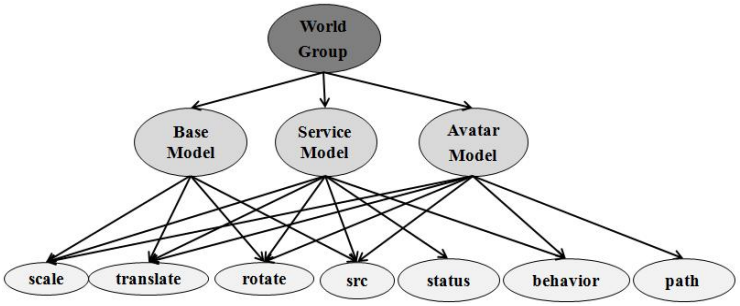
module receives entities' information to configurate a simulation environment. The communication between entities is accomplished through network.

We use Unified Context-aware Application Model(UCAM) [9] to satisfy requirement (1). As shown in table 1, we define serveral components and classes. Main components are *Communicator, Context Monitoring, GUI, and Environment Configuration*. We modified UCAM in parts to satisfy requirement (1). Using *Context Monitoring*, a user can observe context information from UCAM which is independently assigned in real-time. To satisfy requirement (2), we use existing *Communicator* in UCAM which is in charge of communication between entities for context information through User Datagram Protocol communication. *Communicator* sends the active message to all existing entities in local network whenever an entity is active. And the entity which receives the active message displays a join message to inform addition of an entity. To satisfy requirement (3), the proposed architecture provides *GUI* component. Using *GUI* component, a user defines the layout about an entity's GUI and a behavior activated according to each button. A layout is to arrange each button and decides basic appearance of a button image.

To satisfy requirement (4), we define *EnvironmentConfiguration* component as a module to organize independent entities in a simulation space according to developer's definition. EnvironmentConfiguration manages a 3D model of an existing entity in virtual space and provides an interface in XML format. As shown in Fig. 6 (a), a 3D model is managed as base model, service model, and avatar model according to each entity's characteristic. A base model does not define the status and the behavior of a 3D model as a static model in the simulation environment. A service model defines the status and the behavior of a 3D model in accordance with the change of the entity's status. An avatar model can define the status and the behavior such as a service model and have path. As *EnvironmentConfiguration* provides a interface of XML format in Fig. 6 (b), a developer can configurate file path, position, size, and rotation of all 3D models.

Table 1. Main component and class

Component	Class	Description
Communicator	Communicator	Responsible for exchanging context information between entities by UDP
Context Monitoring	Browser	Display context information from an entity
GUI	Control Button	Select layout according to button image
	ButtonExecutor	Select behavior of activated entity according to each button
Environment Configuration	PickableObject	Recognize composed entity
	Environmental Setup	Manages entity 3D models
		Provide XML interface for user defined environmental configuration



(a)

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
- <EnvironmentConf version="1.0" xmlns="http://uvr.gist.ac.kr/" xmlns:xsi="http://www.w3.org/2001/
  - <Header copyright="Changgu Kang">
      This is environment configuration for simulation!
      <Simulator name="3D Smart Home Simulator" version="1.0" />
    </Header>
  - <Environment>
    - <BaseModel>
        <SRC>Model/BaseModel/Room.osg</SRC>
        <SCALE>"1.0 1.0 1.0"</SCALE>
        <TRANSLATE>"0.0 0.0 0.0"</TRANSLATE>
        <ROTATE>"0.0 0.0 0.0 0.0"</ROTATE>
      </BaseModel>
    - <BaseModel>
```

(b)

Fig. 6. (a) Structure for managing 3D model and (b) XML interface for entity's configuration

Additionally, a developer can set up the name of a service entity and profile information of an avatar entity.

3 Implementation and Scenario

3.1 ubiHome 3D Simulator

We implemented a simulator and service entities using previously mentioned components. The implemented simulator was based on ubiHome [3] which exists as a smart home in our laboratory. We named ubiHome 3D Simulator as the system prototype of the proposed architecture. A service was implemented as the form of dynamic link library, and it is possible to distribute to a developer who uses the same system. We used OpenSceneGraph Library [10] as a 3D graphic toolkit. And we used Cal3d [7] and osgcal [11] library for the animation of a 3D model. 3D models were made using 3D MAX [14].

Fig. 7 shows components and data flow of implemented services and simulator. There are additional components such as *EventHandler, EntityCore, and Visualization* except main components. *EventHandler* manages animation according to the changes of service's status. And *EntityCore* has 3D model information about a service and manages all components of a service. *Visualization* shows services composed according to developer's definition.

We implemented virtual services such as TV, window, lamp, air conditioner, light, and avatar. TV, window, and lamp service also exist in real ubiHome. And air conditioner, light, and avatar service only exist in virtual ubiHome. As shown in table 2, characteristics of services are as follows. The services which exist together in real and virtual ubiHome are synchronized. For the synchronization, TV and window service use JPEG as the format of image which input from real TV and real window at 20 fps. To synchronize with a real lamp, a virtual lamp service has characteristics of three colors and three brightness levels like a real lamp. The brightness of virtual light can be controlled by using a real illuminance sensor and a virtual light service has thirteen levels. The air conditioner

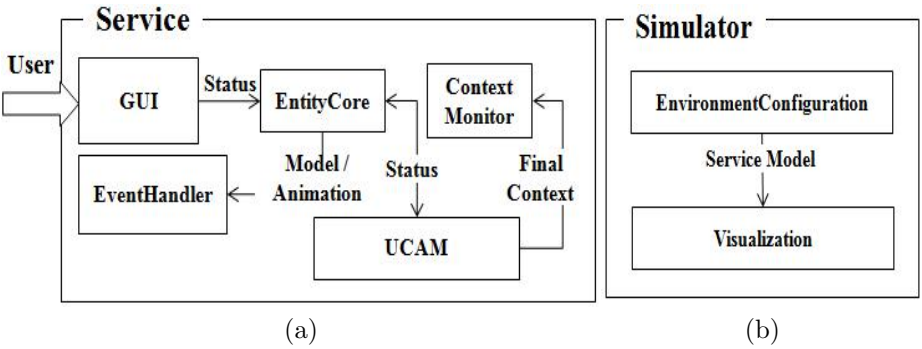


Fig. 7. The components and the data flow of (a) the implemented services, and (b) the implemented Simulator

Table 2. Service specification

Space	Service	Specification
Real ubiHome	TV, Window	JPEG Format, 20fps
	Lamp	Three color(blue, red, green), Three levels of brightness
Virtual ubiHome	TV, Window	Real time control, Synchronizing real TV and window
	Lamp	Real time control, Synchronizing real lamp, Three color(blue, red, green), Three levels of brightness
	Air conditioner	Real time control
	Light	Real time control, 13 levels of brightness
	Avatar	Real time control, Synchronizing real human using physical position and activity sensor

(a)

(b)

Fig. 8. (a) Real ubiHome and services, and (b) the implemented virtual ubiHome and services

service can be controlled using a real temperature sensor. An avatar has profile information such as age, name, and gender. And an avatar can be controlled by a devloper and reflects behaivor or positon of a real human using position sensors(cushion sensor, IR sensor) and an activity sensor(particlesensor [13]). The behavior of an avatar is walking, running, sitting, and standing. Fig. 8 (a) shows real ubiHome and real services, and Fig. 8 (b) shows the implemented virtual ubiHome and virtual services.

3.2 Scenario

We wrote a scenario to test ubiHome 3D Simulator. The targets of the written scenario are cushion sensor and IR sensor. The virtual services used for cushion sensor and IR sensor are TV and lamp service. Because these virtual services synchronize with real services, real and virtual services are actioned. The scenario is as follows.

(a)

(b)

(c)

Fig. 9. Demo screenshot: (a) Enter a room, (b) Virtual lamp and TV service are active, (c) Go out and all service are turned off

"On Feb 1, 2009, PM 5:00, after work, Chan enters a room. When Chan enters a room, IR sensor is active in real ubiHome. At the same time, a Chan's avatar enters a virtual room because context information of IR sensor is reflected into a virtual room. Chan moves forward to a cushion to take a break and sits down. Then the cushion sesnor detects the behavior and the position of Chan, and Chan's avatar moves forward a virtual cushion and sits down. When a cushion sensor detects the behavior of Chan, which is to sit down, a virtual lamp and a virtual TV service are activated. After taking a break, Chan goes out. When IR sensor detects Chan's leaving, a Chan's avatar goes out and all virtual services are turned off."

We defined the behavior of a service according to needed context information to be applied to our scenario. And we set up cushion sensor and IR sensor in real ubiHome. We confirmed working of rhe cushion sensor and IR sensor, and Fig. 9 is a screenshot of demonstration about our scenario. Fig. 9 (a) shows when chan enters a home. And Fig. 9 (b) shows that services are active. Final Fig. 9 (c) shows that all services are turned off.

4 Conclusion and Future Work

In this paper, we proposed a system architecture which keeps independency among all entities composed in a simulation environment and is useful for implementaion, addition, and remove of an entity whenever a developer organizes the simulation environment. The proposed system architecture removes dependency which is related to a parameter among functions of each entity, and individually interprets and generates context information. A developer can implement graphical user interface(GUI) of new entities without considering the structural dependency about overall GUI of a system.

We defined requirements for the proposed architecture and implemented ubiHome 3D Simulator and virtual services. After writing a scenario, we tested ubiHome 3D Simulator based on our architecture. Using real sensors(IR sensor, cushion sensor) and virtual services(TV, lamp), we confirmed our system. As the future work, we are considering to apply our architecture to other domains and confirm the usefulness of our architecture.

References

1. Alverson, D., Saiki, S., Caudell, T., Panaiotis, K., Sherstyuk, A., Nickles, D., Holten, J., Goldsmith, T., Stevens, S., Mennin, K., et al.: Distributed immersive virtual reality simulation development for medical education. Journal of International Association of Medical Science Educators 15, 19–30 (2005)
2. De Carolis, B., Cozzolongo, G., Pizzutilo, S., Plantamura, V.: Agent-Based Home Simulation and Control. In: Hacid, M.-S., Murray, N.V., Raś, Z.W., Tsumoto, S. (eds.) ISMIS 2005. LNCS, vol. 3488, pp. 404–412. Springer, Heidelberg (2005)
3. Jang, S., Shin, C., Oh, Y., Woo, W.: Introduction of'ubiHome'Testbed. IPSJ SIG Technical Reports 2005(60), 215–218 (2005)

4. Kim, I., Park, H., Noh, B., Lee, Y., Lee, S., Lee, H.: Design and Implementation of Context-Awareness Simulation Toolkit for Context learning. In: IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing, 2006, vol. 2 (2006)
5. Kock, N.: E-Collaboration and E-Commerce In Virtual Worlds: The Potential of Second Life and World of Warcraft. International Journal of e-Collaboration 4(3), 1–13 (2008)
6. Lee, E., Wong, K.: A Review of Using Virtual Reality for Learning. In: Pan, Z., Cheok, D.A.D., Müller, W., El Rhalibi, A. (eds.) Transactions on Edutainment I. LNCS, vol. 5080, pp. 231–241. Springer, Heidelberg (2008)
7. C. library, http://home.gna.org/cal3d
8. Nishikawa, H., Yamamoto, S., Tamai, M., Nishigaki, K., Kitani, T., Shibata, N., Yasumoto, K., Ito, M.: Ubireal: realistic smartspace simulator for systematic testing. In: Dourish, P., Friday, A. (eds.) UbiComp 2006. LNCS, vol. 4206, pp. 459–476. Springer, Heidelberg (2006)
9. Oh, Y., Woo, W.: How to build a Context-aware Architecture for Ubiquitous VR. In: International Symposium on Ubiquitous VR, p. 1 (2007)
10. OpenSceneGraph, http://www.openscenegraph.org/
11. osgcal library, http://osgcal.sourceforge.net
12. Park, J., Moon, M., Hwang, S., Yeom, K.: CASS: A Context-Aware Simulation System for Smart Home. In: 5th ACIS International Conference on Software Engineering Research, Management & Applications, SERA 2007, pp. 461–467 (2007)
13. Particle(TECO), http://particle.teco.edu/
14. A. D. StudioMax9, http://usa.autodesk.com/adsk

A Distributed Multi-agent Architecture in Simulation Based Medical Training

Jun Hu and Loe Feijs

Department of Industrial Design
Eindhoven University of Technology
5600MB Eindhoven, The Netherlands
{j.hu,l.m.g.feijs}@tue.nl

Abstract. In the United States as many as 98,000 people die each year from medical errors that occur in hospitals, according to a book with the title *To Err is Human*. It was found that in America 75 percent of the failures in rescue were caused by either the diagnosis or the treatment being too late. Many of these deaths could have been avoided by improved the communication and coordination with in the medical teams.

Team training using medical simulators is one of the methods to increase the skills of a multidisciplinary group of employees in the delivery room and especially to prevent inadequate communication in critical obstetric situations. Hoever with most of the currently available simulators, the level of realism is not particularly high. Next to the toy like external appearance, it is also the not really flexible material applied which has the effect that the training experience is still quite remote from the reality. Especially, most of the commercial products today are designed as a stand alone system that does not really take the team training aspects into account. For a more realistic experience and an optimal training result, we are aiming at the next generation simulation based training facilities, involving as many different senses as possible: vision, sound, smell and also importantly a realistic touch experience (moistness, warmth, friction). It brings more software and hardware devices and components into the training room.

This paper addresses the issues of distributed interactions in such a simulation based medial training environment. A scripting language is proposed, using a metaphor of play, with which the timing and mapping issues in describing the distributed presentations are covered. A distributed multi-agent based architecture for the such systems is also presented, which covers the timing and mapping issues of conducting such a script in a medical training environment.

The concepts of the play metaphor, the scripting language and the architecture are found to be applicable in simulation based medical training, because of the similar requirements on timing and mapping in applications of both distributed multimedia entertainment and simulation based medial training. However there are also clear differences between these two application areas. Further research and development need to be done to deal with the issues such as multiple participants in team training and the verification of the actual performance of a training session.

Keywords: Distribution, multi-agent, delivery simulator, medical training.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 49, 2009.

A Review on Augmented Reality for Virtual Heritage System

Zakiah Noh[1], Mohd Shahrizal Sunar[1], and Zhigeng Pan[2]

[1] Faculty of Computer Science and Information System, Universiti Teknologi Malaysia, 81310 Skudai, Johor
zakiahnoh@gmail.com, shah@fsksm.utm.my
[2] State Key Lab of CAD&CG, Zhejiang University, Hangzhou, 310027, China
zhigengpan@gmail.com

Abstract. Augmented reality is one of the emerging technologies to reconstruct the historical building and monument in the previous era, where the user experiences with the real environment or virtual scene. In education, Virtual Heritage becomes as a platform of learning, motivating and understanding of certain events and historical elements for the students and researchers. The significance of reconstruction of digital culture heritage are to preserve, protect and interpret of our cultural and history. In recent year, there are a number of significant researches and techniques that have been developed, which is focusing on virtual restitution of historical sites. This paper will present an overview on augmented reality in Virtual Heritage system and also consists with the explanation of techniques to reconstruct the historical sites.

Keywords: Virtual Reality, Augmented Reality, Virtual Heritage, 3D Reconstruction.

1 Introduction

With the increase of computational speed and advancement of specific computer technology, virtual reality or augmented reality applications become feasible in multidisciplinary areas such as in simulation, education, entertainment, medical and game. Furthermore, researches in Virtual Reality (VR) and Augmented Reality (AR) have shown considerable growth with the development of interactive computer technology and sophisticated 3D modeling packages.

Virtual Heritage is one of the computer-based interactive technologies in virtual reality where it creates visual representation of monument, artifacts, building and culture to deliver openly to global audiences [1]. In education, Virtual Heritage becomes as a platform for enhancing the learning process, motivating and understanding of certain events and historical elements for the use of students and researchers. In developing Virtual Heritage application, eight requirements have been specified: high geometric accuracy, capture of all details, photorealism, high automation level, low cost, portability, application flexibility, and model size efficiency [2].

Digital technology is used for the anthology, preservation and discovery of art and cultural heritage. However, in the developments of the concept of cultural park, AR

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 50–61, 2009.

technologies are significance on the re-enact of historical monuments to reproduce on site historical places as in the golden period [3].

Recently, AR technology has become a well-accepted technology among scientific community and public, which used for combining of real and virtual objects and mixed it into the real environment. In virtual heritage, this technology is used for improving the visitor experience of a cultural heritage site.

This paper will present a review on augmented reality in virtual heritage. Section 2 will discuss the previous research works of Virtual Heritage system. Section 3 will elaborate about augmented reality in Virtual Heritage and Section 4 will explain further about 3D reconstruction in AR for virtual heritage. Afterwards, we conclude this paper with summarize the related to this study.

2 Virtual Heritage System

Mixed reality is one of the technologies that encompass all the fields of reality, namely physical reality, augmented reality, augmented virtuality and virtual reality. Mixed reality refers to space which consists of real and virtual elements that interact with each other. The user will be experienced by putting them into certain type of reality. This technology has affected various fields of applications, from sociology to informatics and from art to architecture [4]. The concept of virtuality continuum defined by Milgram and Kishino [5] that relates to the mixture of classes of objects presented in any particular display situation.

Virtuality continuum defines the environment consisting of real object or real environment. This real world scene can be observed either via conventional video display or not using any particular electronic display system. For example, in cultural heritage system, visitor can see the real museum or artifact in real scene.

The continuum also presents the virtual environment, known as Virtual Reality that consists of only a virtual element. Virtual environment allows a user to interact with a computer-simulated environment where the user experience is real or imagined one. This technology completely immerses a user into an artificial environment such as in development of virtual museum. The most current VR environments are primarily visual experiences, which displayed either on a computer screen or through stereoscopic displays, speakers or headphones.

Augmented reality and augmented virtuality are two technologies in the mix reality area. AR is a combination of real object and computer-generated data where virtual object are blended into the real world. It means that user could see virtual and real object coexisted in the same space. Thus, AR technologies supplement reality rather than completely replacing it [6]. In [6], three criteria of AR system are defined: 1) Combination of real and virtual; 2) Interactive in real-time; 3) Register in 3D. For instance, in virtual Pompeii, the virtual characters are superimposed into a real environment. The visitors can see the animated characters acting a storytelling drama on the site of ancient Pompeii using mobile AR-life system's i-glasses in the real world.

On the other hand, augmented virtuality, also referred to as mixed reality, is a technology that merges the real world element into virtual environment. Augmented virtuality environment is mostly in a virtual space, where physical objects are integrated and interacted with the virtual world in real-time. For example, augmented

virtuality technologies bring the visitor into the virtual museum environment. Various techniques are used to achieve this integration such as using streaming video from physical spaces.

In general, the term of heritage refers to the study of everything that is inherited and recovery to remain through the archeology, art, tradition, religious and cultural. Cultural heritage is one of the valuable assets need to be preserved and protected for the future generation.

The aim of Virtual Heritage is to restore ancient cultures as a real environment that user can immerse and understand a culture. By creating ancient culture simulation, Virtual Heritage applications become as a link between the user of the ancient culture and the modern user. The interaction between them is one way, where the Virtual Heritage applications are dead and user can learn about the culture by interacting with their environment [7]. The efficient approach is to use VR in teaching students about ancient culture by sharing social space between user and virtual world.

According to [2], there are several motivations for Virtual Heritage reconstruction which are:

- Documenting historic buildings and objects for reconstruction in case of disaster;
- Creating educational resources for history and culture;
- Reconstructing historic monuments that no longer or only partially exist;
- Visualizing scenes from viewpoints impossible in the real world due to size or accessibility issues;
- Interacting with objects without risk of damage; and
- Providing virtual tourism and virtual museum exhibits.

Currently, Virtual Heritage has become increasingly important in the preservation, protection, and collection of our cultural and natural history. The world's resources of historical in many countries are being lost and destroyed. With the establishing of new technology, it can be used as a solution for solving problematic issues concerning cultural heritage assets [8]. The paradigms of Virtual Heritage project are discussed in the following section.

2.1 Virtual Hagia Sophia

Virtual Hagia Sophia was developed by researchers from MIRALab at University of Geneva [9]. It was under the Conservation of the Acoustical Heritage by the Revival and Identification of the Sinan's Mosques (CAHRISMA) project. Hagia Sophia Museum formerly was a mosque which is known as Masjid Sinan. The aim of this project is to develop an interactive simulation of Hagia Sophia museum that produces realistic environment with the illumination. This project also presented the simulation of characters and sound background.

2.2 Ancient Malacca Project

The purpose of Ancient Malacca project [10] is to produce the visualization of environment at Malay Sultanate of Malacca era during Sultan Mansur Syah's rule in 15th century. This project was developed in 2003 at Virtual Reality Center at Multimedia Development Corporation Sdn Bhd (MDeC) in Cyberjaya. The Ancient Malacca

Fig. 1. Ancient Malacca Virtual Heritage application [10]

project is based on research works done by historian that study about Malay Sultanate of Malacca history. The visualization of Ancient Malacca project was implemented by using high specification machine, namely SGI Onyx 3800 with 16 CPUs. This visualization was developed by using Iris Performer's software and displayed using dome approach. Fig. 1 shows the screenshot of Ancient Malacca project.

2.3 Virtual Campeche

Virtual Campeche [11] was created to simulate an old Mexican city located on the Yucatan Peninsula. It was found by the Spanish in 1540. In 2001, UNESCO declared Campeche as a World Cultural Heritage site. By creating the virtual Campeche, it allows the user to visit virtual Campeche through a web-based application using standard PCs. It was developed based on standard approach that is data acquisition and building reconstruction. To maximize interactivity and system responsiveness, three main techniques was applied in the virtual Campeche; 1) level of detail, 2) progressive scene display, 3) potential visibility computation.

2.4 Virtual Pompeii

In 1995, the virtual Pompeii project [12] was developed to recreate the theater area of the ancient Roman city of Pompeii in virtual space. This project has integrated with models of the Temple of Isis, the grand Theater, the Triangular Forum and connecting areas in three dimensional. The supporting historical documentation, original musical, dramatic compositions and imagery sources also have been produced in this project. To construct an interactive historical recreation, virtual Pompeii project has exploited the new immersive Virtual Reality as a medium.

3 Augmented Reality in Virtual Heritage

Recently, AR is widely being used in many applications such as education, entertainment, virtual heritage, simulation and games. In virtual heritage, AR is used to enhance the overall experience of the visitor of a cultural heritage site. Furthermore, with the interactive, realistic and complex AR system, it can enhance, motivate and stimulate students' understanding of certain events, especially for the traditional notion of instructional learning that has proven inappropriate or difficult [13]. With the

increasing of development current technologies, a lot of projects related with AR technologies are present, for example in Virtual Heritage application. The paradigms of AR in Virtual Heritage project are discussed in the following section.

3.1 Ancient Pompeii

Papagiannakis et al. [14][15][16] described mixing virtual and real scenes in the site of ancient Pompeii. Ancient Pompeii is a symbolic site for European cultural identity and archeology history. This project is based on 3D reconstruction of ancient frescos-paintings for real-time revival of their fauna and flora, featuring groups of virtual animated characters with artificial life dramaturgical behaviors in an immersive, fully mobile AR environment.

In this project, video-see-through HMD is used to capture real scene. After that, this scene was blended by precise real-time registration and 3D modeling of realistic complete simulation of virtual humans and plants in a real-time storytelling scenario based on the environment. These virtual humans are completely with real-time body, speech, face expression and cloth simulation. The project was performed in a mobile and wearable setup with markerless tracked camera and was implemented in real-time.

Fig. 2. Virtual human character in ancient Pompeii (*Left*) and AR scenario with plant simulation (*Right*) [15][16]

3.2 AR Based System for Personalized Tours in Cultural Heritage Sites

The project developed by ARCHEOGUIDE [17][18] is associated with the development of personalized electronic guide and tour assistant. The system was developed to transform the method of viewing and learning about a cultural heritage site for the visitors. In this beginning of system, the visitors are providing with user profile representing their interest and background. Then, the system provides a set of predefined tour that the visitor must choose. From that, the system will guide the visitor through the site, acting as a special instrument. To display AR reconstruction of the temples and other monuments of the site, the system will depend on the position-orientation tracking component. Fig. 3 illustrates the natural view from the visitor's viewpoint and followed by the same view augmented with the 3D model. The site visitors are wearing AR glasses to see the 3D image display. This system is handy unit carried by visitor during their site tours and communication networks.

Fig. 3. Original image (*Left*) and Augmented image (*Right*) of Ancient Olympic Games [18]

3.3 ARICH and ARCO Projects

Augmented Reality in Cultural Heritage (ARICH) and Augmented Representation of Cultural Objects (ARCO) has been discussed in [19]. For visualization of archaeological artifacts, ARICH project focuses on the design, development and implementation of an indoor augment reality system. The scope of this project covers the automated modeling from architectural plans to efficient and realistic AR rendering. The archaeologist provided 2D architectural plans to ARICH project as the input of the system. Meanwhile, in ARCO project, it is based on novel and robust digital capture and presentation technique. The overview of this project is to technical solution for automated creation of virtual cultural objects using object modeling through photogrammetry. Enhancement of these objects, management of all data and re-enactment and arrangement of the collections and their environment based on augmented interface or a web browser.

3.4 Virtual Reality for Archeological Maya Cities

Ruiz et al. [20] developed the VR for archeological Maya Cities. Their project is based on reconstruction of Calakmul's archeological site located in the State of Campeche, Mexico. AR technology is used in this system to give the visitor two different sights of the same situation. At the one sight, the system will present a state of the funerals which it's physically reproduction. Another sight, the system can present accordingly with laboratory test, which is theoretically virtual superposition of the elements of Calakmul. The visitors can use this virtual Calakmul system in several ways: 1) As a looped-projection of pre-established walkthrough around the structured; 2) As a self guided experience with or without immersive devices; 3) As a guided tour for learning of each structure aided with an intelligent agent provided with a voice recognition system. The advantage of virtual technology for Calakmul archeological site is to provide more information and understanding about the Calakmul's building where the location is very deep in the tropical forest which requires five hours trip just to see it.

3.5 The PRISMA Project

F. Fritz et al. [3] were presented the PRISMA project. The purpose of this project is to design, develop and implement of new 3D visualization device based on AR

technologies that incorporates with a tourist application. The concepts of this combination are known as tourist binoculars with AR system, which multimedia personalized interactive information can enhance the real scene in order to increase the user experience. With these technologies, the user can retrieve interactive multimodal information about monuments and historical buildings. Basically, the PRISMA system record the real-time video stream using a video-see through visualization system composed of a camera. To visualize the scene, this project used visualization device that is binoculars and the point of view and rotation of the binocular is track by inertial sensor. The camera mounted on the binoculars will capture the field of view of the spectator. Then, it will send to the processing unit to add graphical data and the augmented stream is sent back to the binocular screens.

4 3D Reconstruction Techniques for AR in Virtual Heritage

AR technologies are becaming increasingly popular. This technologies not only practically for the AR system developers but also for the scientific community. However, the development of AR technologies involved the several issues as depicted in Fig. 4.

This figure illustrates the overview of AR issues in Virtual Heritage that have been studied and well-structured that is reconstruction, registration, rendering or animation and position orientation tracking. According to [6], registration is the one of problem that limiting in building effective AR applications. Registration means an accurate alignment of real and virtual elements. Without accurate registration, AR will not be accepted in many applications because it fails to show precise results. In [14][15], the project associated with the simulation of virtual humans and plants in a real-time. The issues with the rendering and animation are considering increasing the realism and the presence of the user in the scene. Besides that, virtual animation system currently does not consider interaction with object in the scene. Position and orientation tracking system relates with the issues of position and direction of view. Based on [26], there are a few current tracking technologies that offer high accuracy and low latency

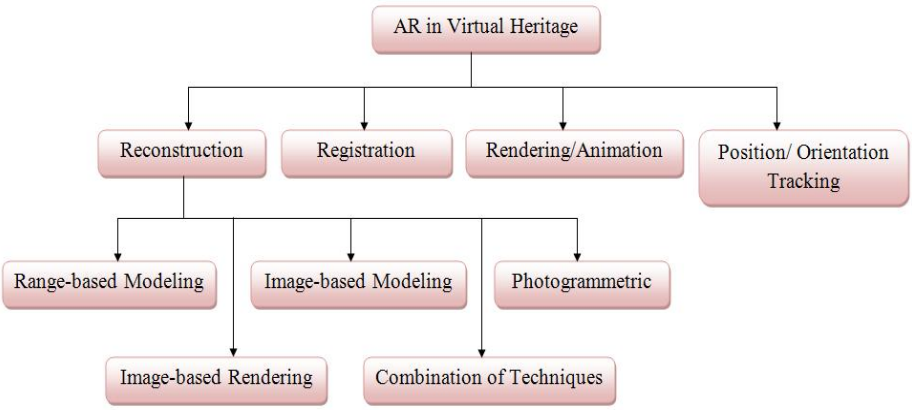


Fig. 4. Structure of AR in Virtual Heritage

Table 1. Techniques for 3D Reconstruction

Technique	Description
Image-based modeling	This technique commonly used for geometric surfaces of architecture objects [21][22] or for precise terrain modeling. Image-based modeling refers to the use of images to make the reconstruction of 3D models. It is use a mathematical model to pick up 3D object information from 2D image dimensions or they get 3D data using methods such as shape from shading, texture, specularity, contour and from 2D edge gradients. Image-based 3D modeling method consists of several steps: 1) design (sensor and network geometry); 2) measurement (point, cloud, lines); 3) structuring/modeling (geometry, texture); 4) visualization/analysis [23]. The advantage of image-based representations is the capability to represent arbitrary geometry. For modeling complete geometric structures, it is typically essential to remove the labor-intensive task through this approach. This technique also can handle subtle real-world effects captured by images, but difficult to reproduce with usual graphics techniques [21].
Range-based modeling	3D geometric information of an object can directly capture through this technique. It is based on costly active sensor that often lack in texture information, but can give a very detailed and precise illustration of most shapes. However, the information of texture or color can be attached from the scanner through color channel or from separate digital camera, [22][23]. Textures with high-resolution color that get from separate digital camera support the creation of realistic 3D models. To wrap every aspect of the object, it is generally required to make multiple scans from different locations, which appropriate to object size, shape and occlusions. The alignment and combination of the different scans can influence the final accuracy of the 3D model, where every scanner has different range of accuracy. Besides that, range-based modeling can provide precise and complete details with a high degree of automation for small and medium size objects, which up to the size of a human [22].
Image-based rendering	Image-based rendering uses images as modeling and rendering primitives. The goal of this technique is to get more realistic and faster renderings and to simplify the modeling task. This technique is considered as a good technique for the generation of virtual view, where particular objects and under specific camera motions and scene conditions. From the input image, this technique creates novel view of 3D environment. In general, image-based rendering technique is only used for applications requiring limited visualization. The technique relies on accurate camera positions or performing automatic stereo matching, where the absence of geometry data, need a large number of closely spaced images to succeed [23]. Most of image-based rendering match to image-geometry hybrids, by means of the equivalent amount of geometry ranging from per-pixel depth to hundreds of polygons [21].
Photogram-metric	Photogrammetric is an instrument for the efficient and accurate gaining of information for topographic and thematic mapping applications. High geometric accuracy can attain using photogrammetric methods, even though without capturing all fine geometric details. To get image data, it

Table 1. *(Continued)*

Technique	Description
	can be acquired from ground level or at different altitude and with different sensors. The main benefit of photogrammetric technique is the possibility to simultaneously provide both geometry and surface texture for depicted objects [24].
Combination of image-and range-based modeling	The combinations of technique require the modeling of large structures and scenes because there is no single technique by itself can efficiently provide the complete model. Thus, the coherent solution is determined by image-based methods and get details by laser scanning. The aerial and terrestrial images for the main shapes and laser scanning for fine geometric details to fully model the abbey of Pomposa in Italy have already used by [2]. [25] combined the 3D technologies to model the heritage site of Selinunte and a Byzanthine Crypt near Lecce (Italy) [22][23].

but none of the available system appropriate for outdoor usage with adequate precision such as for [17][18].

However, in this paper, reconstruction in AR will describe more details. In development of reconstruction cultural heritage, 3D modeling became an important and elementary step in the process of development. Nowadays, there are many investigations have been conducted in the fields of 3D modeling object. This is because 3D modeling object can be used in many applications such as visualization, navigation, animation and inspection. It also can be seen as complete process that starts from data acquirement until ends with 3D virtual model visually on a computer screen. Based on previous research works, there is no single technique that can be considered as a best technique for all applications including reconstruction of cultural heritage. Most of the techniques that were proposed have different accuracy, consistency and facility to capture details and their level of automation.

On the other hand, in this study, the reconstruction technique is emphasized in order to get accuracy and photorealistic 3D measurements. In [22] 3D object measurement and reconstruction technique are divide in two: contact methods and non-contact methods. In contact methods, coordinate measuring machines, calipers, rules and bearing are used, meanwhile in non-contact methods, it used tool likes X-ray, SAR, photogrammetry and laser scanning. Currently, the generation of 3D model is achieving using non-contact systems based on light waves. Several techniques for reconstruction in Virtual Heritage application are shown in Table 1.

5 Conclusion and Discussion

We have presented a review of AR in Virtual Heritage studies that focuses on 3D reconstruction of cultural heritage. Virtual Reality and Augmented Reality technology are commonly used for cultural heritage purposes which focus on learning process, as well as for education and entertainment through interactive experience. Virtual reality technologies are totally simulated the environment, which commonly immerse the user into synthetic environments. The user experiences in virtual reality environments

are real. Meanwhile, AR technology is a combination of real and virtual objects, where virtual spaces are mixed with the physical spaces. Furthermore, AR can provide more information and knowledge for user to gain. For instance, in virtual Pompeii, the visitors can observe the animated characters perform in a storytelling drama on the site of ancient Pompeii using mobile AR-life system's i-glasses in the real world environment. On the other hand, augmented contribute virtual in reality rather than replace the real world.

In this paper, several projects related to AR and Virtual Heritage developed by previous researchers have been discussed. In virtual heritage, every object in real world such as museum must be modeled to create interactive virtual environment. Hence, the system required a lot of memory to render every model that has been created. Ultimately, it increases the computation cost and reduces the rendering speed in order to perform large-scale sites. AR in Virtual Heritage is not required a lot of space of memory. This is due to AR is not modeled everything in real world, but only adds a certain virtual object in the real world. Thus, this may speed up the rendering process because only small quantity of virtual objects will be rendered and overcome the computation cost problems. The overview on AR issues in Virtual Heritage that have been studied and well-structured consists of reconstruction, registration, rendering or animation and position orientation tracking. However, in this paper, a major focus is reconstruction in AR. The importance of reconstruction of digital culture heritage is to preserve, protect and interpret of our cultural and history.

This paper will bring benefits especially for academic purposes and research studies in Virtual Heritage application. This Virtual Heritage application can enhance and stimulate student's understanding of certain features particularly for inappropriate or difficult learning instructional. As a conclusion, we hope that this study is useful for the AR system developer and therefore, contributing to the computer graphics community.

Acknowledgments

We would like to express our appreciation to Universiti Teknologi Malaysia (UTM) and Malaysian Ministry of Science, Technology and Innovation (MOSTI) for providing financial support for this research through eScienceFund grant (79282).

References

1. Stone, R., Ojika, T.: Virtual Heritage: What Next? IEEE Multimedia, 73–74 (2002)
2. El-Hakim, S., Beraldin, J.A., Picard, M., Godin, G.: Detailed 3D reconstruction of large-scale heritage sites with integrated techniques. IEEE Computer Graphics and Application 24(3), 21–29 (2004)
3. Fritz, F., Susperregui, A., Linaza, M.T.: Enhancing Cultural Tourism experiences with Augmented Reality Technologies. In: The 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST (2005)
4. Mixed Reality, `http://www.architecturemixedreality.com/`
5. Milgram, P., Kishino, F.: A Taxonomy of Mixed Reality Visual Displays. IEICE Trans. Information Systems E77-D(12), 1321–1329 (1994)

6. Azuma, R.: A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments 6, 355–385 (1997)
7. Jacobsen, J., Holden, L.: Virtual Heritage: Living in the Past. Techné: Research in Philosophy and Technology 10(3) (Spring 2007)
8. Vlahakis, V., Ioannidis, N., Karigiannis, J., Tsotros, M., Gounaris, M.: Virtual Reality and Information Technology for Archaeological Site Promotion. In: 5th International Conference on Business Information Systems (BIS 2002), Poznań, Poland (2002)
9. Foni, A., Papagiannakis, G., Magnenat-Thalmann, N.: Virtual Hagia Sophia: Restitution, Visualization and Virtual Life Simulation. In: UNESCO World Heritage Congress Proceedings (2002)
10. Sunar, M.S., Mohd Zin, A., Tengku Sembok, T.M.: Improved View Frustum Culling Technique for Real-Time Virtual Heritage Application. The International Journal of Virtual Reality 7(3), 43–48 (2008)
11. Zara, J., Beneš, B., Rodarte, R.: Virtual Campeche: A Web Based Virtual Three-Dimensional Tour. In: Proceedings of the Fifth Mexican International Conference in Computer Science (ENC 2004), pp. 133–140 (2004)
12. Jacobson, J., Vadnal, J.: The Virtual Pompeii Project. In: Richards, G. (ed.) Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2005, pp. 1644–1649. AACE, Chesapeake (2005)
13. Fällman, D., Backman, A., Holmlund, K.: VR in Education: An Introduction to Multisensory Constructivist Learning Environments. In: Conference on University Pedagogy. Umea University, Sweden (1999)
14. Papagiannakis, G., Ponder, M., Molet, T., Kshirsagar, S., Cordier, F., Magnenat-Thalmann, N., Thalmann, D.: LIFEPLUS: Revival of life in ancient Pompeii. In: Virtual Systems and Multimedia, VSMM 2002 (2002)
15. Papagiannakis, G., Schertenleib, S., O'Kennedy, B., Poizat, M., Magnenat-Thalmann, N., Stoddart, A., Thalmann, D.: Mixing Virtual and Real scenes in the site of ancient Pompeii. Computer Animation and Virtual Worlds 16, 11–24 (2005)
16. Papagiannakis, G., Magnenat-Thalmann, N.: Virtual Worlds and Augmented Reality in Cultural Heritage Applications. In: Baltsavias, et al. (eds.) Proc. Recording, Modeling and Visualization of Cultural Heritage, pp. 419–430. Taylor and Francis Group, Abington (2006)
17. Stricker, D., Dähne, P., Seibert, F., Christou, I., Almeida, L., Ioannidis, N.: Design and Development Issues for ARCHEOGUIDE: An Augmented Reality-based Cultural Heritage On-site Guide. In: EuroImage ICAV 3DConference in Augmented Virtual Environments and Three-dimensional Imaging, Mykonos, Greece (2001)
18. Vlahakis, V., Karigiannis, J., Tsotros, M., Gounaris, M., Almeida, L., Stricker, D., Gleue, T., Christou, I., Carlucci, R., Ioannidis, N.: ARCHEOGUIDE: First results of an Augmented Reality. In: Mobile Computing System in Cultural Heritage Sites, Virtual Reality, Archaeology, and Cultural Heritage International Symposium (VAST 2001), Glyfada, Nr Athens, Greece (2001)
19. Mourkoussis, N., Liarokapis, F., Darcy, J., Pettetsson, M., Petridis, P., Lister, P.F., White, M.: Virtual and Augmented Reality Applied to Educational and Cultural Heritage Domains. Business information Systems. In: Proceedings of BIS 2002, Poznan, Poland (2002)
20. Ruiz, R., Weghorst, S., Savage, J., Oppenheimer, P., Furness, T.A., Dozal, Y.: Virtual Reality for Archeological Maya Cities. Presented at UNESCO World Heritage Conference, Mexico City (December 2002)
21. Oliveira, M.M.: Image-Based Modeling and Rendering Techniques: A Survey. RITA 9(2), 37–66 (2002)

22. Remondino, F., El-Hakim, S.: Image Based 3D Modeling: A Review. The Photogrammetric Record 21(115), 269–291 (2006)
23. Remondino, F., El-Hakim, S.: Critical Overview of Image-based 3D Modeling. In: Workshop 3D laser Scanning and Photogrammetry for Building Information Modeling, Trondheim, Norwey (2008)
24. Gonzo, L., Voltolini, F., Girardi, S., Rizzi, A., Remondino, F., El-Hakim, S.: Multiple Techniques Approach to the 3D Virtual Reconstruction of Cultural Heritage. In: Eurographics Italian Chapter Conference 2007 (2007)
25. Beraldin, J.A., Picard, M., El-Hakim, S., Godin, G., Valzano, V., Bandiera, A.: Combining 3D Technologies for Cultural Heritage Interpretation And Entertainment. In: Beraldin, J.A., El-Hakim, S., Gruen, A., Walton, J. (eds.) Videometrics VIII, vol. 5665, pp. 108–118 (2005)
26. Hildebrand, A., Daehne, P., Christou, I.T., Demiris, A., Diorinos, M., Ioannidis, N., Almeida, L., Weidenhausen, J.: Archeoguide: An Augmented Reality based System for Personalized Tours in Cultural Heritage Sites. In: International Symposium of Augmented Reality 2000 (2000)
27. Addison, A.C.: Emerging Trends in Virtual Heritage. IEEE Multimedia 7, 22–25 (2000)
28. Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., MacIntyre, B.: Recent Advances in Augmented Reality. IEEE Computer Graphics and Applications (2001)
29. Azahar, M.A.M., Sunar, M.S., Daman, D., Bade, A.: Survey on Real-Time Crowds Simulation. In: Pan, Z., Zhang, X., El Rhalibi, A., Woo, W., Li, Y. (eds.) Edutainment 2008. LNCS, vol. 5093, pp. 573–580. Springer, Heidelberg (2008)

Mixing Telerobotics and Virtual Reality for Improving Immersion in Artwork Perception

Luca Brayda, Nicolas Mollet, and Ryad Chellali

TEleRobotics and Applications dept.
Italian Institute of Technology
Via Morego, 30 16163 Genoa, Italy
{luca.brayda,nicolas.mollet,ryad.chellali}@iit.it

Abstract. This paper aims at presenting a framework to achieve a higher degree of telepresence in environments rich of artistic content using mobile robots. We develop a platform which allows a more immersive and natural interaction between an operator and a remote environment; we make use of a multi-robot system as the mean to physically explore such environment and we adopt virtual reality as an interface to abstract it. The visitor is thus able to exploit the virtual environment both for keeping the sense of direction and for accessing a high-resolution content, while the immersion is achieved through the robot sensors. This study represents a starting point for overcoming the limits of the current use of virtual technology associated with artistic content. Long-term results of such study can be applied to tele-didactics, remote tele-visits for impaired users and active man-machine cooperation for efficient tele-surveillance.

1 Introduction

Robots are entities being used more and more to both extend the human senses and to perform particular tasks involving repetition, manipulation, precision. Particularly in the first case, the wide range of sensors available today allows a robot to collect several kind of environmental data (images and sound at almost any spectral band, temperature, pressure...). Depending on the application, such data can be internally processed for achieving complete autonomy [1,2] or, in case a human intervention is required, the observed data can be analyzed off-line (robots for medical imaging, [3]) or in real time (robots for surgical manipulations such as the da Vinci Surgical System by Intuitive Surgical Inc., or [4]). An interesting characteristic of robots with real-time access is to be remotely managed by operators (Teleoperation), thus leading to the concept of *Telerobotics* [5,6] anytime it is impossible or undesirable for the user to be where the robot is: this is the case when unaccessible or dangerous sites are to be explored, to avoid life threatening situations for humans (subterranean, submarine or space sites, buildings with excessive temperature or concentration of gas).

However, any teleoperation task is as much effective as an acceptable degree of immersion is achieved: if not, operators have distorted perception of distant world,

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 62–73, 2009.

potentially compromising the task with artifacts, such as the well know tunneling effect [7]. Research has focused in making Teleoperation evolve into Telepresence [8,9], where the user feels the distant environment as it would be local, up to Telexistence [10], where the user is no more aware of the local environment and he is entirely projected in the distant location. For this projection to be feasible, immersion is the key feature. One way to achieve a high degree of immersion is Virtual Reality [11,12,13]. Virtual Reality (VR) is used in a variety of disciplines and applications: its main advantage consists in providing immersive solutions to a given Human-Machine Interface (HMI): the use of 3D vision can be coupled with multi-dimensional audio and tactile or haptic feedback, thus fully exploiting the available external human senses. The relatively easy access to such interaction tool (generally no specific hardware/software knowledge are required), the possibility of integrating physics laws in the virtual model of objects and the interesting properties of abstracting reality make VR the optimal form of exploring imaginary or distant worlds. A proof is represented by the design of highly interactive computer games, involving more and more a VR-like interface and by VR-based simulation tools used for training in various professional fields (production, medical, military [14]). Collaborative teleoperation is also possible [15] thanks to this framework, because through VR more users can interact with the remote robots and between them. With VR the door for immersive exploration are open: a typical scenario in which a thorough, continuous, detailed, immersive exploration is needed is represented by places rich of artistic content, such as rooms of any size where walls, possibly hosting paintings, ceiling and floor are the target of the user attention. Furthermore, such space can be enriched by sculptures or other objects which make the immersion more necessary, as their perception through still pictures risks to be most of the time "flat". In this work we propose a VR-based approach to achieve Telexistence using mobile robots to explore a distant place which is rich in artistic content. The reminder of this paper is organized as follows: Section 2 details the common features between VR and art, while Section 3 analyzes the currently use art and Robotics. In 4 we present our general scheme for mixing Telerobotics and VR. Finally, discussion and future work are stated in Section 5.

2 Virtual Reality and Art

The connection between art and Virtual Reality is evident: VR is an evolution of computer graphics, which is a discipline strongly relying on images. In turns, images are one of the fundamental languages of art [16]. Well-designed interfaces can thus efficiently "trick" the user's senses and convey a visual 3D sensation

Virtual museums are a very useful way to convey artistic content to remote users over the internet. Examples are Visita 3D of the Galleria degli Uffizi[1], where a certain degree of immersion is provided by a 360 degrees reconstruction from several pictures. This technique shows two main drawbacks: first, the observation considers a single viewpoint, thus preventing a realistic sensation of movement; second,

[1] Visita 3D, Galleria degli Uffizi, http://www.polomuseale.firenze.it/musei/uffizi/filmati.asp

objects are distorted when they reach the interface borders, thus making this immersion implicitly limited. A more precise idea of the user location inside a museum can be given by adding a 2D map of the room currently visited[2]. Another approach consists in creating a purely virtual environment[3]: immersion is somewhat given by pre-loaded movements the user can choose while navigating from one room to another or across floors (an elevator can be simulated); this ensures a nice sensation of movement, but little faithfulness to reality. Some fixed views of the artistic content are an efficient approach to paintings galleries[4]: simple pictures from a single viewpoint illustrate a number of artworks the user can click on, thus accessing higher resolution pictures. This approach gives no movement sensation, but conveys a strong and detailed content of the artwork. Recently the Museo del Prado (Madrid, Spain) made ultra-high resolution pictures (up to 14 Gpixels) freely available over the Internet through Google Earth ™. To the best of our knowledge, the more complete compromise between immersion and detail is represented by the *Musée du Louvre*[5], which reconstructs real environment with textures and allows users both to freely navigate and to zoom on higher resolution artworks. The freedom of movement helps the user to locate himself in the virtual room. We point out that the perception of the artwork depends also on the enclosure containing the artwork: very often the enclosure *is* an artwork itself. Furthermore, in the last years the digital representations have become a form of art themselves [17,18]: the so-called *Net.Art* is thus a new may to make Virtual Reality a potential artwork together with an immersive mean of access.

By stating the problem from the standpoint of immersion in a distant world where the artwork is located, the following means of access can be available: pictures (at various resolutions), a whole website, a pure virtual model of the world, a webcam. We believe that the degree of immersion is related much more to a realistic sense of movement and direction rather than the quality of the representation: in fact, a low-res webcam, possibly panned and tilted by the user, offers much more sense of *being there* rather than a very well equipped website, because the piece of information is unique in the moment the user experience it. *Real movement* and *synchronization* are thus the major drawbacks in the state-of-the art systems which prevent a true remote user immersion. We believe, as we will see in section 4, that Telerobotics can overcome such drawbacks.

3 Robotics and Art

Robots have been successfully used in the past years as a link between humans and art. A first kind of use are robot-guides: in [19,20] prototypes of robots interact with users, each with a good level of autonomy (obstacle avoidance, path planning, simultaneous localization and mapping). Research is also focusing on

[2] Van Gogh's Van Goghs, Virtual Tour, National Gallery of art, `http://www.nga.gov/exhibitions/vgwel.htm`

[3] Museo Virtuale di Architettura, Regione Campania et al, `http://www.muva.it`

[4] Galleria Virtuale, Carlo Frisardi, `http://www.cromosema.it/arte/`

[5] Musée du Louvre en 3 dimensions, Musée du Louvre, `http://www.louvre.fr`

how such robots can gesture similarly to humans [21], either in an autonomous way or remotely guided by an operator [22]. Recently, some products are available on the market [23]. A second, more challenging kind of use are robot-explorers of artistic sites: the problem of perceiving art through an interface is clearly more difficult to face: some researchers [24,25], within the framework of the Minerva and Rino projects, have added to their robots a web-based interface which informs the user on the robot's current position, all by providing instant pictures of the robot camera. Other studies [26] implied visitors who could pilot a small rover in a small environment, but relying on the fact that the operator could both see the interface and the real scene. Perceiving a remote exhibition is undoubtedly a challenge: if the problem is effectively solved, then artistic resources would be available to millions of people, connecting through a highly scalable system. In this paper we focus on the second kind of robots, even if we are aware that every explorer robot must have an impact on the public possibly visiting a museum or an exhibition. Though effective solutions have been proposed, there seem to be no research involving a deep immersion of the operator while performing his/her exploration task.

4 Mixing Telerobotics and VR

We point out that the VR-oriented approach used in the *Musée du Louvre* is still limited, because the virtual environment lacks any natural light conditions. Another interesting point is that the user is always alone in exploring such virtual worlds. The technologic effort to make an exploration more immersive should also take into account such human factors: should navigation compromise with details when dealing with immersion? We believe this is the case. Does the precise observation of an artwork need the same precise observation during motion? Up to a certain degree, no. We propose a platform able to convey realistic sensation of visiting a room rich of artistic content, while demanding the task of a more precise exploration to a virtual reality-based tool.

4.1 Deployment of the ViRAT Platform

We are developing a multi-purposes platform, namely ViRAT (Virtual Reality for Advanced Teleoperation [27,28]), the role of which is to allow several users to control in real time and in a collaborative and efficient way groups of heterogeneous robots from different manufacturers, including mobile robots built in IIT. Virtual Reality, through a Collaborative Virtual Environment (CVE), is used to abstract robots in a general way, from individual and simple robots to groups of complex and heterogenous ones. Robots virtually represented within the interface of ViRAT are thus the avatars of real robots, with a shared state and an updated position in the virtual world. The advantage of a VR-based approach offers in fact a total control on the interfaces and the representations depending on users, tasks and robots. Innovative, user-oriented interfaces can then be studied using such platform, while inter-sensory metaphors can be researched and designed.

Fig. 1. A robot, controlled by distant users, is *visiting* the museum like other *traditional* visitors

We deployed our platform according to the particularities of this application and the museum needs. Those particularities mainly deal with high-definition textures to acquire for building the virtual environment, and new interfaces that are integrated into the platform. In this first deployment, consisting in a prototype which is used to test and adapt interfaces, we only had to install two wheeled robots with embedded cameras that we have developed internally (a more complete description of those robots can be found in [29]), and a set of cameras accessible from outside trough the internet (those cameras are used to track the robot, in order to match virtual robots' locations and real robots' locations). We modeled the 3D scene of the part of the museum where the robots are planned to evolve. The platform uses a peer-to-peer architecture, where the VR environment and the control routines are installed both at the teleoperator side and in the remote artistic place of interest, while the latter hosts the tracking cameras. The teleoperator thus uses the internet to connect to the distant computer, robots and cameras. Once the system is ready, he/she can interact with the robots and visit the museum, virtually or really.

4.2 Usage of Telerobotics and VR for Artwork Perception

As previously underlined, existing works with VR offer the ability to virtually visit a distant museum, but suffer from the lacks of a complete set of sensory feedback: first, users are generally alone in the VR environment, and second, the

degree and sensation of immersion is highly variable. The success of 3D games like *second life* comes from the ability to really *feel* the virtual world as a real world, where we can have numerous interactions, in particular in meeting other *real* people. This sensation is active at the cognitive level, since the interface would be the same if the avatars were not driven by humans. Moreover, when a place is physically visited, a certain atmosphere and ambience is felt, which is in fact fundamental in our perception, memory and, thus, feeling. Visiting a very calm temple with people moving delicately, or visiting a noisy and very active market would be totally different without those feedbacks. The kind and degree of immersion is a direct consequence of these aspects. Thus, *populating* the VR environment is one of the first main needs, especially with real humans *behind* those virtual entities. Secondly, even if such VR immersion gives a good sensation of presence, so of a visit, we're not really visiting the reality. Moreover, virtual characters of *second life* do not really mirror their users: the reasons for this mismatch are sociologic and behind the scope of this paper; however a fully immersive environment would, on the contrary, create a bijection between the *reality* and the *virtuality*. This is what we intend to do and believe being more effective. Seeing virtual entities in the VR environment and knowing that behind those entities a very similar real world is represented, directly increases the feeling of really visiting, being in a place. This is especially confirmed when the operator can anytime switch between virtual world and real world.

Following those comments, the proposed system mixes VR and Reality in the same application. Figure 2 represents this mix, and its usage.

On the left part, the degrees of immersion are represented, while on the right part, the level of details are depicted. Our approach is to split the degrees of immersion in three layers [28]: Group Management Interface (GMI), Augmented Virtuality (AV) and Control, in order of decreasing abstraction capability:

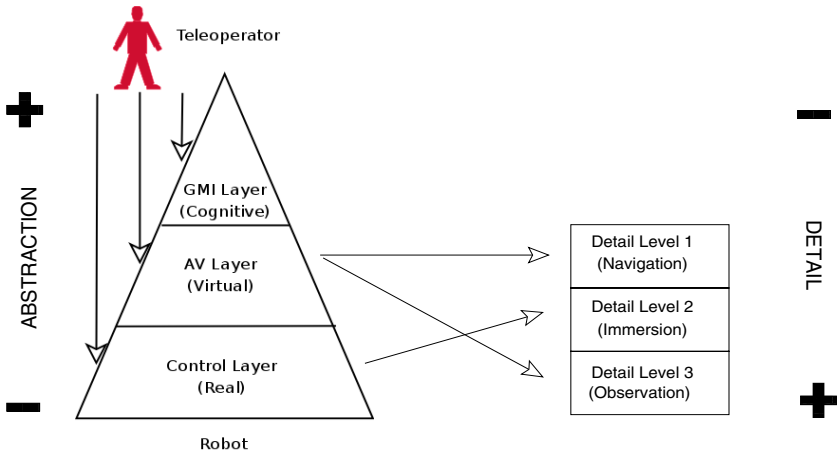


Fig. 2. Different levels of abstraction mapped into different levels of detail

- First, the GMI layer, gives the ability to control several robots. This level could be used by distant visitors, but in the actual design it's mainly used by people from the museum to take a global view on robots when needed, and to supervise what distant visitors are doing in the real museum.
- Second, the AV layer -*Augmented Virtuality*- allows the user to freely navigate in the VR environment. It is called *Augmented Virtuality* because it includes high-definition textures, coming from real high-definition photos of the artworks (e.g. paintings). This level offers different levels of interactions: precise control of the virtual robot and its camera (so as a consequence, the real robot will move in the same way), ability to define targets that the robot will reach autonomously, ability to fly though the 3D camera in the museum, etc.
- Third, the Control layer. At this level, teleoperators can control directly the robot wheels or camera. Users can directly watch the environment as if they were located at the robot's location. This level is the *reality* level, the users are immersed in the real distant world where they can directly act.

On another hand, on the right part of the figure 2, the level of details represent the precision the users perceive of the environment:

- Detail Level 1 mainly represents an overview of the site and robots for navigation. Figure 3 shows the bijection between virtual and real, thus the use that a distant visitor can make of the virtual world as an abstraction of the real word.
- Detail Level 2 represents the reality, seen through the robots' cameras. At this level of detail, users are limited by the reality, such as obstacles and cameras' limitations. But they are physically immersed in the real distant world.
- Detail Level 3 is used when distant visitors want to see very fine details of the art-paintings for example, or any art-objects that have been digitized in

Fig. 3. Detail Level 1 is purely virtual: it is the equivalent of the real environment and it includes the robot avatar

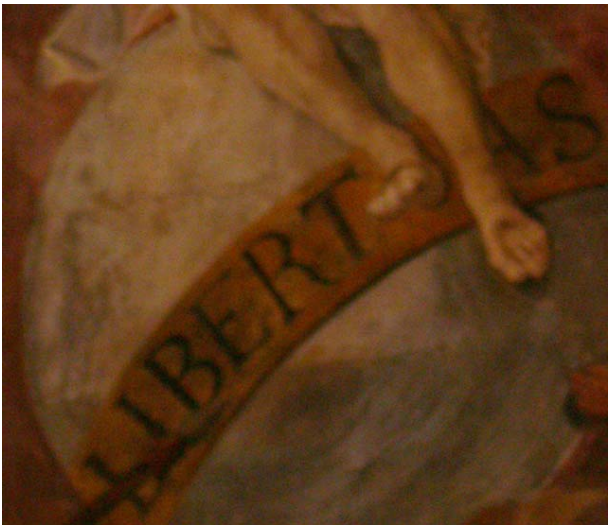


Fig. 4. Detail Level 3 (high detail) is purely virtual, with high-resolution pictures as textures. This one is used in the scene of Figure 3

high-definition. We can see in figure 4 a high-definition texture, that a user can observe in the virtual world when he/she wants to focus the attention on parts of the art-painting of the figure 3, that could not be accessible with the controlled robots because of technical limitations (limited dimensions of the robots, limited resolution of the on-board camera system).

When distant visitors want to have an overview of the site, and want to easily move inside, or on the opposite when they want to make a very precise observation of one art-painting for example, they use the Detail Levels 1 and 3, in the Virtual Environment. With this AV level, they can have the feeling of visiting a populated museum, as they can see other distant visitors represented by other virtual robots, but they do not have to fit with real problems like for example occlusions of the art-painting they want to see in details due to the crowd, or displacement problems due to the same reasons.

On another hand, when visitors want to feel themselves more present in the real museum, they can use the Detail level 2. This is the point where we mix Telerobotics with Virtual Reality in order to improve the immersion feeling. In Figure 5, a robot observing one art-painting is depicted. This implies that a first distant visitor is currently observing through the robot's camera the *real* environment, and in particular the *real* art-painting rather than observing it in the virtual world in high-definition. Moreover, this picture corresponds to the field of view of another robot's camera: it means that a second distant visitor is actually observing the first distant visitor in front of the painting. We offer here the ability for the visitors to be *physically* present in the distant world with this Telepresence system, and to evolve like if they were really present. As a

Fig. 5. Detail Level 2 is purely real. A user is observing, through his robot and its camera, an art-painting. This screenshot comes from a robot observing another robot, thus from a user able to observe another user

consequence, they can see the real museum and art-work, but also other visitors, local or distant, as we can see in figure 1.

5 Discussion

In this paper we offered a platform to achieve exploration of artistic art sites with a high degree of immersion. This could be further enhanced by the use of stereo audio system, able to capture the remote sound. Further work is ongoing to develop this aspect. Part of our future research is to establish quantitative methods to evaluate the degree of immersion, which would represent the validation of our concept. Specifically, minimal information about a remote environment accessible in real-time may be enough to achieve a relatively high degree, while consistent information about the artworks may not require real-time constraints: in other words, where exactly the need of synchrony between the real and virtual world is located is still to be clarified. While studying the reactions of the remote operators relative to the robot use, at the same time we intend to study the

ways such robots can be integrated among the ordinary visitors inside museums: specifically, would an effective telepresence motivate a past user to physically visit an artistic site? Furthermore, we intend to investigate whether the presence of a robot within the public can possibly infer some ludic aspects which would in turn make the visit more interesting for everybody. The acceptability of the system must be addressed, first of all concerning the motion planning of our explorers, then concerning the kind and size of our robots. We are aware that the more security constraints are respected, the more the acceptability is likely to increase. The accessibility of such a system can be addressed: it is important to clarify if such platform can be used by everybody or only by selected groups of people, such as schools, art and architecture university. Apart from the observation of artworks, it is within the scope of our work to find its possible direct application in active video-surveillance system when the museum is closed: in this case the operator would be a guardian, and robots would help him/her to keep much more than two eyes, which would be moving and not (almost) still as currently deployed camera systems are.

Acknowledgments

The locations for our platform are kindly provided by Palazzo Ducale, Genoa. We also thank Laura Taverna for the image processing and rendering.

References

1. Warwick, K., Kelly, I., Goodhew, I., Keating, D.: Behaviour and learning in completely autonomous mobile robots. In: IEE Colloquium on Design and Development of Autonomous Agents, November 1995, pp. 7/1–7/4(1995)
2. Lidoris, G., Klasing, K., Bauer, A., Xu, T., Kuhnlenz, K., Wollherr, D., Buss, M.: The autonomous city explorer project: aims and system overview. In: IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2007, 29 2007-November 2 2007, pp. 560–565 (2007)
3. Glasgow, J., Thomas, G., Pudenz, E., Cabrol, N., Wettergreen, D., Coppin, P.: Optimizing information value: Improving rover sensor data collection. IEEE Transactions on Systems, Man and Cybernetics, Part A 38(3), 593–604 (2008)
4. Saffiotti, A., Broxvall, M., Gritti, M., LeBlanc, K., Lundh, R., Rashid, J., Seo, B., Cho, Y.: The peis-ecology project: Vision and results. In: IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2008, September 2008, pp. 2329–2335 (2008)
5. Urbancsek, T., Vajda, F.: Internet telerobotics for multi-agent mobile microrobot systems - a new approach (2003)
6. Elfes, A., Dolan, J., Podnar, G., Mau, S., Bergerman, M.: Safe and efficient robotic space exploration with tele-supervised autonomous robots. In: Proceedings of the AAAI Spring Symposium, March 2006, pp. 104–113 (2006) (to appear)
7. Wertheimer, M.: Experimentelle studien ber das sehen von bewegung. Zeitschrift für Psychologie 61, 161–265 (1912)

8. Hickey, S., Manninen, T., Pulli, P.: Telereality - the next step for telepresence. In: Proceedings of the World Multiconference on Systemics, Cybernetics and Informatics (SCI 2000), Florida, vol. 3, pp. 65–70 (2000)
9. Kheddar, A., Tzafestas, C., Blazevic, P., Coiffet, P.: Fitting teleoperation and virtual reality technologies towards teleworking (1998)
10. Tachi, S.: Real-time remote robotics-toward networked telexistence. IEEE Computer Graphics and Applications 18(6), 6–9 (1998)
11. Eckhard, F., Jrgen, R., Marcel, B.: An open multi-agent control architecture to support virtual reality based man-machine interfaces. In: Sensor fusion and decentralized control in robotic systems, vol. 4571, pp. 219–229 (2001)
12. Zhai, S., Milgram, P.: A telerobotic virtual control system. In: Proceedings of SPIE, Boston. Cooperative Intelligent Robotics in Space II, vol. 1612, pp. 311–320 (1991)
13. Yang, X., Chen, Q.: Virtual reality tools for internet-based robotic teleoperation. In: DS-RT 2004: Proceedings of the 8th IEEE International Symposium on Distributed Simulation and Real-Time Applications, Washington, DC, USA, pp. 236–239. IEEE Computer Society, Los Alamitos (2004)
14. Gerbaud, S., Mollet, N., Ganier, F., Arnaldi, B., Tisseau, J.: Gvt: a platform to create virtual environments for procedural training. In: IEEE VR 2008 (2008)
15. Monferrer, A., Bonyuet, D.: Cooperative robot teleoperation through virtual reality interfaces, p. 243. IEEE Computer Society, Los Alamitos (2002)
16. Tiziani, E.: Musei moderni tra arte e multimedialitá (February 2006), http://musei-multimediali.splinder.com
17. Marco Deseriis, G.M.: Net.Art: l'arte della connessione. Shake Edizioni, CyberpunkLine (2003)
18. Quaranta, D.: Net.Art 1994-1998. Milano,Vita & Pensiero (2004)
19. Schraft, R.D., Graf, B., Traub, A., John, D.: A mobile robot platform for assistance and entertainment. Industrial Robot Journal, 252–253 (2000)
20. Nourbakhsh, I., Kunz, C., Willeke, T.: The mobot museum robot installations: A five year experiment. In: Proceedings of International Conference on Intelligent Robots and Systems (2003)
21. Kuno, Y., Sadazuka, K., Kawashima, M., Yamazaki, K., Yamazaki, A., Kuzuoka, H.: Museum guide robot based on sociological interaction analysis. In: CHI 2007: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 1191–1194. ACM, New York (2007), http://doi.acm.org/10.1145/1240624.1240804
22. Kobayashi, Y., Hoshi, Y., Hoshino, G., Kasuya, T., Fueki, M., Kuno, Y.: Museum guide robot with three communication modes. In: IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2008, September 2008, pp. 3224–3229 (2008)
23. Frontech, F.: Service robot enon (2004), http://www.frontech.fujitsu.com/en/forjp/robot/servicerobot/
24. Thrun, S., Beetz, M., Bennewitz, M., Burgard, W., Cremers, A., Dellaert, F., Fox, D., Haehnel, D., Rosenberg, C., Roy, N., Schulte, J., Schulz, D.: Probabilistic algorithms and the interactive museum tour-guide robot minerva. International Journal of Robotics Research (2000) (to appear)
25. Thrun, S., Bücken, A., Burgard, W., Fox, D., Fröhlinghaus, T., Hennig, D., Hofmann, T., Krell, M., Schimdt, T.: Map learning and high-speed navigation in RHINO. In: Kortenkamp, D., Bonasso, R., Murphy, R. (eds.) Artificial Intelligence and Mobile Robots. MIT/AAAI Press (1997)

26. Nourbakhsh, I., et al.: The design of a highly reliable robot for unmediated museum interaction. In: Proceedings of International Conference on Robotics and Automation (2005)
27. Mollet, N., Brayda, L., Chellali, R., Fontaine, J.: Virtual environments and scenario languages for advanced teleoperation of groups of real robots: Real case application. In: IARIA / ACHI 2009, Cancun (2009)
28. Mollet, N., Brayda, L., Chellali, R., Khelifa, B.: Standardization and integration in robotics: case of virtual reality tools. In: Cyberworlds, Hangzhou, China (2008)
29. Mollet, N., Chellali, R.: Virtual and augmented reality with head-tracking for efficient teleoperation of groups of robots. In: Cyberworlds, Hangzhou, China (2008)

Developing a Film-Based Learning System with English Verbal Reduced Forms for Supporting English Listening Comprehension

Jie-Chi Yang, Yi-Lung Lin, and Ching-I. Chung

Graduate Institute of Network Learning Technology,
National Central University, Taiwan
{yang,nigel,cecilia}@cl.ncu.edu.tw

Abstract. English listening comprehension is always bewildering for language learners. English language students are generally not taught to recognize English in reduced forms (contractions) in verbal exchanges; they also lack opportunities for practicing listening exercises in reduced forms of English vocabulary. This study developed a film based vocal language learning system working with English reduced forms, thus enabling students to learn English in reduced forms. The film includes an abundance of learning situations, which are easily learned from. Within this system, the learner can import subtitles from English films by themselves. The system also automatically marks reduced English forms in verbal conversations, and offers many example sentences for listening exercises. The system uses subtitles as the source of examinations for students after completing course sections. The system can generate items from movie subtitles automatically, as well as evaluating learner performance. This study probes the effectiveness of the aforementioned learning system as well as the user's attitude and satisfaction with the system. The results show that the learning system of English reduced forms in verbal conversations had a positive effect on the experimental group's learning which was significantly better than traditional film systems without English reduced form subtitles used by the control group. Hence this system benefits students learning English contractions. In English listening tests, the results of experimental group were significantly higher than the control group. The results of post-course survey showed positive satisfaction by system users. All students using the system reported a positive attitude after using the system. The system can be improved by enhancing the interfaces which broadcast the films and subtitles as well as increasing the course and experimental time periods.

Keywords: reduced forms, contractions, film based learning, listening comprehension, computer assisted language learning.

1 Introduction

Currently, English is the global language. Studying English helps to gain knowledge through different learning processes. In addition, it can be a more convenient and efficient way of international communication. Listening is crucial while communicating in a foreign language. Without properly understanding the context, it is difficult to

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 74–84, 2009.

express one's opinion correctly. According to Rivers' research, roughly 40% to 50% of people's communication is taken up by listening. In the course of studying English, listening comprehension becomes an essential element in English communication. In recent years, scholars have attempted to uncover learning obstacles and create a teaching strategy for English listening comprehension [1][2][3]. However, listening comprehension is often neglected from Taiwan's foreign language teaching processes. As many studies have pointed out [4][5], Taiwanese students generally have difficulties discerning previously learnt vocabulary items from listening comprehension.

As Brown and Yule [6] pointed out, native English speakers tend to abbreviate vocabulary which adds greater comprehension difficulties for English learners [7][8][9][10]. Taiwanese students, as English as a Foreign Language (EFL) learners must overcome a great amount of difficulties in English listening comprehension. Many scholars had argued that English contractions in verbal communication have crucial characteristics in the teaching process [7][11][12][13].

In recent years, many instructors had begun to include the teaching of English contractions within their teaching materials [14][15][16]. Many researchers believe, in order to be familiar with the English contractions; one must immerse themselves in a contraction laden environment, and through practice and one's involvement. Since films and television programs reflect authentic situational use of English conversation, they are suggested learning materials for verbal English contractions by many researchers [8][11][17][18].

However, these films and television programs are not to be watched aimlessly and without a purpose. An interactive learning program is crucial to the learning process thus achieving maximum learning benefits and learning efficiency. As the production of films and TV programs increase, it has also become increasingly difficult to add study notes to these media as learning materials. Thus, the development of an automated system is necessary.

The purpose of this study consists of two parts: First, the design and development of a learning program for verbal English contractions through visual media, such as movies or television programs. Secondly, to investigate the end results and the effect after using such learning program, as well as surveying user satisfaction.

2 Literature Review

2.1 Listening Comprehension

O' Malley *et al.* [19], state that listening comprehension is an active and conscious process in which the user constructs their information by using cues, and multiple strategies to achieve the task requirement. Anderson [20] suggests that listening comprehension consists of three procedures, perception, parsing and utilization. These three procedures may be carried out in order. They can as well, overlap or cycle. Therefore, the listening process is carried out in no particular order. The listening comprehension process is very complex. Clark and Clark [21] state that language learners, when listening, have a limited amount of abilities. Thus, when they are conversing in an unfamiliar language environment, if the speaker speaks too fast or other factors pose interference, the listener fails to comprehend the message. English is an unfamiliar language for many Taiwanese students; therefore, listening comprehension failure is common.

Boyle [22] stated that there are four factors influencing listening comprehension; the speaker, the listener, the environment, and factors in the material and medium. Medium refers to the language features such as reduced forms, tone, and stress. Henrichsen [23] examined how the presence and absence of reduced forms influence ESL learners' listening comprehension process. The results of this study confirmed that ESL learners' listening comprehension was significantly influenced by English reduced forms, more so than by other factors. Many scholars [6] [7][8][9][10] have pointed out that reduced forms are the main reason for pronunciation difficulties. Chen and Cheng [4] indicated that Taiwanese students are unable to decipher reduced forms; therefore, they cannot recognize chunks of words from sentences in conversations. Fan [17] mentioned reduced forms make it difficult for students to distinguish individual words in a stream of speech. Field [7] explicitly pointed out that reduced forms lead to difficulties for learners' chunking of words and recognition. Assimilation[1] and elision[2] lead to a difficulty in recognizing words; liaison[3] leads to chunking of word problems.

2.2 Reduced Forms

Reduced forms are an important feature in spoken English [10][12][18], and are one of the main factors that influence listening comprehension [6][7][8][10]. Many researchers have emphasized that the teaching of English contractions must be increased as well as the rules and structure of reduced forms further explored [12][24][25]. Several related studies [11][17][26] have encapsulated four reduced forms: assimilation, liaison, reduction[4], and elision. Many researchers have pointed out that reduced forms are of great importance in English listening instruction [7][12][13][18]. Brown and Hilferty [27] studied instruction activities and how those instructions can improve English listening comprehension. The results revealed that learners are more able to adapt to authentic spoken English. Norris [11][18] included reduced forms in his English listening instruction in Japanese classes. Taiwanese scholars use multimedia teaching materials to teach reduced forms and study if they can enhance students' English listening comprehension [4][28]. Many studies concluded that using multimedia materials to learn English contractions is of great importance. Furthermore, many of the studies recommended using films and television series as of form of listening exercises.

3 Implementation

The learning system was created in five modules: Support Vector Machine (SVM) Training Module, Characteristic Judging Module, Characteristic Annotation Module, Listening Cloze Module, and Film Subtitles Searching Module. Figure 1 shows the

---

[1] Assimilation: Assimilation is a process which takes place when a sound is modified to become comparable to an adjacent sound.
[2] Elision: When a sound between two words is omitted.
[3] Liaison: The pronunciation of a normally silent consonant when it is followed by a word beginning with a vowel sound.
[4] Reduction: When a normally stressed sound is reduced to non-stressed sound.

system architecture. First, a collection of training data, movies and television programs, were annotated by their containing set verbal contractions and were then imported to the SVM training module [29] which produced a database of reduced form in vocal language automatically. Relevant listening practice textbooks were collected and annotated manually, for submission to the SVM training module. Learners may choose a film and subtitle source from the 'Subtitle Importing Interface'. The subtitles are imported in the Characteristic Judging Module; subsequently, the characteristics of the sentence are examined, word positioning within the sentence, the syllable position in each word, as well as the pronunciation of new syllables by 'reduced form' variation. Then, the information is imported to a Characteristic Annotation Module. The Characteristic Annotation Module produces an XML file to create a sentence pattern database of the reduced forms in conversations (Figure 2). The sentence pattern data is then, the reference source of Film Subtitle Example Sentence Searching Module as well as the Listening Cloze Module. The Film Example Sentence Searching Module offers a 'keyword' searching function. The results offer example sentences for broadcast. This module continues comparing and searching the database by keywords, the film example sentences searched are returned to the learners.

A Listening Cloze Module categorizes questions and assigns them to each verbal contraction (the aforementioned 5 types of assimilation, liaison. reduction, elision, and hybrid). This module will randomly choose questions from the database, and return the questions to a Listening Cloze Practice Interface for student training.

The system interface consists of five parts: the film, a Subtitle Importing Interface, courses, Example Sentence Broadcasting Interfaces, and a Listening Cloze Practice Interface. Users can import an assigned film into the system by using the film subtitle importing system; it is then used for future listening cloze exercises. In addition, students can use course and film examples from the sentence broadcasting interfaces to make reduced forms in verbal conversations.

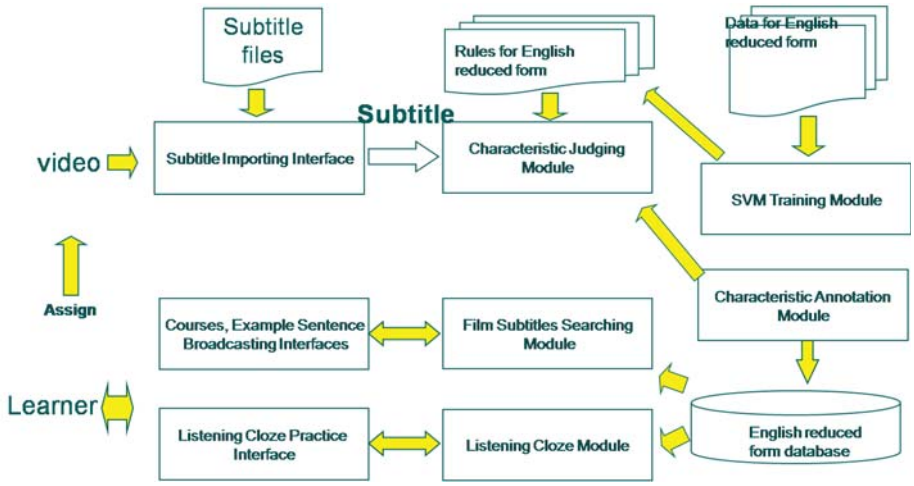


Fig. 1. System architecture

```
- <movieSCset moviename="六人行8">
    ...
  + <Sentence num="8" mvPath="E:\六人行\[六人行].Friends.10X08.The.One.With.The.Late.Thanksgiving.AC3.DVDRip.XviD-Fov.Avi" moviename="六人行8">
  - <Sentence num="9" mvPath="E:\六人行\[六人行].Friends.10X08.The.One.With.The.Late.Thanksgiving.AC3.DVDRip.XviD-Fov.Avi" moviename="六人行8">
      <totalCharNum>4</totalCharNum>
      <wholeSentence>What</wholeSentence>
      <duration>00:00:11,400 --> 00:00:12,833</duration>
      <iflink>False</iflink>
      <ifAssimilation>False</ifAssimilation>
      <ifDisappear>True</ifDisappear>
      <ifreduced>False</ifreduced>
      <ifReducedCharactor>True</ifReducedCharactor>
    - <keyword>
        <keyword_Id>0</keyword_Id>
        <keyword_spell>What</keyword_spell>
      </keyword>
      <Num_Disappear>1</Num_Disappear>
    - <Disappear_Class DCNum="0">
        <Pho_location>3</Pho_location>
        <Spell_location>3</Spell_location>
        <wordLocation>0</wordLocation>
        <wordNum>0</wordNum>
        <ifinLink>False</ifinLink>
      </Disappear_Class>
      <Num_words>1</Num_words>
    - <Word_Class WCNum="0">
        <wordspell>What</wordspell>
        <syllablesSet>HH W AH T</syllablesSet>
        <phoneticStr>hwat</phoneticStr>
        <Morpho>n</Morpho>
        <Num_syllable>4</Num_syllable>
      </Word_Class>
      <Num_ReducedCharactor>1</Num_ReducedCharactor>
    - <ReducedCharactor_Class RCCNum="0">
        <wordNum>0</wordNum>
        <Type>4</Type>
      </ReducedCharactor_Class>
    </Sentence>
  + <Sentence num="10" mvPath="E:\六人行\[六人行].Friends.10X08.The.One.With.The.Late.Thanksgiving.AC3.DVDRip.XviD-Fov.Avi" moviename="六人行8">
    ...
</movieSCset>
```


Fig. 2. An example of an XML file with reduced forms

On the program interface, there are demonstration words and phrases on buttons located in the course window. These buttons open a broadcasting window that includes media clips of the demonstration words in example sentences. This allows the users to listen to the film example sentences to learn the usages of the reduced forms. After course completion, the system makes a listening cloze exercise for the learner. For different course again, this program allows the user to examine verbal reduced form words that they have learned. In addition, this system offers feedback and a word inquiry function. The feedback includes a check of the results; an answer situation and question replay.

4 Experimental Design

4.1 Participants

All participants were accepted into a university English level course. The participants were all between the age of 23 and 33, with an average age of 25. The participant group is comprised of nineteen males and thirteen females.

4.2 Learning Materials for Reduced Forms

The content of computer assisted verbal contraction learning material collected existing English listening materials. The experimental design included an English language course comprised of four units including voice type assimilation, liaison, reduction and elision. Each unit had specific demonstration words and phrases. The verbal contractions were additionally offered to the control group for learning. This system uses the 10th season of "Friends", an American television series (length: 440 minutes) as a learning module.

4.3 Procedure

The experiment took place over three weeks. The learning course was comprised of 180 minutes. The experimental design included a pretest, a structured course for learning, a post-test as well as a questionnaire given to both the experimental group and the control group. The experimental group and the control group were both grouped according to the participants' results on the Test of English for International Communication™ (TOEIC) listening test. Participants are also tested on their knowledge of English verbal contractions. Throughout the course, the experimental group used verbal contractions from the learning material. Learners could search the media for demonstration words in the learning material, match demonstration words and phrases of the example sentences to conduct listening exercises. Listening cloze exercises were used as a form of review. The control group uses demonstration words and phrases for listening in course learning. This group was not offered the searching function, but watched the media as a form of reviewing. Finally, the two groups took part in a post-test of verbal reduced forms. The experimental group filled out the relevant questionnaires for an evaluation of the system. Figure 3 shows a learner is interacting with the system.

Fig. 3. A learner is interacting with the system

4.4 Instruments

The experimental instruments included: a TOEIC listening comprehension test, a test of students' knowledge on verbal contractions, system questionnaire, and a learning attitude questionnaire.

(1).TOEIC listening comprehension test: Adopting "TOEIC Official Test-Preparation Guide" [30]. The test included 100 items.
(2). the verbal contraction language test: The items of the test were modified from a book entitle "A guide to speaking and pronouncing colloquial America English" [15], and was examined by two English teachers.
(3). System questionnaire: this questionnaire consisted of three separate aspects, including system utilization, information quality, and quality of Human-Machine Interface. The system questionnaire was designed for the experimental group. The questionnaire was designed using a 7-point Likert scale, in which "7" is regarded as "Strongly Agree", and "1" is regarded as "Strongly Disagree".
(4). Learning attitude questionnaire: this questionnaire consists of two aspects, the learners' attitude on the effect the system has, in regards to their English listening comprehension and the learners' attitude on how the system effects their English listening comprehension cloze test. The questionnaire is designed as 7-point Likert scale, which is same format as the system questionnaire.

5 Results and Discussions

5.1 Results

5.1.1 TOEIC Listening Comprehension Test

The result of experimental group and control group in the pretest is shown in Table 1. The independent sample T-test is performed by comparing the differential of pretest result. There is no significant difference between the pretest (t=0.045, p=0.964) result. This explains that there is no significant difference in the TOEIC listening comprehension test result of pretest. For the purpose of pretest, experimental group and control group have to receive the instruction before the experiments; we can prove their listen comprehension between these two groups to be equal. Due to the same level of the listen comprehension, we can notice the change of these two groups' growth after instruction.

Table 1. The TOEIC listening comprehension test

Groups	N	Mean	SD	t	p-value
experimental group	16	52.686	9.680	0.045	0.964
control group	16	52.500	13.426		

5.1.2 The Reduced Form in Vocal Language Test

In the test results, the outcomes show (Figure 4) that the result of experimental group (t=7.472, p=0.000) has significant improvement. It clearly shows the difference in pretest and post-test. The experimental group had noticeably progressed. The test

results of the control group (t =1.365, p=0.192) show that there was no significant improvement in test results. This shows that there is no apparent difference in pretest and post-test results. After the examinations of the pretest and post-test in both groups, the findings suggest that there is no significant difference in pretest scores (t=0.513, p=0.612). However, there is a significant difference in post-test results (t=2.328, p=0.029). This implies that the experimental group, after the experimental teaching, had progressed further in their knowledge of verbal English reduced forms than those in the control group.

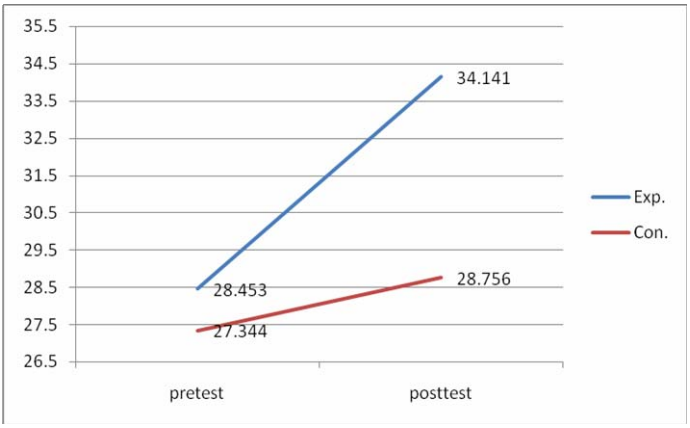


Fig. 4. The reduced form in vocal language test

5.1.3 System Questionnaire

The results of the questionnaire of student satisfaction with the system are shown in Table2. The first part, system utilization: investigates student attitudes on the system's functioning. The questionnaire asks if the system functions sufficiently and effectively, as well as if it is fast and easy to use. All users surveyed reported a positive attitude (M=5.633, SD=1.041). Secondly, the questionnaire probes the users for attitudes regarding the course content, its clarity, ease of understanding, and organization. All users answered positively and looked upon the system as satisfactory (M=5.633, SD=0.885). The last of aspect was the quality of Human-Machine Interface (HMI): User satisfaction while using the HMI. The assessment which users gave was above average (M=5.250, SD=0.916). The overall results; the users reported satisfaction as to the functioning which the system offered (M=5.625, SD=0.869).

Table 2. System questionnaire

Aspects	Mean	SD
System utilization	5.633	1.041
Information quality	5.633	0.885
Quality of HMI	5.25	0.916
Total	5.625	0.869

5.1.4 Learning Attitude Questionnaire

There were two aspects regarding the learners' attitude (Table 3). These included the learners' attitude towards the effect of system supporting their English listening comprehension and the effect of system supporting English listening comprehension cloze.

With reference to learners' attitude on the effect of system supporting English listening comprehension, the content of the questionnaire probed if the users can: understand every syllable within each word; correctly judge the pronunciation of each word; increase the degree of understanding of the contractions; become aware of the actors' pronunciation and apply the knowledge in authentic situations. The users reported satisfaction for the effect to which system supported their English listening comprehension (M=5.586, SD=1.008).

With reference to the attitude of the effect of system support English listening comprehension cloze, this section discusses the listening comprehension cloze that helps user learning. It includes that user can understanding the syllable with each word, judging the pronunciation of word and increasing the degree of word. In general, the user holds positive attitude in this part (M=5.333, SD=0.981).

Table 3. Learning attitude questionnaire

Aspects	Mean	SD
System support English listening comprehension	6.411	0.643
System support English listening comprehension cloze	5.322	0.742
Total	5.838	0.938

5.2 Discussions

5.2.1 The Verbal English Reduced Forms

After the experimental group used the system, it reported a significant amount of improvement regarding the use of verbal English contractions. Comparatively, the control group did not demonstrate the same effect in the post-test of verbal English reduced forms. Thus, this study demonstrates the effectiveness of the experimental design procedures. These procedures are significantly higher than traditional learning methods.

5.2.2 Suggestions in System Improvement

Users report a positive attitude to training listening comprehension, but they also emphasize that the experimental procedures must match instruction with supplementary learning functions. Furthermore, there is problems arise with the understanding of phonetic symbols used in the course. During the experiment, subjects often inquired how to pronounce the phonetic symbols used in course. This also reflected a need which must be integrated into the pre=experiment interview. Then the instruction of phonetic symbol usages or a phonetic symbol spelling demonstration may be considered as an addition to the course, improving understanding.

5.2.3 Learning Time of Verbal English Contractions

As a learner, it is easier to learn rules and apply the rules to listening comprehension. However, the more learning rules, the harder it is to instantaneously apply the rules while listening. Inquiring into the reason of difficulties in usage in the interview, subjects reported that it is difficult to grasp and use the rules smoothly during listening exercises. From the above, it is understood that learners should be given more time in order to grasp the rules and smoothly apply them to listening comprehension.

6 Conclusion

The findings of this study have lengthy implications for the teaching and learning of verbal English contractions. Learners benefited by learning verbal English reduced forms through audio-visual media based and listening comprehension. Compared to traditional English learning materials which emphasize contractions, the utilization of audio-visual media based English reduced forms students receive more immediate results in their understanding of verbal English communications. This is especially the case in the areas regarding assimilation, liaison and elision. The subjects reported positive satisfaction with the usage of learning system. They also reported a positive effect concerning their English listening comprehension as well. In general, all the subjects supported the use of such a learning form for learning verbal English contractions and listening comprehension. It is further suggested, that proceeding a long-term research and collection of data for further analysis, an improvement on the system interface offering a more user friendly interface is necessary.

Acknowledgements

The authors would like to thank Mr. Aubrey Neil Leveridge for proofreading on an earlier version of this paper. The authors would also like to thank all the subjects who participated and cooperated in the experiment. This study was partially supported by grants (NSC 97-2628-S-008-001-MY3, NSC 97-2631-S-008-002) from the National Science Council of Taiwan.

References

1. Chen, Y.: Barriers to Acquiring Listening Strategies for EFL Learners and Their Pedagogical Implications. Teaching English as a Second of Foreign Language 8(4), 38–57 (2005)
2. Rost, M.: Commentary: I'm only trying to help: a role for interventions in teaching listening. Language Learning & Technology 11(1), 102–108 (2007)
3. Richards, J.C.: Second thoughts on teaching listening. RELC Journal 36(1), 85–92 (2005)
4. Chen, H.M., Cheng, S.H.: An investigation on the listening difficulties of technical college students in Taiwan. Journal of China Institute of Technology 36, 335–361 (2007)
5. Goh, C.C.M.: A cognitive perspective on language learners' listening comprehension problems. System 28(1), 55–75 (2000)

6. Brown, G., Yule, G.: Teaching the spoken language. Cambridge University Press, Cambridge (1983)
7. Field, J.: Promoting perception: lexical segmentation in L2 listening. ELT Journal 57(4), 325–334 (2003)
8. Ito, Y.: Effect of reduced forms on ESL learners' input-intake process. Second Language Studies 20(1), 99–124 (2001)
9. Brown, H.D.: Teaching by principles: An interactive approach to language pedagogy, 2nd edn. Pearson Education, New York (2001)
10. Richards, J.C.: Listening comprehension: approach, design, procedure. TESOL Quarterly 17(2), 219–240 (1983)
11. Norris, R.W.: Teaching reduced forms: an aid for improving lower-level students' listening skills. Fukuoka Women's Junior College Studies 46, 49–56 (1993)
12. Pennington, M.C., Richards, J.C.: Pronunciation revisited. TESOL Quarterly 20(2), 207–225 (1986)
13. Brown, G.: Listening to spoken English. Longman, London (1977)
14. Weinstein, N.J.: Whaddaya say?: Guided practice in relaxed speech, 2nd edn. Longman, White Plains (2001)
15. Cook, A.: American accent training: a guide to speaking and pronouncing American English for everyone who speaks English as a second language, 2nd edn. Barron's Educational Series. The United States of America (2000)
16. Vogt, L.: Translated by Lo, Helen and Chen, M. Y. (2003). Listening skills for English as It's really spoken. Cosmos Culture Ltd. (1999)
17. Fan, Y.: Listening: problems and solutions. English Teaching Forum 31(2), 16–21 (1993)
18. Norris, R.W.: Teaching reduced forms: putting the horse before the cart. English Teaching Forum 33, 47–50 (1995)
19. O'Malley, J.M., Chamot, A.U., Kupper, L.: Listening comprehension strategies in second language acquisition. Applied Linguistics 10(4), 418–437 (1989)
20. Anderson, J.R.: Cognitive psychology and its implications, 4th edn. Freeman, New York (1995)
21. Clark, H.H., Clark, E.V.: Psychology and language: An introduction to psycholinguistics. Harcourt Brace Jovanovich, New York (1977)
22. Boyle, J.P.: Factors affecting listening comprehension. ELT Journal 38(1), 34–38 (1984)
23. Henrichsen, L.E.: Sandhi-variation: A filter of input for learners of ESL. Language Learning 34(3), 103–126 (1984)
24. Rosa, M.: Don't cha know? A survey of ESL teachers' perspectives on reduced forms instruction. Second Language Studies 21(1), 49–78 (2002)
25. Rost, M.: Listening in action: activities for developing listening in language teaching. Prentice Hall, New York (1991)
26. Bowen, J.D.: Pattern of English pronunciation. Newbury House, Rowley (1975)
27. Brown, J.D., Hilferty, A.: The effective of teaching reduced forms of listening comprehension. RELC Journal 17(2), 59–70 (1986)
28. Lin, L.Y.: Improving listening comprehension using essential characteristics of oral production. Hwa Kang Journal of TEFL 4, 55–71 (1998)
29. Wu, Y.C., Lee, Y.S., Yang, J.C.: Robust and Efficient Multiclass SVM Models for Phrase Pattern Recognition. Pattern Recognition 41(9), 2874–2889 (2008)
30. Arbogast, B.: TOEIC official test-preparation guide, 2nd edn. Peterson's (2001)

An Interactive 3D Exhibition System with Global Illumination for Digital Museum

Gang Bai and Yue Qi

State Key Laboratory of Virtual Reality Technology and Systems,
Beihang University,
Beijing, 100191, China
{baigang,qy}@vrlab.buaa.edu.cn

Abstract. Interactive exhibition of three-dimensional models in digital museums can significantly impact learning and understanding. Current 3D exhibition systems commonly provide viewers with local illumination effects. Interactive exhibition with high realistic rendering quality is becoming a necessity. In order to enhance the sense of reality and immersion, we develop a 3D exhibition system for interactively displaying relic models with global illumination effects. In our system, the precomputed radiance transfer(PRT) method is used for solution to the global illumination effects including diffuse reflection, shadows and inter-reflections. In addition to diffuse reflections, we also extend standard PRT method by blending previously generated textures for heterogeneously colored surfaces. Our system has applied to several cultural relics, of which the results are presented in this paper.

Keywords: digital museum; global illumination; precomputed radiance transfer.

1 Introduction

With the rapid development of Virtual Reality and resource management technology, Digital Museum has become a popular and evolving application in recent years. Most of current systems for displaying items typically provide visitors with static images or videos, which is insufficient for a full-dimensional comprehension. Some digital museum systems display 3D models, but usually with local illumination effects which is not realistic enough. On the other hand, interactive exhibitions can significantly impact understanding. In order to enhance the sense of reality and immersion, we develop a 3D exhibition system for interactively displaying relic models with global illumination effects.

In this paper, we present techniques to realize a system that interactively displays rigid artifacts, such as carvings, in real-time with global illumination effects, with feedback of users' operations, which includes changing the viewpoint, as well as adjusting the lighting environments. By involving global illumination effects, our system provides viewers with significant cues of shapes, materials and spatial relationships in the virtual scene and prominently improves the realism of the virtual relics and heritages.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 85–92, 2009.

We use precomputed radiance transfer(PRT) method[1] to obtain shadows and multi-bounce inter-reflection effects in our system. PRT method involves pre-computation to reduce the intensity of calculation in rendering stage, so PRT enables real-time rendering. What's more, PRT method uses spherical harmonics for a compact representation for global illumination solution, which enables transmission over internet. Comparing with wavelets[2], spherical radial basis[3] and others, spherical harmonics are especially suitable for our application due to the rotational invariance property and the low-frequency lighting environment for exhibitions. Therefore we adopt spherical harmonics in our system.

The remainder of this paper is organized as follows: We first review the Precomputed Radiance Transfer method in Section 2. Next we provide an overview of our system in Section 3. Then the implementation details of precomputation and rendering are presented in Section 4 and 5 respectively. The experimental results are given in Section 6. Finally, we conclude our work and discuss future research directions.

2 Review of PRT Method

By simulating the light transport, global illumination obtains the radiance in every direction of each point in the scene, which determines the color value of each pixel in the finally synthesized 2D image. This simulation is time consuming as the lighting pathes to be calculated are of huge amount, which is impossible for traditional methods to handle in real-time. PRT method is an approximate solution to the light transport by involving linear approximation with spherical harmonic(SH) basis. The core idea of this method is to divide the integral part of the rendering equation into two parts: a light source function $L(\ )$, which can be changed dynamically when rendering, and a transfer function $T(\ )$, which is precomputable before rendering. The reflection equation is simplified as:

$$B(x,\omega_o) = \int_{\Omega} L(\omega_i) T(x,\omega_i,\omega_o) d\omega_i \ . \tag{1}$$

The transfer function $T(\ )$ describes how the light arriving from direction ω_i is transferred into irradiance in direction ω_o at each point of the scene. The light source function $L(\ )$ describes exactly the fraction of the light incoming at point x from direction ω_i. Sloan et al.[1] use spherical harmonic basis to calculate and store transfer function, which represents how an object cast shadows and inter-reflections onto itself. $T(\ )$ and $L(\ )$ are projected into spherical basis via integration:

$$c_i = \int_S f(s) y_i(s) ds \tag{2}$$

Where c_i is the i-th SH coefficient of the projected function, $y_i(\ )$is the i-th SH basis function.

By virtue of the orthonormal property[1] of SH basis, the integral in (1) is simplified as a dot product of SH coefficients vector:

$$B = \sum_k l_k t_k \ . \tag{3}$$

Where l_k and t_k are the k-th SH coefficients of light source function and transfer function respectively.

This method enables real-time rendering of global lighting effects in dynamic and low-frequency lighting environments. However, only simple BRDF models such as Phong model or other radially symmetric models can be handled because they are adequate for the simple convolution in the spherical harmonic basis. Our implementation differs. For complex materials, we blend the resulted color with previously generated texture to achieve photo-realistic results of heterogeneously colored surfaces.

3 Overview of Our System

Our system is constructed with two components: a precomputation program for precomputing the transfer functions and a set of rendering program that uses precomputed intermediate results for interactive exhibition. For each item to be exhibited, the precomputation program runs once to generate the intermediate result of the model. With the intermediate results handy, the interactive exhibition program renders the exhibition interactively in real-time on user's machine.

We build a simple graphic user interface for users to change the angle and position of view point as well as adjust the lighting environment. GLUI[4] is used as GUI tool, Figure 1 shows our system's GUI.

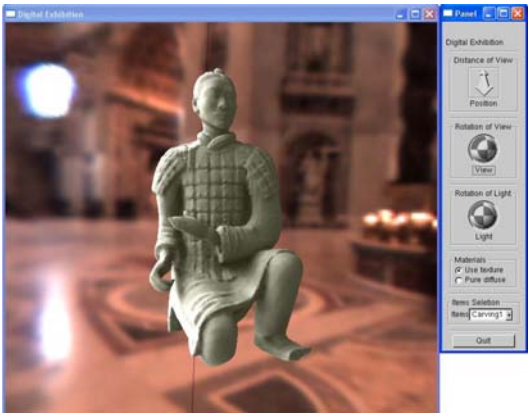


Fig. 1. Graphic user interface of our system

In precomputation stage, the mesh model of the relic is processed to generate intermediate results, which consists of the SH coefficients of the transfer function for each vertex of the mesh model. In rendering stage, a light probe[5] file is loaded and projected into spherical harmonic basis to obtain the SH vector of light function. Then for each frame, after processing the user's operation, the transferred radiance is evaluated for each point via an inner product and then blended with texture. The general working pipeline is shown in figure 2:

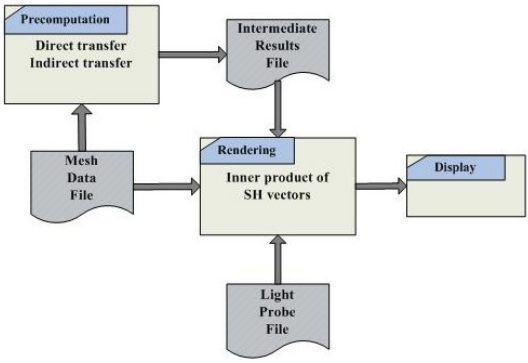


Fig. 2. Overall working pipeline of our system

4 Precomputation

The incident radiance of the environment consists of direct and indirect parts as shown in figure 3. The transfer functions are precomputed in multiple passes. The first pass deals with direct radiance transfer alone followed by a number of iterative evaluations of indirect radiance transfers which represent inter-reflections.

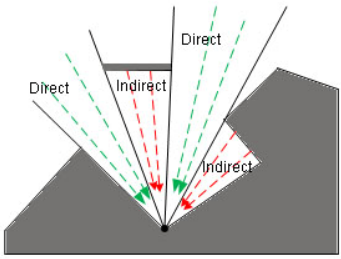


Fig. 3. Two types of incident radiance

The direct illumination represents diffuse reflections and shadows. The reflection equation of direct illumination is:

$$B_D(x) = \rho(x)/\pi \cdot \int_{\Omega} L(\omega_i)V(x,\omega_i)H(x,\omega_i)d\omega_i \ . \tag{4}$$

Inside the integral, for each point, three functions can be identified:

- $L(\omega_i)$ is the radiance from direction ω_i which is dependent on light sources;
- $\rho(x)$ is the albedo which is dependent on the material;
- $V(x, \omega_i)H(x, \omega_i)$ is the visibility and upper hemi-sphere cosine term that is dependent on geometry.

In our application, only geometry information and materials are static and known before the rendering stage. So the geometry term for each point of the scene can be

precomputed as transfer functions and projected into spherical harmonic basis. The transfer function of direct illumination is

$$T_D(\omega_i) = V(x,\omega_i)H(x,\omega_i) \ . \tag{5}$$

The SH projection of a spherical function is simply integrals of the product of the given function and the SH basis functions. We employ Monte Carlo integration[1][6] to calculate the coefficient as shown in (6).

$$c_k(x) = \int_S V(x,\omega_i)H(x,\omega_i)y_k(\omega_i)d\omega_i \tag{6}$$

$V(x,\omega_i)$ is evaluated using the ray-tracing approach. We adopt oc-tree as the acceleration data structure of the meshes, and only the nearest hit points are taken into account.

Indirect illumination represents inter-reflections. The inter-reflection transfer function is very complex and difficult to describe explicitly. Whereas it can be expressed in a recursive form:

$$T_I(x) = \rho(x)/\pi \cdot \sum_i [T_D(x'_i) + T_I^{pre}(x'_i)]H(x, x'_i - x) \ . \tag{7}$$

Where x' is the hit point of a blocked ray sample. $T_I^{pre}(x')$ is the indirect transfer function at point x' of immediately previous pass. In our application, we employ ray-tracer to find x' for each point x, where x' is the hit point of a ray origin from x. In most cases x' is, so the previous transfer function is calculated via a linear interpolation of the transfer functions on the three vertices of the hit triangle according to their barycentric coordinates:

$$c_k(x') = \alpha c_k(x_0) + \beta c_k(x_1) + (1-\alpha-\beta)c_k(x_2) \tag{8}$$

Where α and β are barycentric coordinates of the hit point x', $c_k(x)$ is the k-th SH coefficient of transfer function of vertex x.

The direct and indirect transfer functions are added and stored as intermediate results for each vertex.

5 Interactive Rendering

In the rendering stage, the fast integration property of SH functions is exploited for the lighting integral. We use Paul Debevec's high dynamic range light probes[5] as light source. Before rendering, the light probe image is loaded and the angular map is projected into spherical harmonic basis to obtain light function's SH coefficients. In order to alleviate the ringing or Gibbs phenomenon of SH projection, light probes are processed with low-pass filtering before the SH projection. It is also feasible to artificially generate a spherical function as the light source.

In general we take the steps listed below in the rendering stage to render each frame:

1. Rotate the modelview matrix according to user's manipulations.
2. Rotate the SH coefficients vector of the light source function according to user's manipulations.

3. For each point or fragment, Dot-product the light vector and transfer function's SH vector, the resulted scalar value is the color of the current point.
4. Blend the resulted color with the texture.

In our application, we provide arcballs for users to manipulate the rotations of lights and viewpoint on the control panel as shown in figure 1. All operations are processed in real-time. User's manipulation of viewpoint directly affects the view matrix in rendering pipeline, while the manipulation of light involves the intricate spherical harmonic rotation[1][7]. The rotation of spherical harmonic functions can be considered as a linear transformation of the corresponding band of SH coefficients vector. So for each band, the rotation cab be expressed in (9), where R^l is the l-th band SH rotation matrix and c^l is the l-th band SH coefficients vector.

$$c'^l = R^l c^l \ . \tag{9}$$

Our implementation of SH rotation is based on the recursive relationship described in [8] and [9], where SH rotation matrices for each SH band are constructed recursively. One of the most significant virtues of spherical harmonic function is that when rotated, no aliasing artifacts happen to the value of the function. Therefore in our application, no light amplitude fluctuation occurs while rotating the SH vector of light function.

6 Results

Our system has been implemented in C++ and GLSL shading language. The precomputation program runs on a PC with Intel Core Duo 2.53GHz CPU and Nvidia GeForce 8800 GTX card. We run the rendering program on another PC with Intel Pentium 2.8GHz CPU and Nvidia GeForce 6600 card. Statistics are summarized in Table 1 for precomputation and rendering.

Table 1. Performance of our system

Model	num vertices	num of faces	ray sampling	precomputation time	render rate
Warrior	108897	36299	128*128	5.5 h	81.3 fps
Carve2	90453	30151	64*64	1.2 h	92.7 fps
Carve3	104817	34939	64*64	1.5 h	84 fps

From the results we can see that by using precomputed radiance transfer, we achieve real-time performance at interactive frame rates and the duration of precomputation is acceptable. User's operations on viewpoint and lighting cause no obvious depression on performance.

Rendering quality can be judged from images in this paper. Results are shown in figure 4-6. Figure 4 shows the results of rock carvings under various viewpoints and lights. Figure 5 shows the terracotta warrior exhibition, of which the lighting effects are distinct. Figure 6 shows the details of shadows and inter-reflections by zooming-in the viewpoint.

Fig. 4. Results of Dazu's rock carvings

Fig. 5. Results of the terracotta warrior

Fig. 6. Detail of shadows and inter-reflections when zoomed-in

7 Conclusion and Future Work

In this paper we present an interactive digital exhibition system for rigid objects based on precomputed radiance transfer method. Our application provides global illumination effects such as soft shadows and inter-reflections in real-time, which is superior to current digital exhibition systems. We expect that our application will play significant roles in digital museum.

Although by adding textures the results are of high reality, our application is not yet able to support realistic materials because we implemented rendering method for

only view-independent material and the SH approximation is only accurate for very low-frequency lighting. In future work, we want to apply more sophisticated lighting effects to our application, such as arbitrary BRDF reflection, BTFs and subsurface scattering effects.

Acknowledgments. This paper is supported by National Natural Science Foundation of China (No. 60533070 and 60773153), the Key grant Project of Chinese Ministry of Education (No. 308004)

References

1. Sloan, P., Kautz, J., Snyder, J.: Precomputed radiance transfer for real-time rendering in dynamic, low-frequency lighting environments. In: Proceedings of the 29th Annual Conference on Computer Graphics and interactive Techniques, SIGGRAPH 2002, pp. 527–536. ACM, New York (2002)
2. Ng, R., Ramamoorthi, R., Hanrahan, P.: All-frequency shadows using non-linear wavelet lighting approximation. In: SIGGRAPH 2003, pp. 376–381. ACM, New York (2003)
3. Tsai, Y., Shih, Z.: All-frequency precomputed radiance transfer using spherical radial basis functions and clustered tensor approximation. In: SIGGRAPH 2006, pp. 967–976. ACM, New York (2006)
4. GLUI, `http://www.cs.unc.edu/~rademach/glui/`
5. Light Probes, `http://www.debevec.org/Probes`
6. Kautz, J., Sloan, P., Lehtinen, J.: Precomputed radiance transfer: theory and practice. In: Fujii, J. (ed.) SIGGRAPH 2005. ACM, New York (2005)
7. Lisle, I.G., Huang, S.T.: Algorithms for spherical harmonic lighting. In: Proceedings of the 5th international Conference on Computer Graphics and interactive Techniques in Australia and Southeast Asia, GRAPHITE 2007, pp. 235–238. ACM, New York (2007)
8. Ivanic, J., Ruedenberg, K.: Rotation Matrices for Real Spherical Harmonics, Direct Determination bu Recursion. Journal of Physical Chemistry A 100, 6342–6347 (1996)
9. Ivanic, J., Ruedenberg, K.: Additions and Corrections: Rotation Matrices for Real Spherical Harmonics. Journal of Physical Chemistry A 102(45), 9099–9100 (1998)

Lishe System

Zongquan Ma, Yue Qi, and Ling Zhao

State Key Laboratory of Virtual Reality Technology and Systems
Beihang University
Beijing 100191, China
{mazq,qy,zhaoling}@vrlab.buaa.edu.cn

Abstract. Lishe is the earliest archery competition in ancient China. According to the records of history documents, we elaborately model the Lishe scenes, characters and costumes, reproducing the whole process of Lishe. The system implements a core function module, adds in the Virtual Human technology, and provides multiple HCI (Human-Computer Interaction). It has already been operated as a part of Virtual Olympic Museum.

Keywords: Digital Museum, Virtual Reality, Lishe.

1 Introduction

With the development of information technology, especially the network technology, more and more web-based digital museum appeared, providing various online services, such as information of collections on various aspects of knowledge. Therefore, it is very important to share and protect valuable museum resources.

At present, many digital museums are available. While staying at home, we can enjoy the demeanor of the various museums by visiting the website, such as The British Museum, The State Hermitage Museum, and Louvre Museum, also in China, The National Museum of China, and The Digital Palace Museum. However, among these digital museums, there is no museum about the Chinese history of ancient Olympics. Therefore, Lishe system plays an essential role in making more people better know Chinese Olympics history and spirit.

Lishe is a prototype of Chinese archery competition, which comes into being from the Western Zhou Dynasty, dating back to 700 years BC. It composed of a series of specific and standardized procedures and strict etiquette rules. Each people have a clear division of work and corresponding clothing. The whole process from the beginning to the end has about more than 50 steps. The contest result depends on not only archery score, but also whether respecting his competitors, correct attitude towards failure, and so on.

We elaborately build the Lishe scenes, characters and costumes by the modeling tools, according to the historical records. Lishe system contains a core function module, which are in charge of the organization of scenes. A virtual human technology is used to simulate the characters' movements and activities. Furthermore, a set of multiple HCI is provided to users with easy-to-use roaming.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 93–100, 2009.

2 System Overview

Lishe system is mainly divided into three parts: core function module, virtual human module and multiple HCI module.

The core function module is the base of the system, and in charge of the organization, control and rendering. The module has a complete set of scene graph structure, on the one hand, it provide fast search, insert, modify and delete operations of scene to upper level application, on the other hand, give geometry and appearance information for fast rendering. In addition, the module has a set of state machine based message mechanism, the whole process of Lishe is divided into a number of states, and module can control the process by changing the states of scene.

Virtual human technology is an important component of virtual environment (VE) [1], and plays a significant role in enhancing the reality and immersion of VE. Since a virtual person often has hundreds of control nodes, it is difficult to achieve natural motion by artist, we use the motion capture technology to capture the real man's motion in the real world, and get the motion sequence. Between two motion sequences, the motion synthesis method[2] is used to manage the original motion data segment and synthesize the new motion sequence that can satisfy the user's requirement in real time.

Apart from the traditional keyboard and mouse HCI methods, Lishe system also supports eye tracking device, the system can make use of the device to track the user eyes to get the position where user is looking at, then further to roaming in virtual scene according to user's eyes. This multiple HIC can give users a more realistic experience, and enhance the immersion of system.

3 Core Function Module

Core function module take the responsibility of effective organization and management and control the whole process of Lishe, it is the foundation of Lishe system. It mainly contains two parts: scene graph management and state machine management.

3.1 Scene Graph Management

Scene graph management provides a simple and efficient scene graph structure[3], which can provide search, add, delete and other operations, be able to provide rendering data to the bottom level. Figure 1 illustrates the system's scene graph structure.

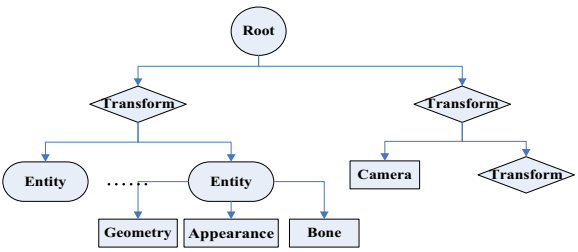


Fig. 1. Scene graph structure

Root node is the farther node of all the other nodes, and unique in the scene.

Transform node record the 3D transformation, so that can provide the translation, scaling and rotation operation to its children, it is can be seen as a local coordinate frame. Transform node's child can be Transform itself, Camera or Entity.

Camera node contains the parameters of the camera, such as focal length, view scope and so on, it can be the child of Transform node, so that camera can be linked to objects in any local coordinate system, move with objects together. There can be more than one camera in same scene, but can only have one active camera at the same time.

Entity node contains the geometry, appearance as well as bones information of object.

Geometry node records the geometry information of object, including vertices, face and index data.

Appearance node keeps the material information.

Bone node contain a bone hierarchy and the relationship between bones and skin, with these information, we can control skin according to bones' position and thus implement the skeletal animation.

3.2 State Machine Management Module

State machine management module implements a set of message circulation to control the system status.

State machine[4] is a simple and practical method of AI (Artificial Intelligence), and its basic idea is to define all the object behavior to states, each object keeps a state changing equation, which decide next state according to current state and received message. Figure 2 show a simple example, a man has three states: "talk", "walk" and "normal", when get the "Walk Start" message, the state transfer from current "normal" to "walk".

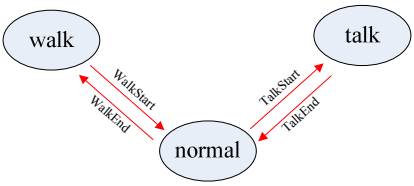


Fig. 2. A simple state example

It needs various commands and parameters to communicate between objects in scene, we used message to manage these commands and parameters. Message has five parts: message type, sender, receiver, time and parameters. As figure 3 shows, There is a message router deals with all the new message generate in one frame time, and send to corresponding receivers, when object get a message, according to state changing equation, object change to next state.

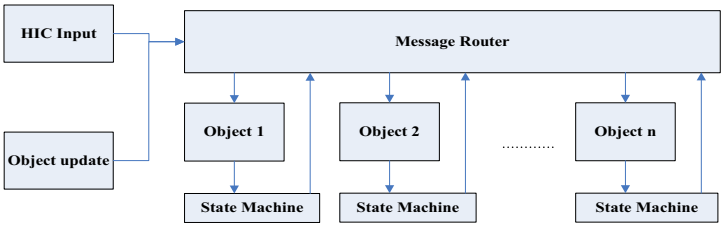


Fig. 3. Sate machine based message management

4 Virtual Human Module

Skeleton animation is often used in virtual environment to represent human's movement and action, we use motion capture method to acquire human motion sequence in real world, and use motion synthesis method to adopt different motion sequences to be smooth transformed, by this way, we can achieve extremely natural human motion in our system.

The movement was measured with a 3D motion analysis system (VICON512, Oxford Metrics Ltd.), and the process of motion capture is shown in figure 4.[5]

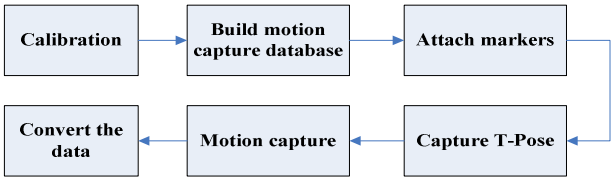


Fig. 4. Process of motion capture

(1) Calibration of capture devices and light intensity. Capture device include 12 cameras around the capture ground, it need to calibrate each camera, and the light intensity. (2) Build up the motion capture database in order to store the capture data. (3) Attach markers. Marker is a sphere which is covered by a kind of special reflective material, we attach these markers to different main joints, 42 markers in total. (4) Capture T-pose. Capture the pose like letter "T", and label each marker for recognition. (Figure 5) (5) Motion capture. Start to capture the motion sequence. (6) Convert the data. The captured data is not in general format, it needs to convert the data to skeletal animation data format.

After motion capture, we can get a set of motion sequences, in our system, character has many motion sequences, and there will have a jump switch between two sequences because of different motion speed and different position. So we use motion synthesis method to smoothly attach two sequences.[6][7]

There are four steps in motion synthesis, as shown in Figure 6, it is need to switch from sequence m_i sequence m_j, First of all, calculate the difference between the end

Fig. 5. Model with T-Pose

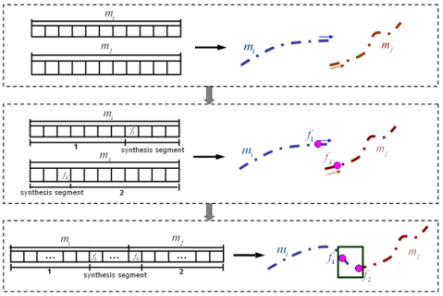


Fig. 6. Process of motion synthesis

part of m_i and the beginning of m_j. Secondly, choose synthesis points on each sequence according to the difference. And next, determine the synthesis segment. At last, smooth two motion sequences and get a new one.

5 Scene Roaming and HCI

Scene roaming directly impact on the user's virtual experience, this system uses a variety of roaming mode and HCI, allowing users to have multi-angle roaming experience.

The roaming mode can be categorized: auto mode, ghost mode and avatar mode.

In the automatic mode, fixed roaming path is set by the program without user invading. The camera automatically controlled by our program will focus on interesting area where events are taken place. By this way, we can show the whole progress of Lishe automatically. The idea is to move the camera along to a path set up by the program according to the current event. The area which triggers an event becomes a hot spot. The camera's orientation keeps changing according to current hot spot.

In the ghost mode, the user can go across the whole scene. Because of the freedom of this mode, users can roam around the scene by their preference.

In the avatar mode, the user can play a role in the scene as a third person in Lishe to walk in the scene. When implementing such a roaming mode, the system provides a simple physical engine to support terrain tracing and collision detection as well. The idea of collision detection is to send out a ray from the view point along the motion direction. This ray intersects with each entity in the scene then each triangle on the entity to find out the closest intersected triangle and corresponding point. The theory of terrain tracing is similar to collision detection. A list including entities on the ground is made up in advance. When performing terrain tracing, the system only needs to judge intersecting with entities in the list.

The system adopts traditional interacting ways (keyboard and mouse) in the automatic and flying modes. The keyboard controls translation and the mouse controls the orientation. In the avatar mode, the system adds in a new eye-tracing interacting method called Quick Glance 2SH from EyeTech Company (figure 8). It can be started by the program and trace users' eyeballs and return the corresponding screen coordinates so as to make the view point changing according to where you are looking at.

1	2	3
4	5	6
7	8	9

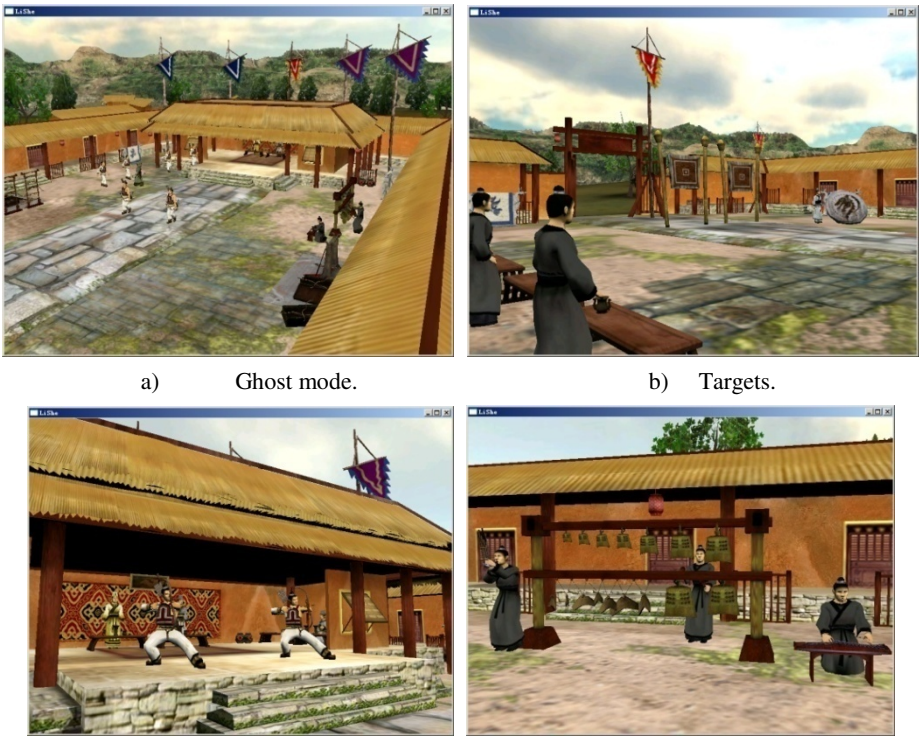
Fig. 7. Eye tracking device (left), and roaming methods when eyes are looking at different screen regions (right). Region 1: move left and forward. Region 2: move forward. Region 3: move right and forward. Region 4: move left. Region 5: no move. Region 6: move right. Region 7: move left and backward. Region 8: move backward. Region 9: move right and backward.

6 Result

As figure 8 shows, master and guests stay inside the house to watch the competition, at opposite side of house, there are target boards, besides are two workers to be

Fig. 8. Overview of Lishe scene

Fig. 9. Lishe character, from left to right: master, musician, judger and contestant



a) Ghost mode. b) Targets.

c) Contestants. d) Musicians are playing music.

Fig. 10. Screen shot of Lishe system

responsible for verification and record, contestants and musicians stay at two sides of house, there also have the specific place to put arrows and bows. The scene and 17 characters(figure 9) totally have about 100 thousand triangles, we tested on the machine that have Intel Core2 2.2GHz CPU, 2G memory, GeForce8800 GTS graphics card, at the resolution of 1440x900 can perform more than 60 fps, so that the system can achieve the virtual roaming with middle size scene.

7 Conclusion

Referring to many historical documents, we elaborately model the scenes, characters and costumes, engage in reproducing the whole process of Lishe competition, from the start to the end, there are about 50 procedures in Lishe process in total. Lishe system build up a 3D graphic framework, and use motion capture and motion synthesis technology to present characters' action, furthermore, apply multiple HCI to user. Being part of Virtual Olympics Museum, Lishe system plays a vital role in presenting Olympics Games' history and let more people better understand Chinese ancient culture.

Acknowledgements

We would like to thank Ning Wang, Wei Wang, Li Mi and others in school of New Media Art and Design for providing the 3D models. Thank Zhiqiang Fan for leading us to accomplish this project. We also thank Shanrui Liu, Yong Hu and Fangyang Shen for their helps. This paper is supported by National Natural Science Foundation of China (No. 60533070 and 60773153), the Key grant Project of Chinese Ministry of Education (No. 308004).

References

1. Kalra, P., Magnenat-Thalmann, N., Moccozet, L., et al.: Real-Time Animation of Realistic Virtual Human. IEEE Computer Graphics and Applications 18(5), 42–56 (1998)
2. Gleicher, M., Shin, H., Kovar, L., Jepsen, A.: Snap-together-motion. In: Proceedings of ACM SIGGRAPH Symposium on Computer Animation 2002, ACM SIGGRAPH (2002)
3. Radek, O., Jiri, S.: A Flexible Low-Level Scene Graph Traversal with Explorers. In: Proceedings of the 21st spring conference on Computer graphics (2005)
4. Buckland, M.: Programming Game AI by Example, pp. 52–100. Wordware Publishing, Inc. (2008)
5. Molet, T., Huang, Z., Boulic, R., et al.: An Animation Interface Designed for Motion Capture. In: Proc. Computer Anmiation 1997, pp. 77–85. IEEE CS Press, Los Alamitos (1997)
6. Wiley, D., Hahn, J.: Interpolation synthesis of articulated figure motion. IEEE Computer Graphics and Application, 39–45 (1997)
7. Wang, L., Qi, Y., Shen, X.: The Design and Implementation of VBS. In: Hui, K.-c., Pan, Z., Chung, R.C.-k., Wang, C.C.L., Jin, X., Göbel, S., Li, E.C.-L. (eds.) EDUTAINMENT 2007. LNCS, vol. 4469, pp. 34–43. Springer, Heidelberg (2007)

E-Learning: The Strategies of Learning Culture and Arts

Chen-Wo Kuo[1], Jiann-Min Yang[1], Quo-Ping Lin[2], and Maiga Chang[3]

[1] National Chengchi University, Department of Management Information Science, Taipei, Taiwan
[2] National Palace Museum, Information Management Center, Taipei, Taiwan
[3] Athabasca University, School of Computing and Information Systems, Alberta, Canada
{paulkuo,james}@npm.gov.tw, jmyang@mis.nccu.edu.tw, maiga@ms2.hinet.net

Abstract. Culture and arts could be very much of hi-tech. Taiwan government has announced that e-learning as the featured policy of Taiwan since 2003. Almost all culture and arts e-learning programs designed by Council for Cultural Affairs and National Palace Museum. Both of them have started e-learning programs and developed a series of e-learning courses in multiple languages, moreover, they keep update related art and literature knowledge which are embedded in the e-learning courses from year to year. The e-learning program of CCA and NPM offers the public opportunity to understand Chinese arts and culture virtually, furthermore, to learn the related knowledge about the collections online. This paper reveals the key issues of how CCA and NPM plan and runs the e-learning program and how this successful model can be apply to other culture organizations.

Keywords: NPM, CCA, e-learning, culture, arts.

1 Introduction

The information and communication technology has been vigorously developing since the end of the 20th century. Many countries, organizations, and businesses, have been put a large number of resources in the researches of learning, teaching, and training programs in order to prepare and improve their competitiveness. Experts and scholars believe that learning technologies would change human learning activities, and moreover, with the lifelong learning and the knowledge economy, learning technologies are creating a brand-new learning and training model.

Taiwan government has initiated the National Science and Technology Program for E-learning. There are many ministries and councils have joined the national program and developed corresponding e-learning systems, platforms, and courses, for educational training. Most of these outcomes are free for public even the cost is extremely high.

In order to help promote the National E-learning Program, the Council for Cultural Affairs (CCA), Executive Yuan has organized various e-learning activities since 2002. Integrating the nation's wish to develop digital learning and make true its own conception and policy. Five objectives have hitherto been given, the curriculum schedule including E-culture Policy, Cultural Creative Industries, Culture of Taiwan,

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 101–107, 2009.

Civic Esthetics and Cultural Citizenship. In all, 261 subjects or 338.5 hours of courses have been launched, with more than two million visitors among whom over 100 thousand were enrolled. [1] The professional and elaborate e-courses, the teachers' online direction, the perfect management of the internet community and the teaching mode which aggregates the virtual and the actual, all these conduce to the establishment of fresh atmosphere for cultural learning.

Besides that, the other organizations to promote culture and arts e-learning are National Palace Museum (NPM). NPM has more than 650,000 artifacts which covering 7,000 years in Chinese history, including ceramics, bronzes, jades, calligraphy, and painting. In recent years, NPM has begun digitizing its collections in order to promote those fine cultural artifacts to the general public. Digitalizing the artifacts will make the public learning the related knowledge much easier. NPM has been used information technologies to develop the novel e-learning methodologies and courses. A number of educational multimedia and courses have been developed for on-line learning, mobile learning, and interactive learning.

This paper reveals the key issues of how CCA and NPM plan and run the e-learning program and how those successful models can be apply to other culture organizations. The following sections would like to describe the recent work of the project and several practical educational activities. Those programs are expected to offer lively and interesting cultural courses to people and to supply them with spiritual nurture. To students they supply information on cultural learning and their career project. To professionals they can give integrated and in-depth information on the culture and art of the whole nation. And teachers can also benefit from those plans and find up-to-date cultural and artistic materials fit for their subjects while cultural groups get a platform where conceptions, ideas, technologies and topics can be communicated and exchanged, and where cultural creation and learning can be animated. At last, those programs can help cultural offices at all levels not only with policy publication and execution but also with the propagation of local cultural information so that the best use of it can be achieved both in information industry and in education.

2 E-Learning Literature Reviews and National Program

There are many different definitions about e-learning: some researchers use it to refer to either packaged content pieces or technical infrastructures; some researchers think it is asynchronous self-learning but others think it can encompass synchronous learning and collaboration. Almost all researchers agree that e-learning is a way for learning. NCSA (the National Center for Supercomputing Applications) e-Learning group also provided a general definition: "E-Learning is the acquisition and use of knowledge distributed and facilitated primarily by electronic means. This form of learning currently depends on networks and computers but will likely evolve into systems consisting of a variety of channels (e.g., wireless, satellite), and technologies (e.g., cellular phones, PDA's) as they are developed and adopted. E-learning can take the form of courses as well as modules and smaller learning objects. E-Learning may incorporate synchronous or asynchronous access and may be distributed geographically with varied limits of time. [2]

Rosenberg addressed that e-Learning refers to the use of Internet technologies to deliver a broad array of solutions that enhance knowledge and performance. It is based on three fundamental criteria; e-Learning is networked, which makes it capable of instant updating, storage / retrieval, distribution and sharing of instruction or information ;It is delivered to the end user via a computer using a standard Internet technology ;It focuses on the broadest view of learning–learning solutions that go beyond the traditional paradigms of training. [3]

The definition of e-learning in the national program is defined as the learning ways, which makes students learning better and teachers teaching more effective. In general speaking, e-learning presents several benefits: lowers the costs of teaching and training in organizations, including schools, government agencies, businesses, and organizations; stimulates learners' learning motivations and interests; and, provides an interactive learning channels and flexible learning platforms to both students and teachers [4] Because e-learning has these benefits, many developed and developing countries allocate funds and resources to encourage researches in e-learning fields. In Europe, the Commission of the European Communities [5] announced the guideline of e-learning policy, The e-Learning Action Plan-Designing tomorrow's education; the Secretary of Commerce in the United States [6] published "2020 Visions-Transforming Education and Training through Advanced Technologies" report; and Taiwan Government [7] also initiated the five-year National Science and Technology Program for E-learning and allocated four billions NTD to promote e-learning in Taiwan.

3 Development of CCA E-Learning Program

For promotion of the program, CCA encourages academia, industrialists and cultural agencies to develop cultural and artistic teaching materials and to make improvement in scope and profundity. Within the framework of the promotion program itself; there are five sub-plans that will be concretized year by year.

As to the execution, four steps are to be followed, namely, infrastructure construction, training & formation of the staff, application and marketing & promotion. The infrastructure construction consists in developing teaching and learning materials within local cultural offices under the Council for Cultural Affairs. The second step will be ensured by digital learning and training in cultural establishments accompanied by digital organization of international seminars and digital artistic learning in elementary and secondary schools. The application lies in good running of CASE (Cultural Affairs, School of E-learning) databank publications. As to the last one, on the one hand it consists in producing and promoting teaching materials merging practical information, and on the other hand cross-ministry and cross-council exhibitions should be organized so that Taiwan will be able to link up with the world and advertise its exquisite culture and art to the world. The CASE plan is the prime task to accomplish for the execution of the whole program of the Council for Cultural Affairs. See Fig.1 for more points. The CASE e-learning website can be found from http://learning.cca.gov.tw/

Fig. 1. CASE e-learning website

In response to the future demand, CCA also made another program, which is composed of three parts: E-learning school, exterior environment and interior environment. To carry out the E-learning school plan, it is necessary to associate cultural organisms of different counties and cities of the whole country, to transform cultural and historical data into digital teaching materials so as to enrich the latter. The second part is to plan sharing digital learning platforms which are intended to afford local cultural organisms resources and technology and to help them as well as professionals make full use of the factors like texts, pictures, graphics, audios and animated cartoons when they design. It is as important to help them develop all-around and smart contents. All those actions lay the basis and framework for the promotion of E-learning.

As concerning exterior environment and resources, ministries and councils will join efforts and exchange experience and resources to solve puzzles that digital learning has to confront, such as infrastructure building, normalization of users' software and hardware and computer ability. The integration of interior resources involves a lot of work and cost, so it requires close collaboration between the central and local authorities concerned. The development of the learning contents on websites in Chinese should move toward multimedia. That is the only way to attract more and more people. Evidently, it is costly; however, it can maximize the overall utility. The problem is that, usually, local authorities do not have sufficient finances and the cultural expense budget is still lower, let alone the information budget. Hence the CCA will assist local cultural centers and cultural establishments to produce, pool and digitize courses fit for e-learning so that cultural and historical data will be transformed into teaching materials and enrich teaching stuff of liberal arts.

4 Development of NPM E-Learning Program

NPM has been planning and implementing a medium-term project, the "National Palace Museum e-Learning", from 2003 to 2007. By using the plentiful cultural resources of the NPM's artifact collections and the newest multimedia information and networking technologies, various digital learning resources and services are being

developed to construct a superior digital learning environment. NPM also establishes a demonstration model for e-learning in museums.

The Learning Management System (LMS) in NPM has the following features: teaching management subsystem covers homework collection, experience sharing, result management, and announcement modules; course management subsystem covers course contents, teaching material management, and questionnaire management modules; and, e-learning activity subsystem for improving teaching and learning efficiency. The NPM e-learning website can be found from http://www.npm.gov.tw/elearning/en/index.htm

Fig. 2. The National Palace Museum e-learning website

NPM developed e-learning courses about those most popular artifacts to general audiences. In the last four years, NPM's e-learning courses cover themes such as bronzes and ceramics. The e-learning courses include more than 53 courses in both Chinese and English. In planning the course contents, NPM considers the learners with different backgrounds and ages when selecting materials and designing the teaching materials in order to make all learners learning something easily. All of teaching materials are done by using rich multimedia methods to stimulate learning motivation. Furthermore, all of e-learning courses have self-evaluation in order to improve the learning effectiveness.

Beside these traditional e-learning technologies, e-learning materials and mobile learning environment, NPM uses the latest information and multimedia technology to develop advanced interactive learning equipment. In order to provide museum visitors personalized learning guidance, NPM creates "digital tour service" which uses ICTs (information technology and communications) and hand-held computer to allow visitors learning in the museum according to their preferences freely. The digital tour service is composed of a tablet PC, wireless earphones, radio frequency identification (RFID) sensors, and straps. Using visitor's preference as the learning setting, visitors not only can select different presentation ways, text, pictures, and audio, but also can choose their favorite learning route.

Based on the learning preferences, the digital tour service offers visitors two main tour-learning scenarios. The first one allows visitors to follow pre-planned learning routes; there are three pre-planned learning routes currently, including "30-minute focus learning route", "60-minute selected learning route", and "120-minute full learning route". The computer will suggest the learning route depending on the artifacts that the visitor wishes to see. In addition, visitors can also do self-learning via RFID sensors. NPM has attached many RFID tags to exhibition items to allow visitors using personalized learning tablet PCs to receive signals from the artifacts and to retrieve related learning materials via wireless network. Visitors can use notebook or tablet PC in the galleries and connect to a NPM's mobile learning portal via wireless network to retrieve learning materials about artifacts. At meantime, the mobile learning portal also provides related e-learning courses and resources. The e-learning courses and resources are presented with varied and highly interactive multimedia forms.

5 Educations and Promotion from the Program

To promote CCA and NPM e-learning projects, they encourage academia; cultural organizations to develop cultural & artistic related teaching materials. For example, NPM follows three steps to do the e-learning project; the four steps are infrastructure construction, staff training, marketing and promotion. The infrastructure construction includes teaching materials development; the staff training holds seminars and digital artistic training courses for elementary and secondary school teachers; The marketing and promotion takes industry's power to promote teaching materials meanwhile to cooperate with other ministries and government agencies in Taiwan, and furthermore advertises to the world.

Taking Taipei city government's case as an example, National Palace Museum cooperates with the Department of Education, Taipei city government in 2005 in the "Wireless Taipei, Unlimited Learning". Taipei city government establishes the wireless networks which are covered all of primary and middle schools' campuses. The Department of Education, Taipei has chosen the NPM e-learning courses and digital tour service to create practice a mobile learning model in primary and middle schools. The mobile learning model involves three stages: "before the visit", "during the visit", and "after the visit". In the "before the visit" stage, instructors compose their teaching materials for students and allow students to access via wireless devices in class; in the "during the visit" stage, the class goes to NPM for experiencing digital tour and advanced interactive learning equipment; and, in the "after the visit" stage, students access the Internet for extended post-class learning anywhere to complete the process.

The works on digital promotion started by the CCA from 2003 are also fruitful. CASE is a more prominent case. The current number of students amounts to 37000 and that of discussers on the bbs 16000 while over 1 million people have visited the website of the school. An online learning community has already been constructed.

6 Conclusion

The main objective of CCA and NPM’s e-learning project are to develop e-learning courses for learners with different needs. Furthermore, they also consider the

e-learning project as its vocation to gather and connect talents and amateurs in art, Chinese culture, history and education through Internet. The influence of their e-learning project spreads to the most far away and to the ordinary people to construct their culture and art knowledge. This paper describes the recent work of CCA and NPM e-learning project and introduces the advanced learning technologies in museum learning developed by NPM. A number of educational multimedia resources, courses, and systems, have been developed, such as digital tour guide and interactive learning equipment, which can support different learning styles. In this respect, they contribute to technology diffusion and coming from this virtual platform vivified by culture knowledge and art life.

References

1. Council for Culture Affairs for e-Learning Information (2009), http://learning.cca.gov.tw/
2. Wentling, T.L., Waight, C., Gallaher, J., La Fleur, J., Wan, C., Kanfer, A.: e-learning - A Review of Literature (2000), http://learning.ncsa.uiuc.edu/papers/elearnlit.pdf
3. Rosenberg, M.J.: e-Learning. McGraw-Hill, New York (2001)
4. Hwang, R.H.: Web-based Distance Learning. The Minister of Economic, Taipei (2003)
5. Commission of the European Communities, The e-Learning Action Plan-Designing tomorrow's education (2001), http://www.ntua.gr/dep/old/International/Europe/com2001_0172en01.pdf
6. The Secretary of Commerce, Visions 2020 - Transforming Education and Training Through Advanced Technologies (2002), http://www.technology.gov/reports/TechPolicy/2020Visions.pdf
7. National Science and Technology Program for e-Learning Information (2009), http://elnpweb.ncu.edu.tw/old/english/english3.htm

SoundTag: RFID Based Wearable Computer Play Tool for Children

Ryoko Ueoka[1], Hiroki Kobayashi[2], and Michitake Hirose[2]

[1] Research Center for Advanced Science and Technology, the University of Tokyo, 4-11-16 Komaba Meguro-Ku Tokyo, Japan
[2] Cyber Interface Laboratory, the University of Tokyo, 7-3-1 Hongo Bunkyo-Ku Tokyo, Japan
{yogurt,hill_koba,hirose}@cyber.t.u-tokyo.ac.jp

Societal demographics inform that the number of children is decreasing. Also there is a shortage of playgrounds around urban areas. These are factors that tend to influence the time children spend outdoors playing with friends. The decrease of outside playing time is unfortunate for children since outdoor activities contribute to children's well-being and development in ways that are not addressed by academic learning. Although there are many social reasons having decreased outside playing time, technological advancement such as television or computer games are considered to be one of the factors. However the authors suggest that the technological advancement is not the reason to cause this tendency. The trend of current computer games induces players doing physical activities indoors. In this study, we take the advantage of technological advancement into positive effect to motivate children playing outdoors. We propose SoundTag, which is a wearable computer prototype system to motivate them to play outside. It employs RFID tag and reader into wears to realize interactive play with sound feedback.

In this paper, we present the SoundTag concept, design theory and two types of wearable system and experiments. the first SoundTag system was applied to a play scenario, which is an enhanced version of a 'tag' game. We performed a pilot experiment partnered with children (from 5 years old to 10 years old) to observe how SoundTag affected playfulness. Playfulness is discussed from the observation of children while playing it and the comments from their parents after the experiment. Followed by the observations of the first experiment, the second version of the SoundTag system is deployed and is applied to the outdoor sound collection game.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 108, 2009.

Sketch Learning Environment with Diagnosis and Drawing Guidance from Rough Form to Detailed Contour Form

Masato Soga[1], Shota Kuriyama[2], and Hirokazu Taki[1]

[1] Faculty of Systems Engineering, Wakayama University
930 Sakaedani, Wakayama 640-8510, Japan
[2] Shima Seiki Mfg., Ltd.
85 Sakata, Wakayama 641-8511, Japan
soga@sys.wakayama-u.ac.jp

There exist many systems and software that support drawing or painting on computers. However, learning support for drawing or painting is a task that differs from drawing support or painting support. Functions for diagnosis and advice are required for learning support. Our project was the first learning environment that could diagnose a learner's sketch and then provide advice.

In addition, our environments are capable of diagnosing sketches drawn on real paper. This function is a unique feature of our environments, and it is important for learners, because drawing on a paper using a real pencil requires a different skill as compared to drawing on a virtual paper using a mouse or a stylus pen.

We developed a new sketch learning environment that provides diagnosis and drawing support from a rough drawing to a detailed contour drawing. We use a cup and a dish as motifs. When a learner uses the environment, the environment first requires the learner to draw a circumscribed rectangle of the motifs' view. Then, the environment diagnoses the circumscribed rectangle and advises the learner of errors, if any. The environment guides the learner from a rough form to a detailed contour drawing by repeatedly drawing circumscribed rectangles.

We evaluated the environment and confirmed a significant learning effect.

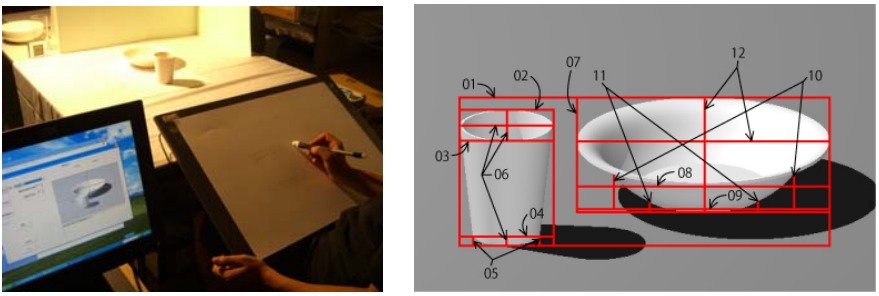


Fig. 1. The left-handed side shows a sketch being drawn on a paper on the tablet Intuos 3 using the improved grip pen by observing motifs on a table. Right-hand side shows all auxiliary lines that are used for guiding the learner from a rough form to a detailed contour form. The numbers for each auxiliary line indicates the order of drawing and diagnosis.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 109, 2009.

Construction of a Computer Game Oriented to Disaster Education and Reflections on Its Problems

Sujing Zhang[1] and Hanjie Gu[2]

[1] College of Education, Zhejiang Normal University, Jinhua, China
sjzhang@china.com
[2] Modern Educational Technology Center, Zhejiang Shuren University, Hangzhou, China
hunjackgoo@gmail.com

Abstract. Despite the fact that greater importance has been attached to educational games, the design, development and application of computer games oriented to disaster education is rarely researched. This paper, therefore, attempts to make use of first aid knowledge targeting teenagers to develop a role-playing computer game oriented to disaster education under the guidance of fuzzy strategy. The paper also reflects on some existing problems after a preliminary experiment with the game.

Keywords: Disaster education, Computer game, Construction.

1 Background

It is of great importance to design computer games oriented to disaster education so as to establish a virtual game environment conducive to the learning of survival knowledge. To begin with, in recent years, disasters such as Indian Ocean seaquake, snow disaster, Wenchuan earthquake have caused great damage to human beings. What should we do when confronted with these disasters? Though China has gained some experience from the public emergencies she has handled these years, the public are still lacking in such education for they feel lost when confronted with crisis, let alone participate actively in crisis management. Besides, at present, there are few domestic video games and websites oriented to disaster education. Therefore, the public lack reliable and stable sources of related knowledge and effective training methods. Once confronted with crisis, they can do nothing but rely on their own experience. Moreover, UNESCO[1] (United Nations Educational, Scientific and Cultural Organization) attaches great importance to the learning of survival knowledge for it puts forward such a slogan for education in the 21st century, "learning survival".

The fact that there is an increasing pool of research on educational games in recent years shows that educational games are becoming the focus of educational informatization. According to statistics, researches on the design of educational games account for 63% of the overall total, with its subclass "the fundamental theory of the design of educational games" taking up 31.4% and those on the application of educational games 26%. From it, we can see at present the research of educational games focuses on theory discussion and technological application with very little research on development (merely 5.7%). [2]. Therefore, our educational game research center developed a role-playing game oriented to disaster education in 2007 and carried out a preliminary experiment with it.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 110–119, 2009.

2 Construction of a Computer Game Oriented to Disaster Education

The computer game takes the name "*Rapid Rescue*", which chooses the popular role-playing as its game type and contains necessary first aid knowledge targeting teenagers. It is developed by the software RPG Maker XP, based on fuzzy strategy (described in 2.4). Its major tasks are: learning first aid knowledge, using types of first aid articles for saving people who suffer from disaster or accident. Its purpose is to promote the learning of survival knowledge in the virtual world.

2.1 Design Process

On the basis of fuzzy strategy and Fang Shengwen's research on educational game design [3], the process of designing this game is shown in Fig.1.

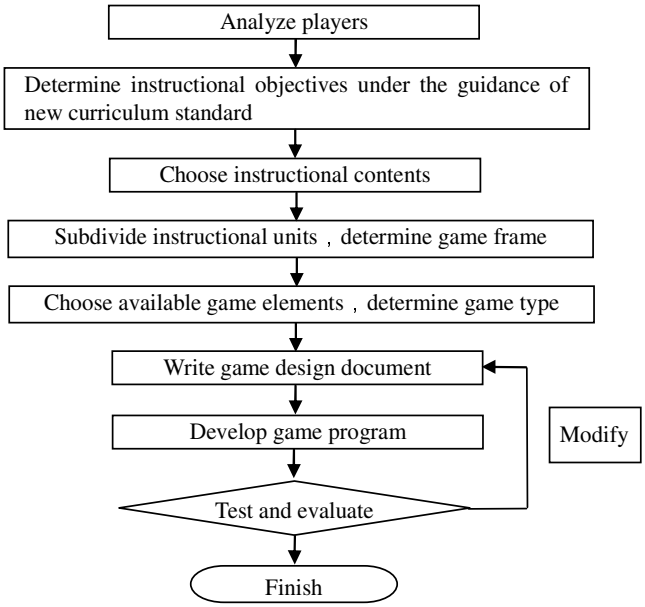


Fig. 1. Design process

On the basis of this design process, some key procedures are analyzed in detail as follows.

2.2 Determination of the Instructional Units and Game Frame

Instructional Units. The game's instructional objectives are: to help players recognize the common accidental injuries (including fracture, drowning, frostbite, scald, etc.), judge their cause and to make use of first aid sills to deal with them; to let players become more experienced when confronted with accidental injuries; to make players more caring, loving and much stronger so as to make them cherish life more.

The instructional contents are from common first aid knowledge, which includes dealing with situations such as getting lost, bruise, sprain, bleeding, concussion, faint, snow blindness, falling in ice crevasses, avalanche, tumble, frostbite in cold areas, self rescue, rescuing others from drowning, using fire extinguishers, fleeing for one's life, and burning in a fire site. According to the actual circumstances in China, the chosen instructional contents are those which we meet frequently, whilst simultaneously letting the game keep certain recreational elements.

According to the instructional objectives and contents, the game's instructional units contain four parts, as is shown in Fig.2: forest, snowfield, water, and fire sites.

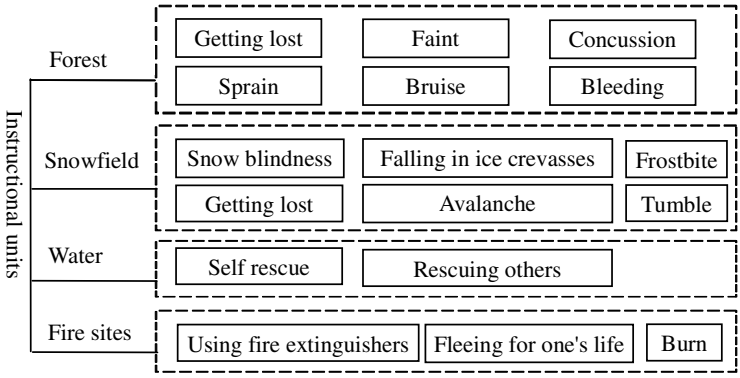


Fig. 2. Instructional units of *Rapid Rescue*

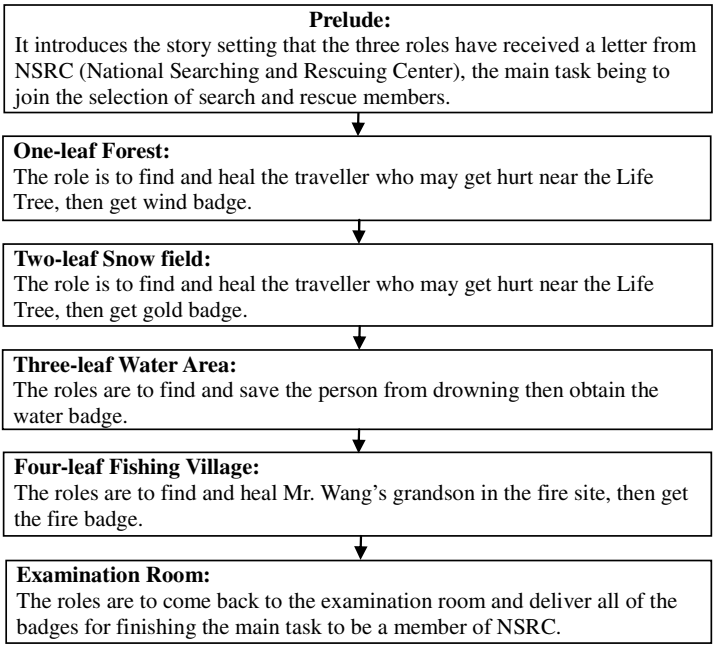


Fig. 3. The game frame of *Rapid Rescue*

Game's Frame. Because of the limited functions of RPG Maker XP, non-linear configuration may require too much time and meet more difficulties. Therefore, our game's configuration is set to be linear. Following the characteristics of first aid knowledge and the theory of experience learning, and considering that the virtual rescue may appeal to players more, the game is designed to simulate rescuing. As Fig.3 shows, it starts from the prelude and crosses four scenes (One-leaf Forest, Two-leaf Snow field, Three-leaf Water Area, Four-leaf Fishing Village) to the examination room. While playing the game, the player must obey the rules and can't fly to the non-adjacent scenes, except for saving the game. For example, when the player wants to enter the Three-leaf Water Area, he must first finish the main task in the Two-leaf Snowfield.

2.3 Determination of the Game Element and Type

To realize the game style mentioned above, we choose the popular role-playing as the game type, and determine the following essential game elements: perfect roles, adventures, epic stories, first aid, temporary tasks, treasure searching, resource managing, and problem solving.

Developing the players' feeling to their roles should be the No.1 priority. The roles controlled by the players aren't just robots in human shape. They should be treated as living ones who have their own needs, feelings and problems. When the roles fail to finish tasks, the players should feel the pain; when the roles get level up or a wonderful reward as a result of finishing tasks, the players should also be proud of it. Essentially the goal we are trying to achieve is getting players to approve of their roles.

The players can explore an unknown area boldly, such as mysterious forests, cold snow fields, broad water areas, quiet fishing villages, etc. In the game, players will feel that they are transferred to a new world, and enjoy the funny adventure. The adventure can satisfy the player's need of curiosity, exploration and aesthetics.

The game should create an important cause that will lead the players to act, and certain threats that will awaken the player's heroic responses. It does not necessarily mean that the world will be dangerous everywhere, but there must be some cases that can have great impact on the role, and lead the players to the belief that the problem can only be solved by them. The story should come about from being invited, stimulated and encouraged, and develop in the interaction between players and game world [4]. The epic story can raise the game's simulative atmosphere and the player's sense of participation and achievement.

In some traditional games, the most effective way of stimulating players' interest is threatening their roles' lives, often using necessary battles. In this game, first aid manifests itself as the battle. Players must choose correct measures in a short time to rescue the people in danger. The stimulation against the clock can also be achieved by rescuing, and the sense of achievement through saving people successfully also attracts players. "First aid" is not only a game activity, but also a learning activity [5].

Designers will provide some small temporary tasks, regardless of whether they are related to the ultimate goal or not. The task is neither cosmic nor compulsive. So the players can determine by themselves whether they will accept the task or not. The design of the temporary task is to raise the game's taste while repeating the scene, and to provide some rewards or help in appropriate time, to help players sustain pleasure and motivation.

One of the most interesting activities in role-playing games is searching for treasures which are hidden in unknown places, and then managing to put it in role's box. In this game, players can search for four symbols of glory: wind badge, gold badge, water badge and fire badge. Searching treasures can stimulate the players to finish the task, and also stimulate their sense of achievement, satisfying the need for exploration.

Resource management is the important part of the game. It always requires the players to manage some petty details for their roles, for example, ensuring the roles are fully dressed, ensuring the preparation of first aid articles are ready, etc. Such resource management is becoming simple in recent years. In the game, players can examine the roles' equipment, task article, etc.

The last representative element is that players will meet all kinds of challenges in the game. The challenges will test the players' wisdom. So they must keep learning new strategies to solve the problem, which makes it easy to combine the game's story and instructional contents. Therefore, on the basis of certain story development, bringing available knowledge into a virtual environment is helpful in improving the players' quality. Moreover, the test can improve the players' sense of achievement.

2.4 Construction of a Game's Scene Based on Fuzzy Strategy

What is fuzzy strategy? Fuzzy strategy is usually used in language communication, mathematics and some other fields, but has rarely been defined. In this case, it is a way to achieve certain goals, through organizing objects efficiently and coordinating them. Since these objects become less evident, the border of different objects tends to become blurred [5]. The educational game based on fuzzy strategy has not been defined clearly up to now. According to the definitions of educational games and fuzzy strategy, we consider it as a computer game which is meant for education [6] and combines education with game together to make the player learn a lot of knowledge unconsciously when they are enjoying the game.

A game's basic frame unit is the game's scene. Every educational game consists of several scenes. The game's scenes embody a game's cream and reflect the game's microscopic characteristics. Fig.4 shows the design of domestic educational game's scenes at present.

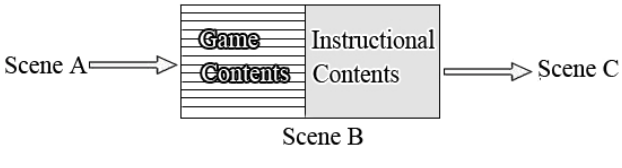


Fig. 4. The common model of domestic educational game's scenes

Scene A, B and C are three continuous scenes in a game. The player enters scene B from scene A, and finds that the boundaries of game contents and instructional contents are decisive. Even if we took away the educational part, scene B can still go smoothly. The whole process of the game would not be disturbed and the player would not feel obstructed by this. In this scene, instructional contents and game actions are built just like blocks. They are not integrated. In these educational games,

instructional contents are set in the games unnaturally by designers, which will weaken the software's taste so as to influence the effectiveness of learning. Such design just considers how to bring game characteristics into education. It ignores the importance of motivating players, which makes it impossible to keep education and game in balance.

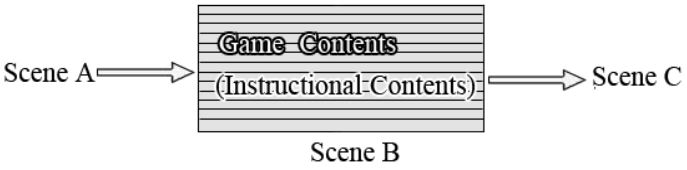


Fig. 5. The model of the scenes of an educational game based on fuzzy strategy

As Fig. 5 shows, scene B makes the instructional contents and game contents blend together. These two merge together as one and can not be separated; if either one is taken away, the scene's frame would be disturbed, which will result in the breakdown of the game's action. In fact, as a learning environment, scene B makes players experience the joy of the game and picks up knowledge unconsciously when they enjoy the game. The instruction contents appear naturally with the aid of a wonderful game world, and get an unexpectedly good effect. So it is better than any mechanical textbook, any impractical courseware and any game software which just brings the book's contents directly without adaptation [7].

Rapid Rescue integrates knowledge into roles, treasure searching, tasks, problem solving and so on. It does not combine different knowledge mechanically [8]. The game elements are not chosen blindly, but in a form conducive to knowledge demonstration. In this virtual learning environment, players learn spontaneously and pleasurably. The fuzzy strategy helps instructional contents and game contents to be in dynamic equilibrium. The fact that the game world is a virtual environment for players to experience has indirect influence on players, which helps them acquire new knowledge on the basis of old one, evaluate the decisions in light of the change in game context, so as to deepen the players'understanding and improve their problem-solving skills.

3 Experiment

After we finished developing the game *Rapid Rescue*, experts presented at National Educational Games and Virtual Reality Conference 2007 made favorable comments on this game and showed great interest in it. In November 2007, *Rapid Rescue* won the first prize in the courseware group in Sixth Zhejiang Undergraduate Multimedia Competition. To test the game's idea of design and players' feelings, we picked up 130 students randomly in grade 2006 and grade 2007 from Educational Technology College studying the course Network Technology in Zhejiang Normal University to help us finish this experiment. Because these students had acquired certain knowledge about basic computer technology, they could accept this new instruction more quickly

than others, and could adapt to the virtual game environment more easily. In addition, Network Technology is a public elective course. The students who studied it usually came from different majors. So the samples were more trustworthy.

3.1 Design of Questionnaire

There were two parts in this questionnaire. One part was participants' basic personal information, and the other part was about their feelings about the game. Every question had several options to choose from. In the first part, we researched on players' sex, age, and so on. In the second part, we tested players' attitudes to game story, visual effect, sound effect and the feelings about the whole game. We also looked into learning effect and players' attitudes towards the way we presented the knowledge, so as to understand all the different types of feelings they had about the game [9].

3.2 Result Analysis

A total of 130 questionnaires were distributed with 107 returned, the response rate being 82.3%. Abandoning 4 ineffective questionnaires, there were 103 effective ones left and the proportion of effective questionnaires was 79.2%. Table.1 shows participants' basic information concerning sex and age.

Table 1. Participants' basic information

	Sex		Age				
Option	Male	Female	<18	18~20	20~22	22~24	>24
Number of people	45	58	0	8	93	2	0
Percentage (%)	43.7	56.3	0	7.8	90.3	1.9	0

As Table 1 shows, the ratio of male students to female students was 1 to 1.28. The majority of students were between 20 and 22, taking up 90.3 of the overall total. 18 to 20 was 7.8% and 22 to 24 was 1.9%. It showed that all of the participants were suitable for the investigation.

Satisfaction of *Rapid Rescue*

Table 2. Participants' satisfaction of *Rapid Rescue*

	Totally Agree	Agree	Not so agree	Disagree
I think it's wonderful	1	66	35	1
The story is attractive	5	68	29	1
The visual effect is attractive	14	72	14	3
The sound effect is attractive	20	66	16	1

As Table 2 shows, the majority of participants were satisfied with the game. Supporters of story, visual effects and sound effects accounted for more than 65%, with supporters of the visual effects and sound effects taking up more than 83.5%. The game's story, visual effects and sound effects were the most important elements to attract players. The story could satisfy the players' need of pleasure, exploration, curiosity, mental weaning and survival; visual effects could satisfy need of pleasure and aesthetics. The data from Table 2 showed that the game was successful in motivating the participants.

Attitude to Learning Effect. As Table 3 shows, approximately 69.9% of participants thought it was a bit difficult for them to cross the barrier. In fact, every scene set necessary barriers to lead players to learn, which blended the story with instructional contents. Because the barrier restricted the way to the next scene by first aid knowledge, the experiment's data showed that its chosen difficult knowledge produced some troubles for players to finish the task.

Table 3. Participants' attitude to learning effect

	Totally Agree	Agree	Not so agree	Disagree
It's difficult to cross several barriers	19	53	29	2
I learned useful first aid knowledge from the game	43	47	12	1

Approximately 88.3% of the participants thought they learned useful first aid knowledge. So the learning effect tended to be consistent with instructional objectives.

Attitude to Appearance of Knowledge

Table 4. Participants' attitude to appearance of knowledge

	Totally Agree	Agree	Not so agree	Disagree
The knowledge appears naturally	28	56	19	0
There is no sense of oppression	19	62	19	3

As Table 4 shows, more than 78.6% of the participants supported the appearance of the knowledge. According to the fuzzy strategy, *Rapid Rescue* was based on the principle that made the border of the game story and instruction blurred, and appearance of knowledge tended to be blended within the story. So the appearance was natural. When the blending got better, the players would like to learn the game; it could even motivate the players to enjoy the first aid. The data from these two questions showed that a majority of participants supported the instructional mode blended with

fuzzy strategy. It proved that the game *Rapid Rescue* was successful in combining education with game and the fuzzy strategy played a very important role in it.

Interest in the Instructional Mode. As Table 5 shows, approximately 65.1% of the participants thought it could develop players' interest in learning by using the instructional mode from the experiment; approximately 70.9% liked the mode, while 85.5% hoped the mode could be applied to other subjects.

Table 5. Participants' attitude to the instructional mode

	Totally Agree	Agree	Not so agree	Disagree
This instructional mode can sustain players' interest in learning.	18	49	32	4
I like this instructional mode.	21	52	29	1
I hope it is applied to other subjects	39	49	13	2

The game *Rapid Rescue* got support from a majority of the participants. It proved that the game was successful in constructing a virtual context, exerting a subtle influence on players. So the fuzzy strategy had certain value to be extended.

4 Reflections

4.1 How to Extend and Apply the Prize Works

On one hand China is short of educational games, especially for adolescents, whilst on the other hand many excellent works haven't been extended to schools. Since 2002, the Zhejiang Undergraduate Multimedia Competition was held annually by the Zhejiang Education Bureau, for improving undergraduates' ability of multimedia design, and cultivating their originality. People have been paying more and more attention to these educational games. The proportion of games in multimedia competition increases every year, and many game works have won the prize. It is a pity that almost all of the prize-winning educational games have no application after the competition, with their value being wasted year by year. The new project we are researching is how to build effective channels for extension, and mechanisms for application, so as to bring the prize works into school. We have signed several vocational senior schools, trying to extend the game *Rapid Rescue* and carry out some tracking experiments.

4.2 How to Produce Useful Relationships between Game and Instructional Contents

Because of the current influence of domestic evaluation mechanisms, the lack of educational games which have no relationship with instructional contents may result in teachers, students and parents all disliking the educational games. We only ever

investigated in three local senior schools in 2008. Though the teachers and students' attitudes to educational games were optimistic, when referred to the topic "Have you ever thought about the possible problems with the application of educational games to instruction?" around 65% of the participants answered similarly, that educational game was less related to instructional contents. Therefore, how to produce a close relationship between game and instructional contents is worth us researching.

4.3 How to Enhance the Gameplay

If the ending of the game is monotonous or the content is too mechanical, once the players are familiar with game, the game will no longer be attractive. There are still some problems with the integration of the game with educational knowledge. For example, game contents are separated from instructional contents, and knowledge often appears in the form of simple options (when roles meet barriers, they must click to answer the question). So in fact the knowledge is not really integrated into game.

4.4 Search for the Network Game Platform for Collaborative Learning

The game *Rapid Rescue* is a stand-alone edition. So it can't share the game resources on network and support players' collaborative learning. Since the network technology and online game develop quickly, it is possible to carry out collaborative learning in online games. How can we apply the resources of educational games to a network so as to make it very well known and support collaborative learning? Searching for a game platform, which has powerful compatibilities, switches data rapidly, and supports working on network is our important work in the later research about educational games.

References

1. Yin, J.: A Brief Discussion on the Disaster Education and Treatment in Science of Senior School's Instruction (in Chinese). Science Education Research 10, 45–46 (2005)
2. Zhang, G., Ma, D.: The Present Situation Analysis and Development Research of Educational Games (in Chinese). E-Education Research 2, 68–72 (2008)
3. Fang, S.: The Scenario Design and Program Development of Educational Game Software Based on Context Instruction (in Chinese). National Center University, Taiwan (1994)
4. Hallford, N., Hallford, J.: Swords&Circuitry: A Designer's Guide to Computer Role-Playing Games, p. 48. Tsinghua University Publishing House, Beijing (2006)
5. Su, Z.: The Fuzzy Strategy of Language in Oral Communication (in Chinese). Northeast Normal University, Changchun (2004)
6. Zhao, H., Zhu, Z.: The Analysis of Definitions and Typology about Educational Game (in Chinese). In: 10th GCCCE 2006 Collected Papers, pp. 39–46. TsingHua University Publishing House, Beijing (2006)
7. Han, Q., Li, Y.: The Discussion of Roles Online Games playing in Distance Education (in Chinese). Chinese Distance Education 15 (2003)
8. Rouse III, R.: The Theory and Practice of Game Design, pp. 369–371. Electronic Industry Publish Company, Beijing (2003)
9. Yang, S.: The Key Factor to Make Our Computer Games Successful (in Chinese). National Traffic University, Taiwan (2003)

CharanisML: A Flexible Virtual Actor Control Interface

Sebastian A. Weiß, Florian Berger, Alexander Marbach, and Wolfgang Müller

PH Weingarten, University of Education,
Media Education and Visualization Group (MEVis)
Kirchplatz 2, 88250 Weingarten, Germany
{weiss,berger,marbach,mueller}@md-phw.de

Abstract. In this submission we present a first step for an author-centric interface to believable agents. Based on a number of approaches for the description of 3D content, we developed *CharanisML*, the Character Animation System Meta Language. It is applicable for controlling both 2D and 3D avatars. To demonstrate this, we implemented two different clients in 2D and 3D that are able to interpret *CharanisML*. Also, they can be adapted as animation engines for interactive digital storytelling engines like *Scenejo*, that are used in the fields of entertainment as well as game-based learning. Using *CharanisML* it is possible for an author to control characters independently from both storytelling engines and two- or three-dimensional representation.

Keywords: embodied conversational agents, interactive digital storytelling, avatar animation, animation language, CharanisML, 2D, 3D, Scenejo.

1 Introduction

Telling a story is independent of a medium. Of course, an appropriate medium must be chosen dependent on e.g. a target audience. In case of interactive digital storytelling (IDS) the main medium will be a kind of computer, but the final representation differs.

If embodied agents are used by meanings of IDS, still different use cases for IDS exist. These require the usage of a different representation technology like animation frameworks or engines. Just a few examples for such use cases:

- **Web**: Flash[1] or similar free frameworks, mainly 2D
- **Online games and communities:** Neverwinter Nights[2], Second Life[3] or any other online game engine, mainly 3D
- **Desktop:** High quality rendering of 2D and 3D avatars (e.g. Unreal Engine[4], Ogre3D[5], etc.)

[1] http://www.adobe.com/products/flash/ (last visited 04.01.2009).
[2] http://nwn.bioware.com/ (last visited 04.01.2009).
[3] http://secondlife.com/ (last visited 04.01.2009).
[4] http://udn.epicgames.com/Main/WebHome.html (last visited 04.01.2009).
[5] http://www.ogre3d.org/ (last visited 03.02.2009).

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 120–132, 2009.

In sum, a lot of applicable animation engines exist. Again, this leads to the problem to decide on an engine that is appropriate to your case. Also, due to this decision, all the story content that has been authored usually only works with this engine. Preferably, it should be possible to author character control in general and not for a specific engine and to have the possibility to re-use already authored content.

There have been several approaches based on generalizing character control but these are either based on direct control of characters, which is in detail much to complex in a dynamic context (e.g. you may not want to control each single bone in a skeleton model), or on simulation of native behavior concerning emotional and knowledge state during a speech act. In terms of telling a specific story both approaches are not leading to the goal. In some situations an author wants to control the behavior of a character, in some not. We present a combined approach supporting both, direct control and autonomous animation based on predefined animation elements. Together with basic camera and scene control *CharanisML* represents an animation metalanguage with a focus on character animation. Also, we introduce two different client engines for rendering full bodied and model independent characters in 2D and 3D. These clients are proving our concept of a generic interface between storytelling platforms (in this case *Scenejo*) and different animation clients.

2 Related Work

In this section, former projects dealing with character animation systems will be discussed to allow for a better understanding how such a generic interface should look like and which features should be supported. Also, animation languages and concepts will be commented. Finally, recent interactive storytelling platforms will be listed and how they could make use of a generic interface.

Improv [1] by Perlin and Goldberg has been the first character animation system, where virtual characters could be controlled directly through scripted commands. Being mainly an authoring tool, an author wrote scripts combining actions, that could been send to the system. It also included support for elimination of conflicting actions and *Perlin Noise* [2] for more “lively” characters. *Improv* does not support speech. That is why it is not suitable for dialog based IDS approaches.

REA [3] has been a specific showcase of a real estate agent. It supported multi modal communication and automatic gesture generation. The *REA* system only supported this specific showcase.

BEAT [4], also a project by Cassell et.al, generates synchronized audio and animation data on base of text input, including mimics and gestures. The results couldn’t be influenced by an author.

NECA [5] has been a project funded by the European Union. It aimed to integrate believable emotional agents into web applications. *NECA* technologies were used to build showcases for simulations. At the beginning agent character settings should be set; during the simulation no further interaction was possible.

The *Virtual Human* project [6] worked on completely autonomous planning of animation and dialog behavior of virtual characters in real time.

For character control several language standards and standard propositions do exist, like the *FACS* [7] system for facial expressions or *H-Anim* [8] for abstract representation for modeling three dimensional human figures. Also integrative approaches do exist like *MPEG-4* [9] that uses so called Body Animation Parameters (BAPs) based on *H-Anim* and Facial Animation Parameters (FAPs) that follow a similar idea than *FACS*.

RRL [10] the Rich Representation Language was developed by the *NECA* Project. Intended is the fully automatically creation of animation based on words to be spoken. No animation control is possible without the text context. Some publications presenting the basic concepts exist, but there is no detailed specification.

The Virtual Human Markup Language (*VHML*) [11] combines several sub languages dealing with emotions, gestures, speech, facial animation, body animation, dialog data and XHTML. The specifications are fragmentary and there seems to be no further development.

AML [12] allows defining a specific timestamp for animation as well to synchronize specific actions. No support for emotions does exist; instead facial expressions are triggered directly. The speed of animations can only be set to slow, normal and fast. With *AML* only avatars can be controlled. Scene, camera and light source can neither be set nor influenced.

BML (Behavior Markup Language) [13] is one of two markup languages used by the *SAIBA*[6] project, that is the most current project dealing with embodied conversational agents (ECA). *SAIBA* is based on a three stage model, where the stages represent intent planning, behavior planning and behavior realization. *BML* describes physical realization, mediating between the last two stages. It is still work in progress and also it focuses on generated content, while we are interested in predefined behavior by an author.

The field of application for such standards is wide, like modeling systems, movie industry, etc. But, we are interested especially in platforms combining IDS with intelligent conversations with animated virtual characters. Successful implementations are rare.

One of the few examples examining a middle course between the two approaches of linear stories and emergent behavior is M. Mateas' and A. Stern's Façade [14]. It is based on a specialized dialogue management system and allows users to participate in a predefined and pre-recorded conversation between virtual characters.

The EU-funded project art-E-fact [15] presents a similar integration of simulation and plot. In contrast to Façade, an authoring system is central to the way a story is built in art-E-fact. It also enables the author to control believable agents.

eCircus [16], also an EU-funded project, is developing an emergent runtime system called *FearNot!*. This includes an empathic character architecture called *FAtiMA*. *FearNot!* is an interactive drama drawing from concepts of role-playing and improv theatre. It has been applied to education against bullying for primary-age children. Actually, *FearNot!* makes use of the very same game engine (*Ogre3D*) as the 3D client presented in this paper.

In [17] we presented *Scenejo* an interactive storytelling platform (see Fig.1). *Scenejo* has been used to build first examples utilizing IDS techniques for game-based learning, like the *Killer Phrase Game* [18]. It enables playful simulations of dialogues

[6] http://www.mindmakers.org/projects/SAIBA (last visited 07.02.2009).

Fig. 1. Avatars formerly used by *Scenejo*. Facial expressions and lip-sync speech are supported rudimentarily. They are not full-bodied.

between several conversational agents and multiple users. It employs current chatbot technology as the basis for text-based interactions as well already animated virtual characters. The bots take into account parametric settings and scene descriptions provided by an author. The aim of the presented approach is to replace the integrated animation module and to extend the control facilities of an author.

3 Requirements and Design

The main task of a character animation engine is to manage and display the visual representation of the characters. Here we will try to formulate requirements for a character animation engine in a rather abstract fashion. We assume a process where there is an *author* who is trying to direct and influence the action, several more or less autonomous *characters* and an *interaction* between characters and between a character and the *interactor*, the user of the application.

3.1 Levels of Control

There are numerous ways to approach the control of a virtual character in an interactive environment. Blumberg has defined three levels of control [19] from an author's perspective:

The Motivational Level: The most implicit way of character control. It is achieved by defining a need for the character, whose fulfillment results in satisfaction, generating motivation to take action. These levels demand a very sophisticated character engine, which must be not only aware of goals and needs, but also of ways to fulfill them.

The Task Level: At this level the author assigns a task to a character, who then tries to complete it. This is a much more straightforward approach, since even though there may be more than one way to fulfill the task. The engine does not have to figure out what the task is in the first place, as was the case in the former level.

The Direct Level: This is by far the easiest way of controlling a virtual character. The author is granted direct access to the internal representation of the character, which may be a 3D skeleton or a series of frames or vector elements of a 2D element. While allowing very fine adjustments, it is also the lowest level and commonly leaves a large amount of work to the author.

3.2 Emotions

It can safely be assumed that the display of feelings and emotions is a necessity for a graphical rendering of believable characters. We should clarify, that we use the term "emotion" here synonymously for a state of how a virtual actor should look like and not in the deeper meaning of moods, sentiments or personality. A character animation engine must have a way to trigger and render a list of base emotions (that has to be extendable as well), and preferably maintains the rendering state of a character. Emotions can interact in complex ways with the actions of a character, especially if high-level character controls are to be implemented. They may shift the motivational state, and may also influence the way a character tries to complete a task - for example, if he shows a diplomatic or a violent behavior.

Ekman und Friesen have made up a list of six base emotions based on experiments on human emotion recognition [20]. These emotions are *joy*, *sadness*, *anger*, *disgust*, *fear* and *surprise*. Later, Ekman expanded this list to fifteen [21]. This list has been tried and tested in several applications and can be sufficient; sometimes as well only six emotions can be adequate [22; 23]. In our approach, the number of emotions used is not limited. Moreover, it is still an author's responsibility to define more emotional states that he needs to achieve the desired result. Therefore, he has to provide also appropriate graphics, models and animations.

3.3 Character Communication

While the last two points have been more or less generic, the concept of character communication in the character engine is strongly influenced by the paradigm of the storytelling application to be connected with. The dialogue-based storytelling framework *Scenejo* requires the rendering of believable character communication. This covers the *verbal* and the *nonverbal* components.

At the *verbal* level, it must be able to output words and sentences, either as audio or as text, and by doing so it preferably keeps (or generates) the stress and rhythm of the text. Concerning *nonverbal* communication, it must control and display the eyes and the face of the character, which is the most critical part in dialogue-based storytelling. Gestures, hand and arm movements and the overall body posture also contribute to the communication process and must be considered vital elements in character control and the overall setup of the scene (see below).

The visible components of character communication are thus quite a few and are as such hard to control for the author, especially in a real-time interactive environment. The character animation engine should preferably support the author with automatic and semiautomatic approaches of generating appropriate facial expressions, gestures and postures [24].

4 Introducing Demands

The concept and models used by the character animation engine are inevitably determined by the paradigms introduced by the storytelling application. There is a wide variety, ranging from text-based interactive fiction to detailed simulations of cognitive processes of virtual agents. With *Scenejo* being the storytelling software to connect

with, a *scene* containing several *characters* is in the centre of interest. The demands which these two cornerstones impose on animation and visualization are described below.

4.1 Scene

A character animation engine for *Scenejo* must be capable of displaying *multiple characters in conversation*. The viewer must have the impression that these characters actually talk to and interact with each other. This has several consequences for the animation engine, like choosing a suitable visual arrangement and making sure vital elements like facial expressions or gestures are clearly to be seen.

To create a context for the character interaction, the engine must be capable to build a *scene* around them, made up of components found in a stage or movie scene: some *objects*, preferably with the option to be used in some way by the characters, a *background* resembling a room or outdoor location, and proper *lighting* following concepts from theater or movie.

For a 3D animation engine there is the additional requirement of *camera control*, which follows from the demand for a clear overview of the conversation taking place. This is a complex issue, especially if the characters are allowed to move around in the scene; a 2D rendering naturally avoids or at least simplifies this problem.

4.2 Characters

Character animation is obviously the main task of an according engine. But as explained above, there are more things to consider than just choosing the next image or skeleton movement for the next frame to be rendered.

In *Scenejo*, characters have an emotional state, and the engine must provide a sort of *emotion management*, and emotions set by the author must also show during other animations, especially *facial expressions.* This is the next major task: to achieve believable character communication, thorough *facial animation* is required, including states and transitions for all possible phonemes.

In line with the levels of control introduced above, there must be a way of *direct eye, face* and *body control*, whatever the underlying concept of animation may be. This should be supplemented by auto-generated animation, which is of special importance for so-called *idle movements*: little variations in posture or eye directions while the character is seemingly doing nothing. A set of *predefined animations* for playback relieves the author from creating them on the fly.

This of course introduces another challenge: auto and direct animation may easily get in *conflict*, and the engine has to provide a solution for solving these.

In our concept, the interaction of characters with each other is conducted in the storytelling applications. *Scenejo* includes natural language processing and emotion control and uses the character animation engine mainly as a display tool.

5 Interface between IDS Applications and Animation Engines

In this chapter we present our approach to a generic interface between interactive storytelling frameworks and animation engines. We called it *CharanisML*, which stands

for **Char**acter **Ani**mation **S**ystem **M**arkup **L**anguage. *CharanisML* is an XML-based command language to control remotely characters and scene environments. It relates to concepts from earlier works like *VHML*, *RRL* and *AML* and partially supersedes them.

Analogue to the described paradigms, the *CharanisML* concept is based on three different levels of control:

- **System Control:** All kinds of system commands; parameter settings, etc.
- **Scene Control**: Adding of characters, objects, control of light source and camera
- **Character Control:** Animation control, playing pre-defined animations, direct control

Its basic concept is that the storytelling application wraps a set of scene and character commands in a package and sends them to the character animation engine. *CharanisML* is generated by our storytelling application *Scenejo* and transmitted to a conforming client via a network connection (see Fig. 2). The following sections give an overview of the capabilities of Scene Control and Character Control in *CharanisML*. To avoid cluttering the article with XML snippets, only tag names and parameters are given. Complete XML example files are available on request.[7]

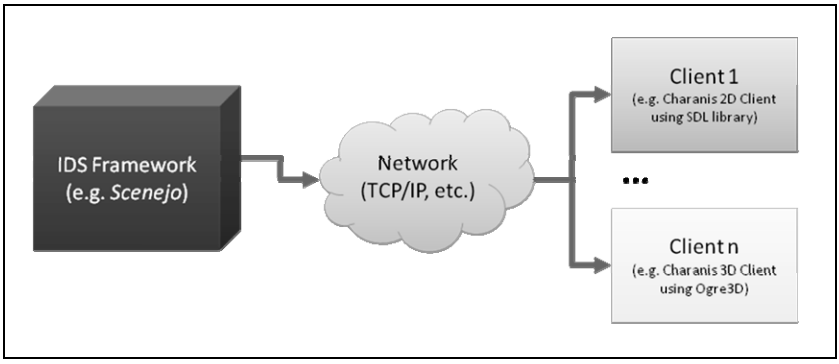


Fig. 2. Simultaneous control of different clients via network using CharanisML

5.1 Scene Control

In conformance with section 4.1, the scene control commands serve the purpose of setting up an environment for the characters where the conversation takes place. The most prominent command `AddCharacter` spawns a character in the scene. It is

[7] The schema currently used can be downloaded under
http://scenejo.org/2008/08/CharanisML/CharanisML.xsd
If you're interested in *Scenejo* and *CharanisML* in detail, please visit http://www.scenejo.org

given a `Name` for later reference. A `ModelName` must be given, which is the name of a data file containing the data for visualization. The data format is application dependent. The coordinates `X`, `Y` and optionally `Z` (for 3D) position the character in the scene. Several commands exist for setting up the lighting of a scene. There are further commands e.g. for object setup which are not covered here.

5.2 Character Control

The major part of the *CharanisML* command set deals with character manipulation. The commands cover the requirements for displaying emotions and character communication given in 3.2 and 3.3, and implement a grammar for the character animation engine functions outlined in section 4.2.

The `PredefinedAnimation` command starts a prepared animation for a character and can be accompanied by the `Speed` and `Intensity` parameters, allowing playback at various speeds and levels of subtlety. `FadeInTime` and `FadeOutTime` can be given to blend the animation with former or later movements. This command is usable for 2D and 3D clients implementing *CharanisML*.

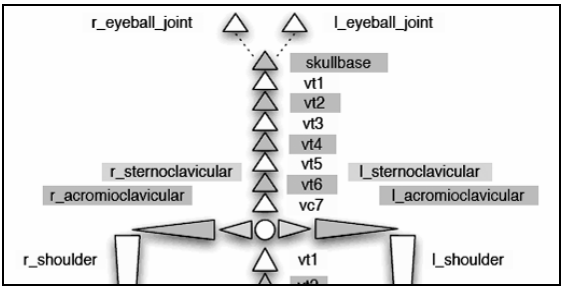


Fig. 3. Detail of schematic view of the H-Anim conform skeleton

Specifically targeted for skeleton animations, the `InlineAnimation` command also offers `Speed`, `Intensity` and `Fade` parameters, but includes a set of `BoneName`, `Time` and `Rotation` command groups which allow the direct manipulation of skeleton elements of a 3D model. Predefined animations can be written in a subset, that we call Skeleton Animation Markup Language (*SAML*). *SAML* files can be externalized from *CharanisML* to group a set of contiguous bone animations.

The emotional state of a character is controlled via the `Emotion` command. It supports all emotions of the model introduced in section 3.2, but since they can be given as free-form strings, additional emotions can easily be added. The command is accompanied by `Time` which gives an offset when the emotion shall be triggered, and the `Intensity` parameter that holds an intensity of the emotion. Thus a conforming client can render several degrees of an emotion, for example by using

different 2D frames or deformations of 3D faces. `Emotion` commands can form an emotion track, in which case the client serializes the emotions and displays an according animation.

The animation of a speaking character, a vital part of a *Scenejo* client for obvious reasons, makes use of the text to speech engine integrated into *Scenejo*, which produces a series of phonemes and from these a trail of facial expressions called *Viseme*. *Scenejo* encodes them as a series of *CharanisML* `Expression` commands. Each Expression has a `Name` and `Time` parameter, giving the name of the facial expression and the time at which it shall be displayed. Similar to a series of `Emotion` commands, this generates a sequential animation of a character speaking. `Expression` and `Emotion` command tracks can be issued in parallel in a package, which a conforming client must render as a superimposing of speech animation and emotional facial expressions. To control facial expressions more detailed another subset, the Facial Expression Markup Language (*FEML*), has been defined. It is based on pose animation and uses *ActionUnits* from *FACS* to control the mimic. All animations can be synchronized on a given timeline. This includes synchronization of actions, mimics, gestures and speech.

6 CharanisML Compatible Clients

In this section we present two implementations of *CharanisML* compatible animation clients. To prove the application of the language to both 2D and 3D, we implemented a client for two-dimensional comic style characters and a three-dimensional client supporting whole 3D scenes and characters.

6.1 Charanis 3D Client

Based on the free *Ogre3D* rendering engine, the 3D Client supports *CharanisML* completely. For modeling characters, any modeling tool that is able to export to the Ogre file format can be used. Models of human figures have to be based on an H-Anim conform skeleton to be controlled.

The client architecture consists of the following four layers:

- **Input:** receiving messages and proxies them two the responsible pipeline. Messages are received via TCP/IP.
- **Character Pipeline:** For each character a single pipeline exists that processes a message. A pipeline consists of several sub steps. The *ActionScriptLayer* processes scripts and commands to create animations. An *AnimationGenerationLayer* adds some default movements like blinking or head movements. For timing correct animations the so called *AnimationCutterLayer* distributes messages over timeslots. And finally a *ConflictEliminationLayer* detects conflicting animations. The processed message is delivered to the output layer.

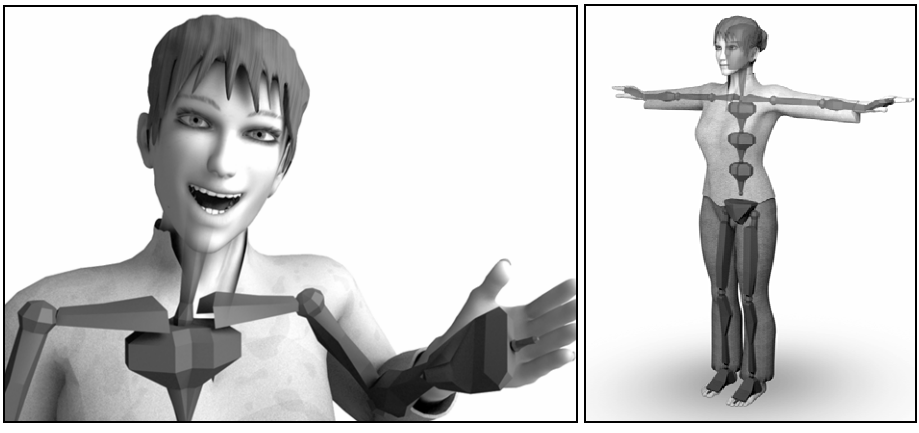


Fig. 4. Left side: Detail of model showing underlying skeleton. Right side: Whole body model.

- **Data Manager:** Central instance to collect the state of each actor, e.g. emotional state etc.
- **Output:** Shows the processed data, both graphics and sound.

6.2 CharanisML 2D Client

The CharanisML 2D Client interprets the *CharanisML* core using a comic-like two-dimensional visualization. It is a cross-platform client built using the Python programming language and the *SDL*[8] graphics library. It utilizes the *Shard* framework for interactive 2D environments and translates *CharanisML* to *Shard* Events using an XML parser. The client features a map-based background for controllable 2D characters to act on. The current implementation disguises the map by use of a sliced background image. The `AddCharacter` command makes the 2D Client load a set of pre-drawn raster images, including all required emotions and facial expressions. Additional animations can be provided to be used with the `PredefinedAnimation` command.

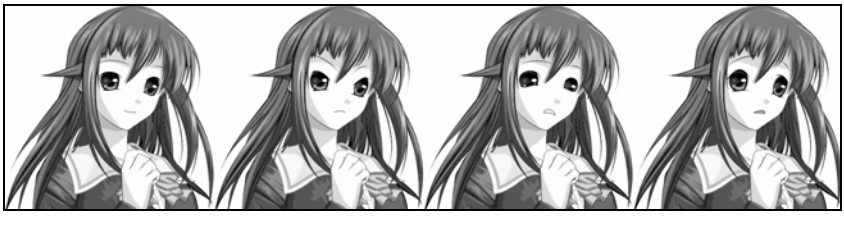


Fig. 5. 2D Client: Some emotions implemented for the main character. From left: neutral, anger, disgust, fear.

[8] http://www.libsdl.org/ (last visited 04.01.2009).

Parallel tracks of timed speech and emotions are of course implemented in the 2D Client as demanded by *CharanisML*. Receiving a combined speech and emotion `Package`, the client establishes an emotion and a facial expression pipeline and decides frame-by-frame which emotion combined with which expression to display. Emotion and facial expression tracks can have different lengths, in which case the client keeps the last emotion given for the remaining expressions or renders the remaining emotion track without lip movement.

The 2D approach has the advantage of making character creation from scratch much easier compared to a 3D client. The images and animations can be made with any drawing application which is able to export raster images. Using clipart or other templates, a satisfying character can be drawn comparably fast, without the need to care for skeletons or texturing issues involved with 3D design. The underlying framework of the 2D Client is ready for user interaction, which is still an issue with the *CharanisML* 3D client. Thus, we are on our way to create a full-fledged interactive storytelling client with *Scenejo* as a true server application.

7 Summary and Conclusions

We presented a first step on standardization for an interface to believable agents. *CharanisML* is based on a number of approaches for the description of 3D content, like *VHML*, *RRL* and *AML*. It is applicable for the use with 2D and 3D avatars. *Ogre3D* has been used as a game engine to build the 3D client. Also free available, the cross platform media framework SDL is the base for the implementation of the 2D client. These successful implementations exemplify prove of concept of our proposition. Using *CharanisML*, an author has the opportunity to create character actions independently from an animation system. That means also, it is possible to reuse content modules in another project requiring a different representation.

7.1 Future Work

Since the process of implementing the clients is ongoing, there a more features to be integrated. Currently, three-dimensional control of bones is ignored by the 2D client. A kind of interpretation layer for generating a two-dimensional equivalent will be implemented. But of course, the control of 3D models may not be really adaptable of a 2D client. Nuances could not be visible or representable at all.

To improve acceptance of 3D avatars *Perlin Noise* will be added as an integrated part of the *AnimationGenerationLayer* of the 3D client.

Beside the ongoing improvement of *CharanisML* due to usability and effectiveness, we want to integrate also a bidirectional interface for user interaction with the ECAs and with surrounding objects that can be added to a two- or three-dimensional scene.

Acknowledgements

We want to thank Holger Biehl for the conceptual ideas behind and the development of the *Charanis* 3D client.

References

1. Perlin, K., Goldberg, A.: Improv: a system for scripting interactive actors in virtual worlds. In: SIGGRAPH 1996: Proceedings of the 23rd annual conference in Computer graphics and interactive techniques, pp. 205–216. ACM Press, New York (1996)
2. Perlin, K.: Noise, hypertexture, antialiasing and gesture. Texture and Modeling: A Procedural Approach. Texturing and Modeling. In: Ebert, D., et al. (eds.) A Procedural Approach. AP Professional, Cambridge (1994)
3. Cassell, J., Bickmore, T., Campbell, L., Chang, K., Vilhjálmsson, H., Yan, H.: Requirements for an architecture for embodied conversational characters (1999)
4. Cassell, J., Vilhjálmsson, H., Bickmore, T.: Beat: The behavior expression animation toolkit. In: Fiume, E. (ed.) SIGGRAPH 2001, Computer Graphics Proceedings, pp. 477–486. ACM Press, New York (2001)
5. Krenn, B.: The NECA Project: Net Environments for Embodied Conversational Agents Project Note. In: Künstliche Intelligenz Themenheft Embodied Conversational Agents, pp. 30–33. Springer, Heidelberg (2003)
6. Göbel, S., Schneider, O., Iurgel, I., Feix, A., Knöpfle, C., Rettig, A.: Virtual Human: Storytelling and Computer Graphics for a Virtual Human Platform. In: Göbel, S., Spierling, U., Hoffmann, A., Iurgel, I., Schneider, O., Dechau, J., Feix, A. (eds.) TIDSE 2004. LNCS, vol. 3105, pp. 79–88. Springer, Heidelberg (2004)
7. Ekman, P., Friesen, W.: Facial Action Coding System: A Technique for the Measurement of Facial Movement. Consulting Psychologists Press (1978)
8. ISO/IEC 19774 — Information technology — Computer graphics and image processing — Humanoid animation (H-Anim), `http://www.h-anim.org/Specifications/H-Anim200x/ISO_IEC_FCD_19774/` (last visited 04.07.2008)
9. ISO/IEC JTC1/SC29/WG11 N4668 (March 2002)
10. Piwek, P., Krenn, B., Schröder, M., Grice, M., Baumann, S., Pirker, H.: RRL: A Rich Representation Language fort he Description of Agent Behaviour in NECA, Bologna, Italy (2002)
11. Gustavsson, C., Strindlund, L., Wiknertz, E., Beard, S., Huynh, Q., Marriott, A., Stallo, J.: VHML. Curtin University of Technology, working draft v0.3 edn. (2001)
12. Kshirsagar, S., Magnenat-Thalmann, N., Guye-Vuillème, A., Thalmann, D., Kamyab, K., Mamdani, E.: Avatar Markup Language. In: EGVE 2002: Proceedings of the workshop on virtual environments 2002, Aire-la-Ville, Switzerland, pp. 169–177. Eurographics Association (2002)
13. Kopp, S., Krenn, B., Marsella, S., Marshall, A., Pelachaud, C., Pirker, H., Thorisson, K., Vilhjalmsson, H.: Towards a Common Framework for Multimodal Generation: The Behavior Markup Language. In: Gratch, J., Young, M., Aylett, R.S., Ballin, D., Olivier, P. (eds.) IVA 2006. LNCS, vol. 4133, pp. 205–217. Springer, Heidelberg (2006)
14. Mateas, M., Stern, A.: Integrating Plot, Character and Natural Language Processing in the Interactive Drama Façade. In: Proceedings of TIDSE 2003, Darmstadt, pp. 139–151 (2003)
15. Spierling, U., Iurgel, I.: "Just talking about art" - creating virtual storytelling experiences in mixed reality. In: Balet, O., Subsol, G., Torguet, P. (eds.) ICVS 2003. LNCS, vol. 2897, pp. 179–188. Springer, Heidelberg (2003)
16. Aylett, R.S., Louchart, S., Dias, J., Paiva, A., Vala, M.: FearNot! – an experiment in emergent narrative. In: Panayiotopoulos, T., Gratch, J., Aylett, R.S., Ballin, D., Olivier, P., Rist, T. (eds.) IVA 2005. LNCS (LNAI), vol. 3661, pp. 305–316. Springer, Heidelberg (2005)

17. Weiß, S.A., Müller, W., Spierling, U., Steimle, F.: Scenejo – An Interactive Storytelling Platform. In: Subsol, G. (ed.) ICVS-VirtStory 2005. LNCS, vol. 3805, pp. 77–80. Springer, Heidelberg (2005)
18. Spierling, U.: "Killer Phrases": Design steps for a digital game with conversational role playing agents. In: Mayer, I., Mastik, H. (eds.) Proc. Isaga 2007, Eburon Pub. (2008)
19. Blumberg, B.M., Galyean, T.A.: Multi-level direction of autonomous creatures for real-time virtual environments. Computer Graphics 29(Annual Conference Series), 47–54 (1995)
20. Ekman, P., Friesen, W.V.: The repertoire of nonverbal behavior: Categories, origins, usages, and coding. Semiotica 1, 49–98 (1969)
21. Ekman, P.: Basic Emotions. In: Dalgleish, T., Power, T. (eds.) The Handbook of Cognition and Emotion, pp. 45–60. John Wiley & Sons, Ltd., Sussex (1999)
22. Patel, M., Willis, P.J.: Faces: The facial animation, construction and editing system. In: Proc. Eurographics, pp. 33-45 (1991)
23. Pelachaud, C., Badler, N., Steedman, M.: Linguistic issues in facial animation. In: Magnenat-Thalmann, N., Thalmann, D. (eds.) Computer Animation 1991, pp. 15–30. Springer, Heidelberg (1991)
24. Cassell, J., Vilhjálmsson, H.: Fully embodied conversational avatars: Making communicative behaviors autonomous. Autonomous Agents and Multi-Agent Systems 2(1), 45–64 (1999)

Game Balance Principles in MMORPG with Pet System

Linlin Shui[1], Guangzheng Fei[1], Guoyu Sun[1], and Chi Wa Leong[2]

[1] Animation School, Communication University of China, Beijing, 100024
{llshui,gzfei,gusun}@cuc.edu.cn
[2] School of Information Technology and Engineering, University of Ottawa, Canada
cwleongmac@yahoo.com

Abstract. This paper proposes a series of pet system design principles which can guarantee the game balance while successfully maintaining attractiveness to game players.

Keywords: game balance, pet system, pet fighting skills.

1 Introduction

Nowadays, many MMORPG games attach great importance to the pet system as a key part of the process of design. Fighting shoulder-and-shoulder with pets has become an important trend in the field of online games development. From the Magic Baby[1] and Journey to the West[2] of several years ago to The Semi-gods and the Semi-devils[3] and the Free Fancy QQ[4] of recent years, all of the games with pet systems have been successful to a large degree.

But the design of pet fighting skills (PFS) has become a difficult problem in programming the games. On the one hand, the variety of fighting skills of the pets can enrich the playability and interests of the game. On the other hand, a careless design of PFS can endanger the balance and interest of the games. If an overwhelmingly powerful fighting skill for the pets is designed, although this can prove popular amongst the players in a short term, the balance of the games will be destroyed in the long term. Yet a design of PFS that is too limited may drive the players away from the games.

This paper seeks to propose a design of PFS that can not only attract the players, but also avoid threatening the balance of the games. A series of famous MMORPG PFS designs are analyzed and categorized. The authors then evaluate the influences of different designs on the balance of games, and propose which PFS designs are best suitable for use by game designers.

2 The Use of Pet System and PFS in MMORPG

An important component of MMORPG is the pet systems. In most cases, it adds to the attractiveness of the games for the players. All kinds of pets can be not only loyal partners of the players, but can also fight with practical skills. Psychologically, every player longs for a lovely and loyal partner. It is true especially for female players, who play games not only to increase their standing levels and kill the enemy, but also

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 133–140, 2009.

for different kinds of fun. Being able to raise a pet is an extremely interesting, emotionally enriching activity for them which augments the playability and the attractiveness of the games. PFS is also very important for a fight. In many cases of MMORPG, the fighting capacity of pets is even higher than the fighting capacity of the players. So in the process of killing monsters, pets are actually the lead actors. PFS can enhance their power of attack, even enabling them to fight against many different targets at one time. PFS can also improve the rank of the players. For example, using PFS can maximize the owners' blood in enabling the owners to supplement their own blood by sacrificing the pets' bloods. PFS can improve the owners' ability of defense, fend the owners from some harmful states or suffer for their owners. In short, PFS makes the players more capable and powerful.

The using of PFS can yield dashing visual effects, making the games more pleasant and beautiful. During group attacks, using PFS can generate dazzling visual effects, allowing the players to show off and satisfy their vanity. Because of the advantages of PFS, it has become a dream and goal for many players to own a pet in MMORPG.

3 The Categorization of PFS in MMORPG

In general, there are two major types of PFS: direct pet fighting skills (DPFS) and indirect pet fighting skills (IPFS).

3.1 Direct Pet Fighting Skills (DPFS)

DPFS refers to the skills used to directly attack the three main properties of an entity: blood, spirit, and rage. DPFS can be classified into three types depending on their intended targets: the enemy, the owner or the pet itself.

DPFS for enemy refers mainly to attacking skills causing the enemy to lose blood and there are two kinds: single attack and group attack. Single attack skill can only wound one enemy at a time while group attack skill can wound many enemy targets at a time. For example, The Semi-gods and Semi-devils[3] boast a single skill of "Thunder Curse" that can hurt the enemy substantively with a single release. The higher ranks the pets are, the more lethal they can be. An example of the group attack skill is the "Five Thunder Blast", which can reduce the blood of six enemies at a time. DPFS can also aim at the enemy's spirit and rage, preventing it from exerting its skills. This PFS can play an effective role in a fight between the players. For instance, the PFS called "Call off Rage" can lower the rage level of the enemy, who cannot use the skills based on releasing rage.

DPFS for the owners can defend them from attacks by sacrificing the pets' blood in exchange for the blood or spirit of the owners. For example, the skill called "Recall the Soul" as a PFS in Free Fancy of QQ[4] can help the players restore their blood and spirit. This process will stop when the spirit and blood of players are fully restored or those of the pets are used up. There are also some healing skills. For example, the PFS called "Awakening" in The Semi-gods and the Semi-devils[3] can eliminate the coma state of owners manually.

DPFS for the pets can give them second life after death. Some can let the pets enter the stealth state. For example, the skill "Escaping" in Free Fancy of QQ[4] can let the

pets go inside the backpacks of their owners without lowering their ranks. The PFS called "Camouflage" in The Semi-gods and Semi-devils[3] can let the pets become invisible.

3.2 Indirect Pet Fighting Skills (IPFS)

IPFS refers to the PFS that don't affect the blood, spirit and rage of the enemy, the owner or the pet directly but can increase their maximum level of blood and spirit or influence other properties. IPFS can usually add a negative buff to lower the attack ability of the enemy. For example, the IPFS called "Weakening" in The Semi-gods and Semi-devils[3] can weaken the single enemy target with a certain odds to lower their attacking power. A positive buff can also be added to the owners to strengthen their power of attack and defense. There are some IPFS that can let the owners enter into an invincible state for a short time. Lastly, IPFS can affect the pets themselves by lowering some properties in exchange for some other higher properties. The "Ice Spirit" skill of The Semi-gods and Semi-devils[3] can make the pets better absorb the harmfulness of the Ice property but would make them more vulnerable to a Fire attack, and vice versa.

4 PFS Influence on the Game Balance

Generally, DPFS has a bigger influence on the balance of games than IPFS, because the former can affect the blood, spirit and rage of the enemy directly, which is much faster and more effective. IPFS can increase or lower the property values of their targets, which is a slow changing process, which is not clearly demonstrated by the changes in blood, spirit and rage. For example, The Semi-gods and Semi-devils[3] has a DPFS called "Thunder Curse", which can cause a sudden decrease of the enemy's blood. But when the pets use their IPFS of "Weakening", can only lower the attack and defense power of the enemy, giving more opportunities for the owners to launch attacks without encountering fierce counter-attacks. This comparison shows that DPFS and IPFS both have influence on game balance, but DPFS impact game balance in a straightway, while the IPFS in a roundabout way. And DPFS has much greater impact on game balance than IPFS.

Players are always trying to break the game balance during play and they are more likely to look for the most effective skills. If DPFS is too powerful, the players won't seek help from the IPFS. But if the DPFS is limited in power, it will lose its attraction.

5 How to Maintain the Balance of Games

Although DPFS has more obvious effects than IPFS, IPFS can last longer and have no freezing time. For example, once the pet adds a powerful buff to the owner, the owner will not lose the buff, if the pet maintains its state as fighting. This characteristic of IPFS supplements the short functional time and longer freezing time of DPFS. Meanwhile, the function of these buffs can improve relatives to the pets' ranks. The higher ranked pets can change the property values of the targets (the enemy, the owner or the

pet itself) for a larger margin. So, this kind of IPFS is also valued by players for its enduring functional time and increasing power.

Generally speaking, PFS for the pets themselves is not popular, whether acting directly or indirectly. In PFS design, more attention should be given to make it compatible with the other pet skills, and make pet systems more powerful through considering PFS with other pet skills, not labeling it as a single or surplus skill.

5.1 Maintain the Balance between Different PFS

5.1.1 Take Advantage of Symmetry

Symmetry is the easiest way to balance a game. Granting different players the same starting level and abilities can ensure that the game results only depend on the player's efforts and skills[10]. But this method is only applicable to some abstract games like Chess. If the pets are equipped with perfect symmetrical skills in MMORPG, the game will become boring. While absolute symmetry is only suitable for abstract games, there are some alternative methods to apply symmetry in a balanced way in MMORPG.

For example, in The Semi-gods and Semi-devils[3], the four skills named "Thunder Curse", "Poisonous Blood Curse", "Fire Curse" and "Ice Curse" are four symmetrical PFS. Although they have different names, they each can cause some damage against the enemy. These four skills belong to four properties namely Thunder, Poison, Fire and Ice. Skills of different properties can cause different injuries against the enemy with different defense abilities. For example, the PFS of fire can cause 100% damage against an enemy of ice, but it cannot inflict any obvious damage towards an enemy having the same property of fire. Each aspect has its advantages as well as disadvantages at the same time. And the influence and dimension of the two sides, in the macro dimension of games, are almost similar to each other[5]. Functional symmetry is realized in this sense.

5.1.2 Relation of Tripartite Intransitive Parties

Almost everyone has played Stone Scissors and Cloth Game in their life time. The rule is simple, scissors can cut the cloth, the cloth can wrap the stone and the stone can smash the scissors. This is the relation of tripartite mutual confining parties, making a simple zero-sum game. In another word, if party A wins, party B must loses, and vice versa. If party A draws with party B, party B must have drawn with party A too.

For example, the game Magic Baby[1] has three PFS, called "Common Attack", "Holy Shield" and "Collapse Hit". When pet A uses "Common Attack" against pet B, pet B can defend with "Holy Shield" to lower the damage to minimum. That is to say, "Holy Shield" can be used to counter "Common Attack". And if pet C launches a "Collapse Hit" against the "Holy Shield" of pet B, pet B will be hit for 100% certainty and the damage will be multiplied up to 200% or even 300%. Therefore, "Collapse Hit" can be used to break the "Holy Shield". And if pet C uses "Collapse Hit" against pet A, who is using "Common Attack", pet C will lose the target, which means "Common Attack" can be used to counter "Collapse Hit".

In this sense, a typical relation of stone, scissors and cloth is constructed among the PFS of "Common attack", "Holy shield" and "Collapse hit".

One problem of this relation is that it cannot be changed, leading to dull games, because every skill actually has the same ability in practical uses. The operating model becomes predictable. One way to improve on this is to attach a strength level to each skill. This added property will make the results less predictable. For example, a thick cloth made of tough material can survive an attack by an ordinary scissor.

5.1.3 Transitive Relation (Recessive Spending)

Transitive relation refers to a single relation among three independent parties. A can beat B. B can beat C. But C cannot beat any one. So it is evident A can beat C. The transitive relation is not symmetrical because C becomes useless.

Generally speaking, the more effective the skills are, the higher are the costs. The cost refers to how much manual effort the players have to make or how much experience or hardships it is required from the players in exchange for the skill. These indirect costs are inconvenient to be directly measured, which are so-called recessive costs, but they can still be able to measure the reward[11]. Recessive costs are generated by some comprehensive factors, whose results can be measured, but can not be changed directly.

For example, there are two PFS called “Blood Sacrifice” and “Higher Blood Sacrifice” in The Semi-gods and Semi-devils[3], which can be served to turn the blood of pets to players’ spirits. “Blood Sacrifice” can sacrifice 50% of pets’ blood and turn 75% of the blood to the spirits of players. And the “Higher Blood Sacrifice” can sacrifice 50% of pets’ blood and turn 100% of the blood to the spirits of players. Obviously, “Higher Blood Sacrifice” is more powerful than “Blood Sacrifice”, but many players choose to let the pets learn how to use the skill of “Blood Sacrifice”, not “Higher Blood Sacrifice”. The reason is simple as the cost of a “Higher Blood Sacrifice” is much more than that of a “Blood Sacrifice” book. The players need to spend more time, effort and even money to meet the target. It is because of the effects of this recessive costs that the balance of the games can be maintained.

Absolute transitive relations without being balanced by recessive costs can give birth to some unwanted and useless choices in games, which will weaken the balance of games. And it is because of the uncertainty of recessive costs that the games are interesting.

5.1.4 Combination

It is unnecessary for the transitive and intransitive relations to be confined to a single skill. In some cases, two or more skills can be treated as a single skill. For example, three PFS in The Semi-gods and Semi-devils[3] named “Absorbing Spirit”, “Beating Rage” and “Weakening” cannot be classified as powerful skills independently. “Absorbing Spirit” can help the user to absorb enemy’s spirits, “Call off Rage” can help to dispel the rage of enemy and “Weakening” can weaken the enemy’s attacking ability. If combined together, all of these skills can make an exclusive pet, which can bring considerable advantage to its owners during a fight between two players.

It is impossible for the players to lay out all of the possible combinations of skills in the game. But they have to pay attention to these combinations and maintain the balance of games through adjusting the skills themselves and keep the balance among different skills by recessive costs. If the basic balance is carefully considered, the

combination effects in the games won't be a serious problem. If we can maintain the balance and solidarity of the foundations of the game, it is less likely to encounter serious problems as a result of combining factors.

5.2 Maintain the Balance between PFS and the Games

Game Balance exists in the feedback recycle of transitive and intransitive relations as well as the obtaining and shifting of the recessive costs between skills. This is static balance. Settling static balances can ensure the staring-point balance when the games start. After the players begin the games, their only purpose is to break the balance which is delicately constructed by the designers. The next issue is how to keep the balance of games during the interaction between players and game systems.

Firstly, DPFS can yield powerful effects, so this kind of effects has to be under control. A period of freezing time is needed. If it is auto PFS, the frequency of its happening can be controlled by programs, inserting an interim between two incidences to ease the impacts of skills on the balance of games.

Secondly, DPFS can influence the balance of games to a larger extent in the manual models, such as the group attacking skills. So these skills need longer freezing time. And this freezing time has to be applicable to all of group attacking skills. For example, during the early stage of the public test of The Semi-god and Semi-devils[3], there were four group attacking skills called "Freezing Ice", "Thunder", "Poison" and "Fire". Although they had freezing time respectively, the freezing time cannot be shared between all of them. Therefore if a player has four pets with the four skills respectively for each, and if he frees the four pets one after the other to use their skills, he can avoid being hampered by the limitation of freezing time and can use group attacking tactics constantly. This lapse of design can seriously break the balance of the game. After upgrading the game, the four skills were cancelled. All of the manual PFS of the same type are settled with public freezing time. For example, "Blood Sacrifice" and "Symbiosis" as two PFS, with the former running on the pets' blood to restore the spirits of the owners according to a certain proportion, and the later using the pets' blood to restore the blood of the owners in a certain proportion. Even these two skills are shared by two pets, they have the same freezing time. After using the "Blood Sacrifice", the player cannot use "Symbiosis" until the former skill freezes, for they are freezing at the same time. The settling of freezing time is essential to solve the conflicts between different advantageous skills and game balances.

Besides, it is also an effective solution to maintain the balance between skills and game as a whole in MMORPG by using recessive costs. The more time, energy and money the players spend on the game, the more powerful skills they will obtain. Because of the constant seeking for powerful skills, the players will spend more time, energy and money participating in the game. Although the recessive costs cannot be calculated precisely, it can be evaluated in a larger scale roughly. The values of powerful skills obtained by players should be equal with or even a little higher than how much the players pay as recessive costs.

Because the recessive costs are more uncertain and because of the factors of luck, two players may harvest different results even though they have the same input towards the game. This kind of uncertainty makes the game more interesting and thrilling.

6 Conclusion

Game Balance is a complex topic, where not only a player's skill but other factors such as luck play an important role. The effective solution is not to consider it as an optimization problem, but to introduce randomized elements such as PFS to a game. When carefully planned, PFS can increase the attractiveness without breaking the balance. In this paper, the authors discuss, analyze and propose some popular design principles for a balance game with PFS. In general, there are two major types of PFS: direct and indirect. The former has an immediate destructive power and is usually restricted by a relatively long freezing period, while the latter has a moderate damaging power and usually has a more enduring effect. Both of them can be applied at the enemy, at the owner, and at the pet level. The limited usage period of DPFS ensures that players in possession of powerful PFS will not have an unfair advantage over other players. This also helps IPFS to retain its attractiveness in comparison to DPFS due to its longer effective period.

In addition, different PFS can be related in one of the following ways: symmetry relationship, tripartite intransitive relationship, and transitive relationship. In a symmetry relationship, different PFS have different usage in various situations, and their destructive powers are averaged-out over a long period of time. In a tripartite intransitive relationship, each PFS has its preys (strength) and predators (weakness), so their average power sums to zero. In a transitive relationship, some PFS may have absolute superiority over others, but the skills require more experience and hardship (a higher recessive cost) to acquire, which limits the extent to which such invincible skills can be learned. These three principles limit the situations where players with powerful PFS can take unfair advantages over others. Besides these principles, the authors also suggest the use of a combination of different types of PFS to bring another degree of fascination to the game. In such a complex environment, balance will be achieved via recessive cost, and by letting players adjust their combination of skills to a manageable and comfortable level.

Finally, the authors address the issue of dynamic balance. Static balance can be accomplished using carefully planned principles and elements as described above. Once a game starts, however, players will interact with one another and try to take advantage in any situations. One way to maintain balance in such a dynamic environment is to impose synchronized freezing time simultaneously on some of the PFS of a player. This will ensure that players in possession of several potent PFS cannot apply them consecutively, thus avoiding an excessive period of dominance over other players. Another way to achieve interactive balance is through recessive cost, making sure that potent PFS can only be obtained through lengthy periods of participation and spending. The factor of luck also plays a role because players of similar abilities may have different outcomes, which involuntarily help driving the system to a balance state. All of theses design principles have been proven to be effective and can be found in many of the new generation games in the market.

References

1. Magic Baby: a 2D MMORPG developed by Enix of Japan (later merged with Square), marketed in Chinese mainland in 2002 (2002)
2. Journey to the West: a famous MMORPG developed by Netease company in 2003, which is most likely to be welcomed by women gamers (2003)
3. The Semi-gods and Semi-devils: a real 3D MMORPG developed solely by Sohu.com, which is based on the novel by Mr. Jin Yong with same name. This game has become very popular ever since the public test (May 2007)
4. Free Fancy of QQ: 2D MMORPG developed by Tencent company which was tested in April (2008)
5. Nighthawk: Pet selection guide of The semi-gods and the semi-devils. Public Software, 23 (2006) (in Chinese)
6. Chang, T.: Pet System in Free Fancy of QQ. NET Friends, 5 (2006) (in Chinese)
7. Novak, J.: Game Development Essentials. Thomson Delmar Learning (January 2008)
8. Rouse III, R.: Theory of Game Designing: Principles and Practices. Electronic Industry Press
9. Xixi, W.: Introduction of Game Designing. Chongqing Uni. Press (March 2006) (in Chinese)
10. Crawford, C.: Theory of Game Designing. Beijing Hope Electronics Press
11. Rongqin Science and Technology: Brief Theory of Game Designing. Beijign Khai Electronics Press (in Chinese)
12. Siyi, Y., Junlu, S.: Life-wide Learning on Game Design. China Railway Press (January 2006) (in Chinese)
13. Jun, X.: An balance test and function test of MMRPG software. Computer and Information Technology (May 2005) (in Chinese)
14. Feng, Z.: Game Balance of MMORPG. Programmer: Game Creation (January 2008) (in Chinese)
15. Liao, C., Chen, Z.-H., Chan, T.-W.: My-Mini-Pet: The Design of Pet-Nurturing Handheld Game. In: 2008 Second IEEE International Conference on Digital Games and Intelligent Toys Based Education, pp. 138–140 (2008)
16. Octogene: Evolution With Pet – Analysis on Pet System of Cross OL.NET Friends, 15 (2008) (in Chinese)

An Approach to Evaluation Component Design in Building Serious Game

Sanya Liu and Wan Ding

Engineering & Research Center for Education Information Technology,
Huazhong Normal University, 430079, Wuhan, Hubei, China
lsy5918@mail.ccnu.edu.cn

Abstract. In our opinion, the evaluation is one of the most important parts in serious games. An approach to evaluation system design for serious game is come up and discussed in this paper. Firstly, we discuss the importance and the function requirements of evaluation system in serious game. These functions are: record & playback, data processing, feedback, database interface, script language support, and so on. Secondly, we design and implement our evaluation system in the form of component for our 3D game engine. Finally, a demonstration is given.

Keywords: serious game, game engine, evaluation, game design.

1 Introduction

Along with the development of IT, Computers have been widely used in education and science research. In recent years, the applications of PC game in these fields are becoming more and more noticeable. In 2002, the Woodrow Wilson International Center for Scholars in Washington D.C. launched a "Serious Games Initiative" to encourage the development of games that address policy and management issues, since then the term "Serious Game" has been widely used. Although we call it "game", serious games are intended to provide an engaging, self-reinforcing context in which to motivate and educate the players towards non-game events or processes, including business operations, training, marketing and advertisement. [1]

Generally speaking, game is composed of three parts - Story, Art and Software. Story is the soul of a game, art can be considered as game's flesh and blood, and software is a game's skeleton. Of course, serious games must have those three parts too, but there is a significant difference between serious games and those games for entertainment - serious games involve pedagogy. Pedagogy means those activities that educate or instruct, thereby imparting knowledge or skill. This difference is indicated by the figure below. [2]

Nowadays games are widely used for "serious" fields such as simulation& training [3] [4], science research [5], health care [6], public policy [7], education [8] [9] and strategic communication [10]. But there is still a long way to go: Firstly, high cost and lack of reusability make it difficult to apply commercial game engines to serious game production. Fortunately there are some solutions to address this problem, such as Delta3D [11], Playmancer [1]. Secondly, pedagogy must be concerned about in serious

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 141–148, 2009.

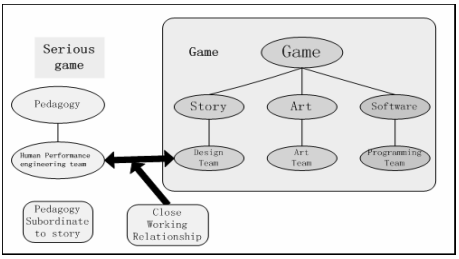


Fig. 1. The relationship between serious game and game

game design, and the designers need a deep understanding in the specific area which the game content refers to. So compare with commercial companies, professional organizations like universities or other research institutions may play a better key role of serious game maker. Another problem is, we cannot just take pedagogy as an individual part of game simply, and it must be smoothly integrated with the other three parts of game. As we know, evaluation is one of the most important parts in teaching and learning activities. So, we think it's necessary to find out an effective way to implement evaluation system in serious game, and this can be helpful for the integration between pedagogy and software part.

2 Function Requirements of Evaluation System

Although the concept of "serious game" have been proposed for 6 years, there is still no mature theory on how to build serious game effectively. In Zyda's point of view, game research agenda has 3 components: infrastructure, cognitive game design, and immersion. In the cognitive game design aspect, he mentioned that one benefit of taking a cognitive approach is giving the developers the tools to create theories and methods for "integrating pedagogy with story in the interactive game medium" [2], and a lot of works have been done about the integration between pedagogy and game content. In our opinion, as software is another important part of game, and an excellent game script can never be implemented perfectly without appropriate software, so it's also necessary to find out effective methods to integrate pedagogy and software. Compare with the games for entertainment, serious games have some unique function requirements in software, such as large-scale terrain, SCORM support. A serious game also needs a more powerful and appropriate evaluation system, because the essence of serious game can be considered as a form of teaching and learning activities, and one of the most important aspects in teaching and learning is evaluation: teachers use kinds of evaluation methods to get the effectiveness of teaching and learning activities; Students can know better about their learning effects according to the evaluation results. Therefore, evaluation system cannot just be considered as a subordinate part, it is as important as rendering module in serious game.

In fact, every genre of game has its own evaluation system or evaluation criteria at least. For example, many games for entertainment have hit point mechanism - The less hit point you lose while playing game, the better you play. And if your character's hit

point reduces to zero, you lose the game. The hit point mechanism can be considered as a kind of evaluation criteria, it indicates player's level of game skill. In simulation & training games, the record function is often required. Player's actions and decisions are recorded, and then can be showed to either player to compare his/her mistakes or experts to assess, like JDoc [3]. In some military background serious games, real time record and playback are needed as well. Generally speaking, function requirements of evaluation system are:

a) **Record & Playback.** One basic function of evaluation is: Judge Participant's actions and behavior based on certain criteria. Appropriate and effective evaluation results can be generated only if we record the participants' actions and behavior in detail.
b) **Data Processing.** The record function logs participant's each action and decision, but that is far from enough. If we want to get full information contained in saved data, further data processing such as data mining is essential. This can make the evaluation results more detailed and meaningful.
c) **Feedback.** Feedback can be given automatically or manually. From feedback participants can learn how much knowledge they possess in game related subject, find out the mistakes they make while playing game. Furthermore, if feedback function can be modified easily, it will be a powerful tool for educational psychology and cognitive science.
d) **Database interface.** Evaluation system also can be used for behavioral analysis and evaluating the effectiveness of serious game in helping participant with certain subject. So we need database interface to store the data of every playing process. Thus we can do mass data mining to get more information. Cognitive and psychology research needs these mass data as well.
e) **Script language support.** Script languages are widely used in game production and testing. Obviously they can be used in building evaluation system as well. With the help of script languages we can modify evaluation criteria and feedback forms much easier.

3 Evaluation Component Design

3.1 Introduction of Game Engine

A game engine is a software system designed for the creation and development of computer and video games [12]. In other words, game engine is in charge of the whole software part of a game, and a good game design can never be implemented without an appropriate engine. Generally speaking, a game engine has these basic modules: rendering, physics, collision detection, input, audio, AI, network, database interface and GUI. But a serious game engine needs more, as shown in figure2.

Our game engine uses component-based architecture to make it easy to be modified and extended. So the evaluation system in our game engine is designed and implemented as a component, say, evaluation component.

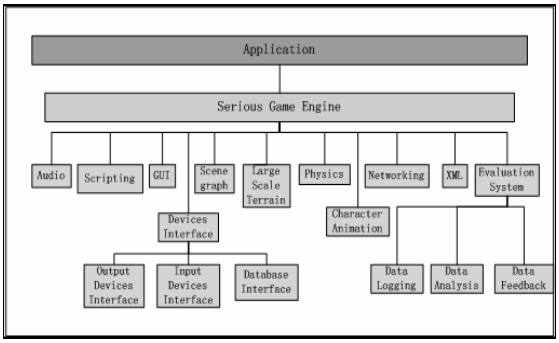


Fig. 2. The modules of serious game engine

3.2 The Relationship between Evaluation Component and Other Parts of Serious Game Engine

As Mentioned earlier, evaluation system must be able to record participant's actions while playing game, in other words, the evaluation component needs to record the events passed by input devices. And to achieve the feedback function, evaluation component also needs to communicate with those output related parts like GUI, audio, virtual scenes. We use input abstraction layer and output abstraction layer to unify the events evaluation component receives and sends. This can improve the component's extendibility and reusability. The evaluation component also has database interface. The relationship between evaluation component and other parts of serious game is shown in figure 3.

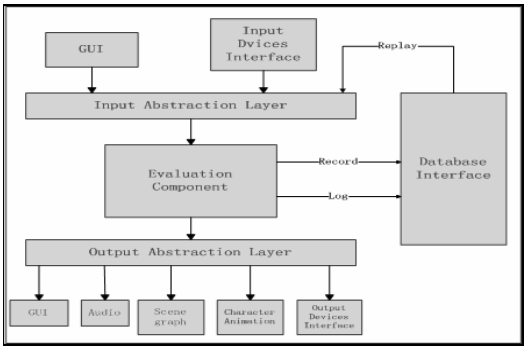


Fig. 3. The relationship between evaluation component and other parts. "Record" and "Replay" are used to record and play back player's actions, and "Log" is used to store evaluation results. These results can be used for further data analysis.

3.3 The Internal Structure of Evaluation Component

Serious games can be of any genre, and we often have to use one engine to build more than one genre of serious games. This is a significant difference between normal game design and serious game design. Innovating new game genres and play styles is also

Table 1. The differences among game genres in terms of evaluation

Genre	Key Data	How to Evaluate	Feedback Form
Simulation Training	User's actions and the cost time of each step	Based on standard steps.	score, rating, mission completion, etc
Education	Answer or solution to the questions(choices, texts, voices, etc)	Based on certain subjects	Score, completion of tasks , etc
Public Policy	User's solution to the tasks(texts, choices, etc)	Laws of society, politics or finance	Development of virtual society.
Strategic Communi-cation	Every step of user's strate-gic decision (text, voice, etc)	Algorithms in computer-aided decision making	Texts, sounds, etc
Science Research	User's operations, parametric variation in virtual environment	Subject related theories	Texts, voices, development of virtual environment
Health Care	User's operations, Medical science related parameters	Medical science related theories or skills	texts, sounds, diagrams, etc

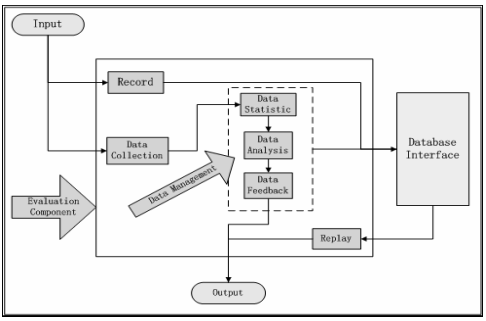


Fig. 4. Structure of evaluation system

one of our goals in serious game research [2]. Table 1 shows the differences among different game genres in terms of evaluation.

In order to meet the requirements of any genre, we divide the evaluation component into 6 parts: record, data collection, data statistic, data analysis, feedback and replay, The 6 parts are loose coupling so each can be separately modified or even replaced to satisfy specific requirements (As shown in figure 4). In our design, Record module is responsible for catching participant's actions or decisions, and stores these data into database or file system. These stored data then can be used for playback, which is implemented by replay module. Data collection is also used to catch input events, but not like record module, it is only interested in those key data which are needed in the coming data processing. The reason that why we have both record module and data collection module is that unlike the record & playback function, data processing does not need to know everything while playing game. Take examination as example, the

clothes each student wears can be seen according the monitor's record, but teachers doesn't need to care about it. (Maybe some certain research institutions are interested in this.) So we use data collection as a data filter.

In order to construct a perfect evaluation system, there are three keypoints:

a) **Data statistic**: This is the first step of data processing. In this step, we do some basic data processing like frequency statistics, the cost time of one specific operation, or the last time of one status. This kind of data processing is common in games for entertainment.
b) **Data analysis**: In games for entertainment, a rough evaluation result may be enough. But in serious games, especially those refer to strategic communication, science research and health care, only a rough result is far from enough. So we use data analysis module to do further data mining.
c) **Feedback**: The results of evaluation should be displayed appropriately. Feedback module is in charge of this. In this module we can modify the results generation mechanisms. For example, we can modify evaluation criteria which are stored in feedback module to adjust player's scores.

3.4 Our Implementation

Our demo is a violin-assemble simulation, it has 6 modules: evaluation component, input component, message manager, scene manager, GUI component and sound component. Figure 5 shows the demo's structure.

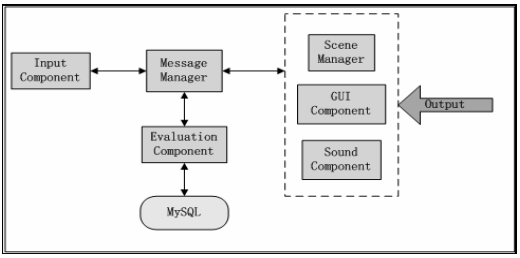


Fig. 5. Structure of violin-assemble simulation

At the game design phase, the evaluation mechanisms should be worked out, and then custom message types are defined since our game is message-driven. For example, if we want to catch the cost time of each assembly step, we can define a message type called "ASSEMBLE_EVENTS". This message type stores the information such as message's sender and receiver, descriptions of specific event and when the event happens. While playing game, data collection module receives messages of certain types (these types are decided according to the evaluation mechanisms), then sends their contained data to data processing module. In our demonstration, we designed our evaluation mechanisms based on 2 aspects, cost time and the completeness of assembly.

Figure 6 shows our demo's interfaces. We also can see an overall evaluation after a number of assemblies and a review the evaluation results of one certain assembly. As shown in figure 7.

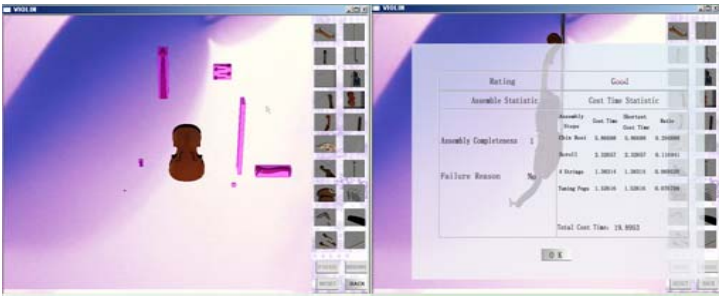


Fig. 6. Interfaces of violin assembly simulation and the evaluation diagram of one time of assembly

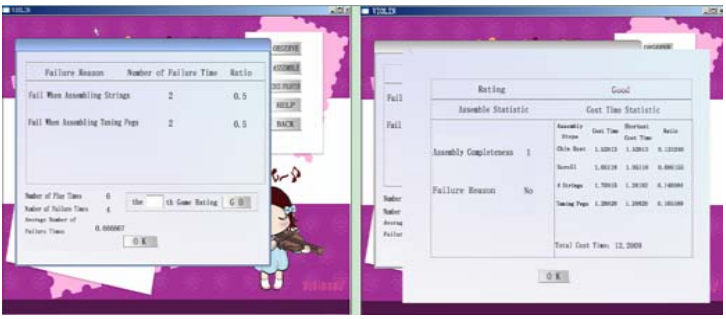


Fig. 7. Diagram of overall evaluation and the review of evaluation results of one certain assembly

4 Conclusion

The requirements of evaluation system in serious game are discussed in this paper, and then an evaluation component design is implemented. Finally a demonstration is presented. Our future works mainly focus on building an editor to simplify the modification of evaluation system. Also we will try to add an in-memory database to the engine, that can make evaluation data access easier. Adding some implementation of classical algorithms to evaluation system is also one of our future goals.

References

1. Conconi, A., Ganchev, T., Kocsis, O., Papadopoulos, G., Fernández-Aranda, F., Jiménez-Murcia, S.: PlayMancer: A Serious Gaming 3D Environment. In: International Conference on Automated solutions for Cross Media Content and Multi-channel Distribution, AXMEDIS 2008, pp. 111–117 (2008)
2. Zyda, M.: From Visual Simulation to Virtual Reality to games. Computer 38(9), 25–32 (2005)
3. Sliney, A., Murphy, D.: JDoc: A Serious Game for Medical Learning. In: 2008 First International Conference on Advances in Computer Human Interaction, pp. 131–136 (2008)

4. Mol, A.C.A., Aghina, M.A.C., Jorge, C., Couto, P.M.: Virtual Simulations of Nuclear Plants for Dose Assessment with On-line Measurements Collected by Networked Radiation Monitors. In: 11th IEEE International Conference on Computational Science and Engineering Workshops, CSEWORKSHOPS 2008, pp. 367–372 (2008)
5. Backlund, P., Engstrom, H., Johannesson, M., Lebram, M., Sjoden, B.: Designing for self-efficacy in a game based simulator: An experimental study and its implications for serious games design. In: 2008 International Conference on Visualization, pp. 106–113 (2008)
6. Sun, H., De Florio, V., Gui, N., Blondia, C.: Towards Building Virtual Community for Ambient Assisted Living. In: 16th Euromicro Conference on Parallel, Distributed and Network-Based Processing, PDP 2008, pp. 556–561 (2008)
7. Schreiner, K.: Digital Games Target Social Change. IEEE Computer Graphics and Applications 28(1), 12–17 (2008)
8. Chiann-Ru, S.: Design and Usability of Web-Based Serious Game for Taiwanese EFL Undergraduate Students. In: Networking, International Conference on Systems and International Conference on Mobile Communications and Learning Technologies, ICN/ICONS/MCL 2006. International Conference, pp. 220–220 (2006)
9. Carr, D., Bossomaier, T., Lodge, K.: Designing a Computer Game to Teach Einstein's Theory of Relativity. In: Computer Graphics, Imaging and Visualisation, CGIV 2007, pp. 109–114 (2007)
10. Rousseaux, F., Lhoste, K.: Towards a Collection-Based Knowledge Representation: Application to Geo-political Risks and Crisis Management. In: 2008 Second International Conference on Digital Society, pp. 81–87 (2008)
11. Darken, R., McDowell, P., Johnson, E.: Projects in VR: the Delta3D open source game engine. IEEE Computer Graphics and Applications 25(3), 10–12 (2005)
12. Wikipedia, `http://en.wikipedia.org`
13. Wilczyhski, L., Marasek, K.: System for Creating Games in Augmented Environments. In: International Conference on Multi-media and Ubiquitous Engineering, MUE 2007, pp. 926–931 (2007)
14. Jacobson, J., Lewis, M.: Game engine virtual reality with CaveUT. Computer 38(4), 79–82 (2005)
15. Mol, A.C.A., Jorge, C.A.F., Couto, P.M.: Using a Game Engine for VR Simulations in Evacuation Planning. IEEE Computer Graphics and Applications 28(3), 6–12 (2008)

Do Improve Typing Skill But No Significant Difference between Drill-Based and Game-Based Typing Software

Chun-Hung Lin[1] and Eric Zhi-Feng Liu[2]

[1] Graduate Institute of Information and Learning Technology
National University of Tainan
No. 33, Sec. 2, Shu-Lin St., Tainan
Taiwan
[2] Graduate Institute of Learning and Instruction
National Central University
No. 300, Jhongda Rd., Jhongli City, Taoyuan County 32001
Taiwan
sjohn1202@gmail.com, totem@cc.ncu.edu.tw

Extended Summary. Improving typing skill can help students use computers to deal with different kinds of tasks more efficiently. In the past, typing software was commonly used to train students' typing skill, and they usually didn't have much attractive multimedia effect. In recent years, games have become more and more popular, and one of the reasons is that games have lots of attractive elements, like lots of multimedia effect and interesting scripts. About the educational effect of typing games, game is more interesting than traditional instruction, and that's the reason why people use typing games to train their typing skill. This study tried to realize the effect on typing skill of drill-based and game-based typing software, and proposed possible design direction for typing software.

There were 160 second year junior high school students participating in this study. The students studied in a junior high school in middle Taiwan, and they came from five different classes. After excluding six invalid samples, 82 students were males (53.2%) and 72 students were females (46.8%). Pretest-posttest control group design was used in this study. The independent variable was different types of typing software. There were 92 students in the control group, and they used drill-based typing software to learn typing. There were 62 students in the experimental group, and they used game-based typing software to learn typing. The dependent variable was typing speed. The difference of typing speed between pre-test and post-test and the effect on typing speed of different software would be compared.

The result showed that both kinds of typing software could improve students' typing speed, but the effect on typing speed between the two kinds of software didn't reach significant difference. The result indicated that both entertainment and learning design direction were beneficial for learning typing skill, but different kinds of design also showed different disadvantages and limitations. Therefore, it is better to consider the two aspects at the same time when design edutainment software, and try to keep the balance between the two elements to produce the optimal learning effect. The future studies may confirm if the learning effect from both learning element and entertainment element is better than the learning effect only from learning element or entertainment element.

Keywords: Computer-assisted instruction, Typing speed, Drill-based typing software, Game-based typing software.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 149, 2009.

Little Big Difference: Gender Aspects and Gender-Based Adaptation in Educational Games

Christina M. Steiner, Michael D. Kickmeier-Rust, and Dietrich Albert

University of Graz, Department of Psychology, Cognitive Science Section
Universitätsplatz 2, 8010 Graz, Austria
{chr.steiner,michael.kickmeier,dietrich.albert}@uni-graz.at

Abstract. Computer games are tremendously successful and this is why the potential of using this medium for educational purposes is increasingly recognized and researched. However, as new learning technologies need to be appropriate for all students and ensure equal learning opportunities, it is important to take into account evidences on gender differences in the context of computer games. This paper reviews relevant research results on gender aspects. Aiming for the realization of gender-based adaptation in digital educational games, a model incorporating research evidences on gender aspects is elaborated and implications for adaptation are derived. Adaptation principles and game design are illustrated by means of the 80Days project.

Keywords: game-based learning, educational game, adaptation, gender difference, game design.

1 Introduction

The young generation is familiar with information technology from earliest childhood on. Today's children grow up being surrounded by and using the whole range of toys and tools of the digital age – computers, video games, internet, music players, cell phones, etc. and consequently, these children are – in the words of Marc Prensky – no longer digital immigrants but rather digital natives [1]. This development necessarily also has consequences for education. As Prensky points out, students of today are no longer the kind of students our educational system was designed for. As a result, the use of computer technology for learning must not and has not stopped short of education.

The fact that young learners of today spend a considerable portion of their lifetime watching TV and playing computer games – by far more than for reading, needs to be reflected by taking advantage and utilizing these very technologies for educational purposes. Computer games, with their dynamic and active nature, their rich and appealing possibilities are an incredibly successful technology, whose potential of being used for learning has been increasingly addressed since the 1990s. The central idea of game-based learning is to utilize at least part of the time people spend on playing computer games for educational intentions [2].

A critical aspect that needs to be considered in this context is whether there are differences in learners concerning their attitude and acceptance towards game-based learning, especially with respect to eventual gender differences. As computer games

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 150–161, 2009.

in general are dominated by males, the question arises whether this fact is immediately transferable to digital educational games. There are, at least, several evidences on gender differences in computer games that are important to be known and understood when aiming in advancing them as a novel approach to learning that is likewise suitable for both groups of learners [3].

This paper elaborates gender aspects in the context of computer games towards a gender-sensitive approach of designing games for educational purposes. This paper is organized as follows: We first give an overview on the state of the art on gender differences relevant and apparent in the scope of computer games. Based on this, the implications on computer game design in general are discussed. As an attempt for creating gender fair educational games, the issue of adaptation to gender-based differences is taken up and an integrated framework for gender-based adaptation in computer games is elaborated. Finally, a case study of an educational game on geography is presented, translating the adaptation model and illustrating an example of an approach to educational games and to learning game design that successfully works for both sexes.

2 Computer Games and Gender Differences

General Attitude and Usage Patterns. Aside from differences that have been proven for computer usage in general, such as that males are more confident and skilled in handling computers [4], there is also particular evidence that males are specifically more engaged leisure game players than females [5]. Despite the popularity of computer games is rising in general, the majority of the medium's audience is still male [6]. As a consequence of that generally greater popularity of computer games amongst males, more males play and they play for longer periods [7, 8].

Personality Factors. Reasons accounting for a gender gap in playing computer games that have been identified and that can be related to personality factors include violence, lack of social interaction, and strong competitive elements in games [9].

Need for achievement refers to humans' desire for accomplishment and competence acquisition [10]. Males seem to have in general a higher need for achievement in playing computer games. Basically, need for achievement can be equated with challenge, which has also proven to be more important for males [3]. Research evidence led to the assumption of a stronger *competition orientation* in males than in females and of females (although able to perform similarly) being less effective in competitive situations [11]. Competitiveness as a trait can be explained by three components – the motivation to win/compete, the need to win, and self-efficacy. In a study on gender and computer games these factors turned out to be significantly higher for males than for females, confirming females' inferior competition orientation in computer games [9].

Sensation seeking refers to the tendency to search for varied, novel, complex, and intense sensations and experiences and to take risks for the sake of such sensations [12]. Findings in gambling and sports have shown that males feature a more distinctive need for sensation seeking than females do [13]. Sensation seeking is directly related to arousal – high sensation seekers have a high optimum level of arousal. Unsurprisingly, arousal, which has been identified as one of the most important reasons for playing games, has also proven to be more important for males than for females [14].

It has been shown that females in general have a low preference for observing or taking part in violent conflicts and resolutions, show in their media genre preferences in general less interest than males in violent entertainment and prefer non-violent entertainment [15]. As most computer games involve to a large extent and increasingly realistic *violence* and violent actions, it is not surprising that this is an important factor of females' dislike of games [9]. On the other hand, it has been argued that violent games provide male adolescents with the opportunity of intensive emotional arousal and thus explaining the appeal of those games to this audience [16].

In their *interaction styles*, females characteristically show pro social patterns. Media research yielded that they value programs with a great extent of meaningful dialogues and interaction. Most often, single-player games provide few possibilities for social interaction and are rather action-oriented. This lack of social interaction is an important reason for females disliking games [9]. Females clearly express a preference for games that involve communication and human relationships [17].

Game Types. Males and females also characteristically differ in the type of games they prefer to play. This is due to differing interests and preferences, which are argued to be grounded already in infancy and socialization, but probably also because computer games are mostly designed by males, therefore, including essentially masculine characteristics, a high level of violence, and strong gender stereotypes [3]. While males have been found to prefer strategy, action, adventure, sports, and simulation games, particularly with violent content [16, 18], females prefer puzzles, board games, quizzes, role-playing, and adventure, as well as educational games [5, 7, 14]. The main theme of computer games preferred by boys is contest between good and evil, competition, and winning, whereas girls favor storylines and exploration of game characters' personalities [17]. [18] underline, though, that in sum the types of games that appear especially usable for learning – like strategy, adventure, and role-playing games – are appealing for both, males and females.

Also game speed and time pressure must be considered. Action games (preferred by male players) require dexterity and fast reaction, and usually a faster game play than role-playing games (preferred by female players). There is also some evidence that young girls prefer colorful, slowly changing screens in a multimedia learning interface [19]. To sum up, females seem to prefer rather an unhurried game play, whereas males opt for action and speed to get encouraged.

Reasons to Play. The reason or motivation to play computer games has also been identified to differ between genders [9]. Existing games are referred to by females as lacking meaningful social interaction and discouraging because of violence and stereotyped gender roles of female game characters. Female players prefer the (para)-social appeal of games, collaboration and community aspects to competitive elements [20]. In the context of massively multiplayer online role playing games it has been found that there are gender differences on the relevant motivational factors for playing – whereas male players feature higher scores on the factors 'achievement' and 'manipulation', females indicate higher scores on 'relationship', 'immersion', and 'escapism' [21].

Skills. It could be shown that males have in general better computer skills and literacy [4]. Research results on online skills have shown that although there are no great

gender differences in online abilities, females self-assess their skills significantly lower than males – which in turn may affect their online and usage behavior [22].

Computer games commonly require cognitive and perceptual skills on which males tend to perform better than females, such as spatial awareness and visualization [23]. It has also been pointed out that the gender-specific differences in cognitive abilities fit well with the general gender-dependent preferences for different game-genres [24]. Interestingly, recent research results, however, have shown that the gender differences on certain aspects of spatial cognition can be reduced through playing an action computer game for a few hours [25]. Current learning games often involve and require an integration of different skills to accomplish combinations of activities, and are thus in general less likely to privilege one gender [3].

Game Characters and Avatar Preferences. It has been shown that female characters are "underrepresented and proportionally more often sexualized to their male counterparts" ([6], p. 103). Analyses of best-selling computer games have shown that only a small percentage of game characters are female, and a large part of them holds roles of rather bystanders than active participants [17]. Traditionally, stereotypes and archaic role models are applied to portray female game characters – they are weak victims that need to be protected or rescued by powerful males and their visual design exaggerates female sexuality [26]. This under- and misrepresentation of game characters is one reason for the inferior attraction of computer games to females – although at least a portion of women feel also ready to accept such role stereotyping [9]. In general, females express strong preferences for female game characters over male ones [27].

Gender differences have been researched on avatars, that is, the representations of gamers in virtual or gaming environments. Most male gamers prefer male avatars, while females prefer female avatars [28], which has also been demonstrated with static avatars outside a game context [29]. Furthermore, it could be shown that males want to have avatars that are powerful fighters, whereas females want to see good fashioned and beautiful characters [28]. In general, players should have the chance to select or create their favorite avatar [28, 29]. If female players have no possibility to choose a female avatar they might feel discontent and, as a result, might feel as like the game was not made for them and refuse to play the game [26].

3 Implications on Game Design

In conclusion, the large body of research on gender differences in the context of computer games calls for an according consideration and reflection in game design and development and for gender-neutral games. There is an emerging discussion and awareness on implications for (educational) practice [17] and female-targeted game design [26, 30]. This led to the evolution of games especially for a female target audience. In the beginning of this development, games were launched that had been designed relying on stereotypical interests of girls, such as fashion, horoscopes, romance – resulting in so-called 'pink software' like the 'Barbie Fashion Designer'. This attempt to create special games for girls, however, did not always succeed [31]. Voices against marketing according to and reinforcing old stereotypes and opting for the opportunity of using game technology instead to go a step further appeared [30]. 'Tomb

Raider' managed to overcome the traditional 'princess to be saved' portrayal of a female character, with a capable and independent woman as main character. A real success story was born with 'The Sims', a game that focuses on social interaction between players and game characters and succeeded in attracting many female players.

Especially in the context of designing educational games a gender-sensitive approach is strongly needed, as the new learning technologies need to be appropriate for and accepted by all students and to ensure equal (learning) opportunities. Thus, in addition to a gender inclusive game design, the approach of adapting the game to gender-based differences appears highly suitable.

4 Gender-Based Adaptation

Instead of designing games that address predominantly one specific group of gamers separately, to date hardly any effort has been made to create games that are equally suited for different preferences and characteristics through the provision of personalized game experiences. By arranging for a variety of differing game features, components, and characteristics that are chosen in accordance to the individual player, one single game could fit different learners.

Although the adaptation to current knowledge and competence is thoroughly being researched and implemented through macro and micro level adaptive approaches in e-learning and also in educational games [32, 33], current computer games – similar to the majority of existing e-learning systems – do not account for gender differences through an according adaptation of the game, game features, story etc. Such an adaptation to gender-based differences appears especially important and relevant for educational games because of several reasons. When designing and developing an educational game it should be appealing to all students. Even more important, as an educational game aims in realizing a learning experience that is appropriately embedded in narrative and game play, it is necessary to create optimal conditions for this. This should involve, aside from an adaptation to the learner's knowledge and competence, also a gender-based adaptation, which should in consequence lead to beneficial effects on motivation and learning performance.

4.1 An Integrated Model of Gender Aspects in Educational Computer Games

In an approach to elaborate a framework for the adaptation of an e-learning system to individual abilities, preferences, and gender differences, the utilization of principles and structures based on *Knowledge Space Theory* has been proposed [34]. Using the framework of *Competence-based Knowledge Space Theor*y [32, 35, 36], these individual characteristics and gender specificities can be modeled and structured. It is assumed that – following the notion of prerequisites – a prerequisite relation between those factors can be established that captures the know-how derived from a large body of research and empirical studies on the involved individual factors. This means, that from the degree of one characteristic the degree of another one can be inferred. [34] identified a model incorporating individual factors influencing learners' choice of using a computer for educational purposes [37] and related it to proven gender differences in order to establish a learner structure modeling gender differences in relation

to those individual factors as a possible basis for adaptation of an e-learning system. Through this approach the number of possible learner states (combinations of individual factors) can be reduced to a meaningful range by establishing structural assumptions based on the existing empirical research evidence in the domain.

Building upon this work and upon the thorough analysis on empirical evidence of gender differences as presented in section 2, the different factors and aspects of individuals and computer games have been analyzed and related to each other. The resulting model is depicted in Figure 1. Based on the overview on gender aspects presented before, it captures the central aspects of computer games on which gender differences have been ascertained, as well as underlying latent constructs of cognition and personality. These underlying constructs, in turn, feature characteristic gender differences and at least partly explain and account for the gender gap in the different game aspects. The model can be understood as a *Bayesian Net* model with the nodes representing probability variables[1] and the arrows representing conditional dependencies representing relationships and influences among the variables [34, 37]. The diverging preferences of males and females for certain game types, for example, can be explained by considering gender differences in competition orientation, sensation seeking, and interaction preferences. The same factors can be assumed to influence also the reason or motivation to play, which in turn will be influencing the preferences on game types and, supposingly, also usage patterns. The frequency and duration of playing computer games furthermore might be influenced and might influence computer and spatial skills.

This framework can be further enriched based on the model established and capturing gender-based differences and individual factors for user modeling and adaptation in educational hypermedia [34, 37]. To this end, factors captured by those models that appear relevant in the context of educational games are taken up (see Figure 1), thus bringing in an additional factor 'visual design' in the model. Research evidence in the field of visual design of web-based learning and web pages has shown that females seem to prefer clearer, undistracting background design and are more attracted by colors, while males tend to prefer a more complex design and are attracted by graphics, animations, and interactive aspects [38, 39]. One possible explanation for such findings are gender differences in processing visual displays [23, 38]. The component 'causal attributions' relates to the causal explanations for success or failure, for which systematic gender differences have been identified. While males tend significantly more likely to explain success as due to their ability, females tend to attribute the cause of failure more likely to themselves than males [40, 41]. These attribution biases are directly related to the self-efficacy beliefs of individuals, which have been proven to be higher for males in the context of computer games and working with computers [9, 41]. Dysfunctional attributional styles in females appear also in other domains [42] and are associated with maladaptive behavior which may eventually lead to giving up earlier and to avoidance [42, 43]. Furthermore, the variables 'expectation' and 'value' adapted from [37] may serve for explaining usage patterns on computer games. While in accordance with the model 'computer literacy', and in the present context, also 'reasons to play' can be assumed to influence the perceived value of playing computer games, the expectations of successfully playing a computer

[1] Variables representing the 'inner state' of an individual regarding different characteristics.

game will be influenced by self-efficacy beliefs. Both, expectations and value of playing computer games will consequently be determining factors of actually choosing to play an educational computer game [41].

In sum, the established model provides useful information about a player for the purpose of adaptation by making (preliminary) assumptions on user characteristics (i.e., the user model) based on well-established research findings without explicit assessment. Hereby, broad overgeneralizations are avoided; rather the model serves the assumption of reasonable tendencies on user variables. This is especially valuable as in the context of a game there is only limited possibility for explicitly querying lots of things.

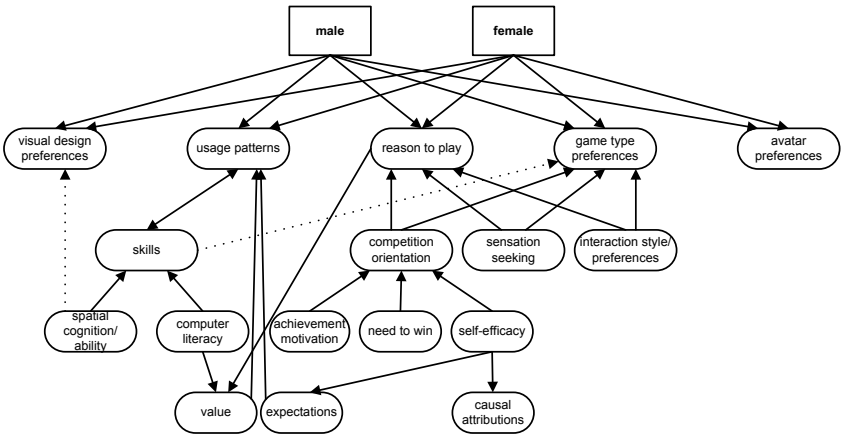


Fig. 1. Model on gender aspects relevant for educational computer games

4.2 Educational Game Design for Gender-Based Adaptation: A Case Study

In the following, implications for gender-based adaptation that can be derived from the model and an according design shall be illustrated by means of a case study game design - the demonstrator game of *80Days* (www.eightydays.eu). 80Days is a European research project aiming in advancing psycho-pedagogical and technological foundations for successful digital educational games through the development of a higher-level theoretical framework for adaptive educational technology. This shall allow an adaptation of a game's story and features to individual learners' abilities and preferences. An educational game is being developed, aiming in a new learning technology that is equally suitable for both, male and female learners. For this, a game genre that has been proven to be suitable and accepted by both groups of learners has been chosen and adaptation principles relying on the presented model on gender aspects have nurtured game design.

Inspired by Jule Verne's novel 'Around the world in eighty days' the game is a modern version of a journey around the world – in a UFO with an alien travel companion. From an educational perspective, the game's main objective is to teach geography skills. From a storytelling perspective, the main task for the player is to explore the planet and collect information for an intergalactic travel guide. From the game

play perspective, the main goal is to navigate the UFO to different destinations around the world and to accomplish a variety of adventurous missions.

In the beginning of the game user characteristics are queried (sex, age, computer game experience and preferences, sensation seeking) which coincide to a large extent with variables covered by our model. The preliminary assumptions on user characteristics (as based on the model) can be verified and adjusted based on the information gathered in the game's intro screen and are later on continuously updated and refined based on the gamer's behavior and interactions during and with the game. The evolving user model serves for adapting the game to the individual player. The game as such foresees a comprehensive adaptation of story elements and learning content to a learner's current skills and needs, as well as to preferences and motivational states. In the following, we want to confine our descriptions to only the implications for gender-based adaptation, as they can be drawn from the model presented in this paper (see Figure 3 for an overview). These adaptation mechanisms build upon the supposed dependencies and influences among the variables as derived from the literature and mirrored by the model.

The **visual design** of the educational game can be adapted in order to meet individual *preferences* and needs. Females should be provided with a clearer, somewhat simpler visual design, while males should be provided with more complex, animated visual design elements [38, 39]. This would also accommodate an adaptation to *spatial ability* [23], as well as to the level of experience with games (*computer literacy*, [4]). In the 80Days game design this aspect of adaptation is implemented in the visual design of the UFO cockpit and head-up-display (HUD), with information displays that can be activated and deactivated (see Figure 2).

Fig. 2. Sketches of different HUD versions in the 80Days game

Adaptation to *competition orientation* [9, 11] should occur through realizing differing **levels of competition** in the game in terms of combatants represented by other players or non-player characters. In case of the 80Days game this aspect can be realized through adapting the number of competing UFOs.

Adaptation to *attribution bias* and *self-efficacy* [9, 40, 41, 43] should be realized by a motivational/attributional training through **feedback** mechanisms that guide learner's perception on causal attribution of success and failure with the aim of increasing motivation and self-worth [42]. In case of high self-efficacy, an individual can be guided towards (more) realistic attributions. And in case of low self-efficacy a training of more realistic and self-confident feedback should be realized, such that successful experiences become more explicit and engaging and help fostering

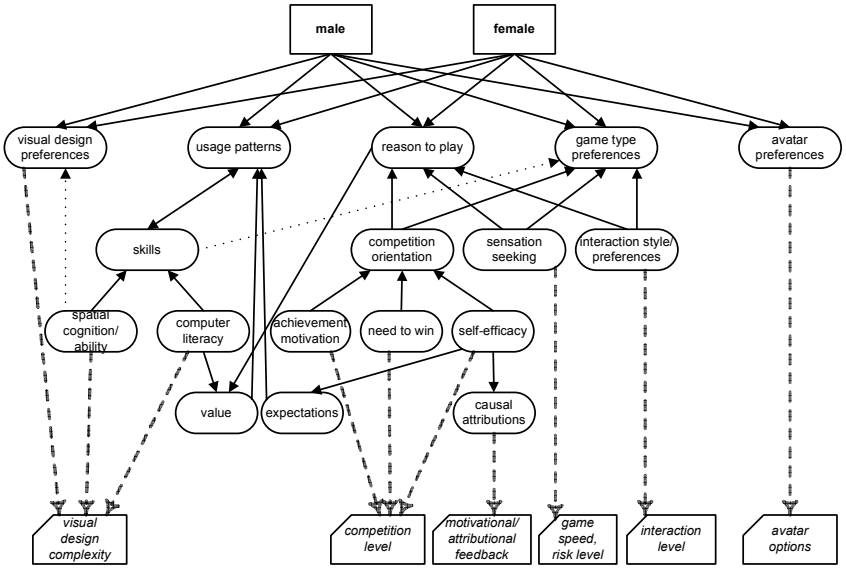


Fig. 3. Model on gender aspects and design implications (dashed arrows) for gender-based adaptation in educational computer games

expectation of success. In 80Days this aspect of adaptation is captured by adaptive motivational interventions during the game given by a non-player character.

Adaptation to *sensation seeking* [13, 14] can be realized through differing levels of **game speed** in a game and differing levels of **risk or adventure**. This most probably needs to be accompanied by an according adaptation of the game story, aligning the level of time pressure and risk and adventure to be taken to each other. The 80Days game realizes a three-mode story pacing with different speed levels – one relaxed version without time pressure, one more driven version with time pressure, and one fast and hectic version with explicit time limits.

Adaptation to *interaction preferences* [9, 17] can be done through realizing differing degrees and options for **interaction** in the game. This can be taken up in 80Days by realizing different extents of dialogues and interaction possibilities between the player and non-player characters, or respectively, other players.

Adaptation to *avatar preferences* [28, 29] can be done through automatic provision of avatars corresponding to known preferences of genders in this regard. Alternatively, a set of different avatars can be provided to the player to choose from it (as an aspect of adaptability through the player). In the 80Days game this aspect is planned to be taken into account by the adaptive selection between two avatars, a boy and a girl.

5 Conclusion

Gender differences relevant in the context of (educational) computer games have been observed with respect to several aspects. Many of them add up or contribute to the fact that the game sector is dominated by males and girls and women are less involved

in games than boys. Recently, however, there seems to be at least a trend of increased involvement of females. Aside from the emergence of female subcultures feeling prepared and willing to adopt contemporary computer games designed for males [9], this development reflects the increasing consciousness on gender specificities and gender sensitivity in the game sector, thus leading to the advent of games appealing and engaging female players.

With the adaptation of computer games to gender-specific characteristics and preferences on a within-game level, this development can be further enhanced. This aspect of adaptation seems especially suited and necessary in the context of educational games, where one learning technology should supply all students with equal opportunities and chances for learning. Through gender-specific adaptation of computer games the implicit classification in typically male or female oriented computer games could be overcome and progress towards the development of games that appeal both, male and female players, could be made. In this paper we presented a framework for gender-based adaptation, integrating research on gender aspects that are relevant for (educational) computer games.

The involvement of male and female members of the target audience in both, the design and evaluation process of a digital educational game (i.e. participatory design, [44]) allows the identification of significant gender-related preferences for a given purpose (target age, subject matter etc.). This ensures acceptability of design and the implementation of relevant adaptation aspects, thus contributing to learners' engagement and successful learning throughout the game.

The realization of gender-based adaptation is not only assumed to have enhancing effects on students' motivation and learning performance, but also opens ways to (cost) effective game development. Gender-based adaptation can be regarded as a step further when aiming in methodologies for more cost-effective development of (educational) computer games – through the realization of one game appropriate for both genders instead of different games for males and females, by efficiently (re)using game assets and resources.

Acknowledgments. The research and development introduced in this work is funded by the European Commission under the seventh framework programme in the ICT research priority, contract number 215918 (80Days, www.eightydays.eu).

References

1. Prensky, M.: Digital Natives, Digital Immigrants. On the Horizon 9, 1–2 (2001)
2. Kickmeier-Rust, M.D., Peirce, N., Conlan, O., Schwarz, D., Verpoorten, D., Albert, D.: Immersive Digital Games: The Interfaces for Next-Generation E-Learning? In: Stephanidis, C. (ed.) HCI 2007. LNCS, vol. 4556, pp. 647–656. Springer, Heidelberg (2007)
3. Boyle, E., Conolly, T.: Games for Learning: Does Gender Make a Difference? In: Conolly, T., Stansfield, M. (eds.) Proceedings of the 2nd European Conference on Games Based Learning, pp. 69–75. Academic Publishing Limited, Reading (2008)
4. Bonanno, P., Kommers, P.A.M.: Exploring the Influence of Gender and Gaming Competence on Attitudes towards Instructional Games. British Journal of Educational Technology 39, 97–109 (2008)

5. Gorriz, C.M., Medina, M.: Engaging Girls with Computers through Software Games. Communications of the ACM 43, 42–49 (2002)
6. Ivory, J.D.: Still a Man's Game: Gender Representation in Online Reviews of Video Games. Mass Communication & Society 9, 103–114 (2006)
7. Bonanno, P., Kommers, P.A.M.: Gender Differences and Styles in the Use of Digital Games. Educational Psychology 25, 13–41 (2005)
8. Phillips, C.A., Rolls, S., Rouse, A., Griffiths, M.D.: Home Video Game Playing in Schoolchildren: A Study of Incidence and Patterns of Play. Journal of Adolescence 18, 687–691 (1995)
9. Hartmann, T., Klimmt, C.: Gender and Computer Games: Exploring Females' Dislikes. Journal of Computer Mediated Communication 11, 910–931 (2006)
10. McClelland, D.C.: Methods of Measuring Human Motivation. In: Atkinson, J.W. (ed.) The Achieving Society, pp. 41–43. D. Van Nostrand, Princeton (1961)
11. Gneezy, U., Niederle, M., Rustichini, A.: Performance in Competitive Environments: Gender Differences. Quarterly Journal of Economics 118, 1049–1074 (2003)
12. Zuckerman, M.: Sensation Seeking: Beyond the Optimal Level of Arousal. Erlbaum, Hillsdale (1979)
13. Arnett, J.J.: Sensation Seeking, Aggressiveness, and Adolescent Reckless Behavior. Personality and Individual Differences 20, 693–702 (1996)
14. Lucas, K., Sherry, J.L.: Sex Differences in Video Game Play: A Communication-Based Explanation. Communication Research 31, 499–523 (2004)
15. Slater, M.D.: Alienation, Aggression, and Sensation Seeking as Predictor of Adolescent Use of Violent Film, Computer, and Website Content. Journal of Communication 53, 105–121 (2003)
16. Jansz, J.: The Emotional Appeal of Violent Video Games for Adolescent Males. Communication Theory 15, 219–241 (2005)
17. Agosto, D.: Girls and Gaming: A Summary of the Research with Implications for Practice. Teacher Librarian 31, 8–14 (2004)
18. Connolly, T.M., Boyle, E.A., Stansfield, M.H., Hainey, T.: A Survey of Students' Computer Game Playing Habits. International Journal for Advanced Technology for Learning 4 (2007)
19. Passig, D., Levin, H.: Gender Interest Differences with Multimedia Learning Interfaces. Computers in Human Behavior 15, 173–183 (1999)
20. Dickey, M.D.: Girl Gamers: The Controversy of Girl Games and the Relevance of Female-Oriented Game Design for Instructional Design. British Journal of Educational Technology 37, 785–793 (2006)
21. Yee, N.: The Demographics, Motivations, and Derived Experiences of Users of Massively Multi-user Online Graphical Environments. Presence 15, 309–329 (2006)
22. Hargittai, E., Shafer, S.: Differences in Actual and Perceived Online Skills: The Role of Gender. Social Science Quarterly 87, 432–448 (2006)
23. Halpern, D.F.: Sex Differences in Cognitive Abilities. Lawrence Erlbaum Associates, Hillsdale (1992)
24. Sherry, J.L.: Flow and Media Enjoyment. Communication Theory 14, 328–347 (2004)
25. Feng, J., Spence, I., Pratt, J.: Playing an Action Video Game Reduces Gender Differences in Spatial Cognition. Psychological Science 18, 850–855 (2007)
26. Graner Ray, S.: Gender Inclusive Game Design. Charles River Media Inc., Hingham (2004)

27. De Jean, J., Upitis, R., Koch, C., Young, J.: The Story of Phoenix Quest: How Girls Respond to a Prototype Language and Mathematics Computer Game. Gender and Education 11, 207–223 (1999)
28. Inal, Y., Sancar, H., Cagiltay, K.: Children's Avatar Preferences and their Personalities. In: Crawford, C., et al. (eds.) Proceedings of Society for Information Technology and Teacher Education International Conference 2006, pp. 4259–4266. AACE, Chesapeake (2006)
29. Nowak, K.L., Rauh, C.: The Influence of the Avatar on Online Perceptions of Anthropomorphism, Androgyny, Credibility, Homophily, and Attraction. Journal of Computer-Mediated Communication 11 (2005), http://jcmc.indiana.edu/vol11/issue1/
30. Cassell, J.: Genderizing HCI. In: Jacko, J., Sears, A. (eds.) The Handbook of Human-Computer Interaction, pp. 402–411. Lawrence Erlbaum, Mahwah (2002)
31. Laurel, B.: Utopian Entrepreneur. MIT Press, Cambridge (2001)
32. Heller, J., Steiner, C., Hockemeyer, C., Albert, D.: Competence-Based Knowledge Structures for Personalised Learning. International Journal on E-Learning 5, 75–88 (2006)
33. Kickmeier-Rust, M.D., Hockemeyer, C., Albert, D., Augustin, T.: Micro Adaptive, Non-invasive Assessment in Educational Games. In: Eisenberg, M., Kinshuk, C.M., McGreal, R. (eds.) Proceedings of the second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning, Banff, pp. 135–138 (2008)
34. Kickmeier-Rust, M.D., Albert, D., Roth, R.: A Methodological Approach to Address Individual Factors and Gender Differences in Adaptive eLearning. In: Siebenhandl, K., Wagner, M., Zauchner, S. (eds.) Gender in E-Learning and Educational Games: A Reader, pp. 71–84. Studienverlag, Innsbruck (2007)
35. Albert, D., Lukas, J. (eds.): Knowledge Spaces: Theories, Empirical Research, and Applications. Lawrence Erlbaum Associates, Mahwah (1999)
36. Doignon, J.-P., Falmagne, J.-C.: Knowledge Spaces. Springer, Berlin (1999)
37. Melis, E., Ulrich, C.: Gender-Biased Adaptations in Educational Adaptive Hypermedia. In: Neijdl, W., De Bra, P. (eds.) AH 2004. LNCS, vol. 3137, pp. 425–428. Springer, Heidelberg (2004)
38. Hall, R.H., Hickman, L.L.: Imagic and Textual Components of Web Page Design: The Role of Gender in Subjective Ratings. Virtual University Journal, 2 (1999), http://lite.mst.edu/documents/vuj_99_hall_gender.pdf
39. Cyr, D., Bonnani, C.: Gender and Website Design in E-business. International Journal of Electronic Business 3, 565–582 (2005)
40. Deaux, K., Farris, E.: Attributing Causes for One's Own Performance: The Effects of Sex, Norms, and Outcome. Journal of Research in Personality 11, 59–72 (1976)
41. Dickhäuser, O., Stiensmeier-Pelster, J.: Gender Differences in the Choice of Computer Courses: Applying an Expectancy-Value Model. Social Psychology of Education 6, 173–189 (2003)
42. Ziegler, A., Stoeger, H.: Evaluation of an Attributional Retraining (Modelling Technique) to Reduce Gender Differences in Chemistry Instruction. High Ability Studies 15, 63–83 (2004)
43. Dweck, C.S.: Self-Theories: Their Role in Motivation, Personality and Development. Psychology Press, Philadelphia (1999)
44. Danielsson, K., Wiberg, C.: Paricipatory Design of Learning Media: Designing Educational Computer Games with and for Teenagers. Interactive Technology and Smart Education 3, 275–291 (2006)

Game-Like Simulations for Online Adaptive Learning: A Case Study

Javier Torrente, Pablo Moreno-Ger, Baltasar Fernández-Manjón, and Ángel del Blanco

<e-UCM> Research Group - Universidad Complutense de Madrid
C/ Profesor José García Santesmases sn. 28040 Madrid, Spain
{jtorrente,pablom,balta,adelblanco}@fdi.ucm.es

Abstract. Serious games are becoming a powerful tool in education. However, there are still open issues needing further research to generalize the use of videogames and game-like simulations in the educational system. On the one hand, how to take advantage of the videogames' inherent adaptation behaviour in order to maximize the effectiveness of the learning experiences is still a world worth to be explored. On the other, there is still a need to develop mechanisms to track and evaluate the performance of the students when they use these learning tools. Finally, it is necessary to elaborate further game-based learning architectures that facilitate the delivery and distribution of the games to the students. In this paper we propose how to deal with all these issues taking also into account other relevant aspects such as development cost and instructor implication. This is exemplified with the HCT game, produced in cooperation with professors of the Complutense University School of Medicine at Madrid.

Keywords: Game-based learning; game-like simulation; assessment; adaptation; learning management system.

1 Introduction

The videogame industry has already become one of the most relevant entertainment industries, with computer and videogame sales growing almost every year. Along with the growth and evolution of the industry, there is in an ongoing discussion about the educational potential of videogames [1-3]. Among the potential benefits of this approach, two have been identified as especially relevant. On the one hand, game-based learning can be used to enhance students' motivation towards learning [4]. On the other hand, videogames can be developed in the form of game-like simulations, providing highly interactive and safe test environments, very adequate for learning complex topics, and which can be accessed at any time without requiring specialized equipment (other than a computer) [5]. Consequently it seems that this interest in the use of game-based learning, although not new (it virtually dates back to the very first steps of the videogame industry [6]), is beginning to represent a real alternative, both from commercial and academic perspectives [7]. As the *e-Learning Guild* report reveals ([8]), the number of productions of serious games is growing every year, along with the number of organizations adopting this kind of learning for their staff training programs.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 162–173, 2009.

However, there are still some open issues requiring further research and discussion. Educational videogames have their own needs, which do not always converge with the requirements of classic videogame development methodologies [9].

First, videogames are not always easy to distribute and deploy. In educational contexts this can be a real burden for instructors when games have to be distributed to many students, and the results of the game experiences must be collected and processed manually. Besides, game-based learning needs to track the performance of the students to check whether the learning goals are achieved or not [10], a feature that is not very common in commercial videogames.

In addition, educational videogames and game-like simulations need to adapt their behaviour according to the profile of the player (i.e. student) in order to cater for the special needs of each student [11]. Commercial videogames are inherently adaptive, but there are still few initiatives trying to ease the design and integration of adaptive behaviour in educational videogames. Finally there are other issues, such as development cost and the difficulties of involving instructors and content experts in the development process.

In this paper we exemplify through a case study how the <e-Adventure> educational game platform [12] addresses these issues, describing the development of a low-cost, adaptive and assessable game-like simulation in the field of Medicine education. The game covers the procedure to measure Hematocrit levels on a blood sample, and was developed with the participation of professors from the School of Medicine at the Complutense University of Madrid.

The paper is structured as follows: in section 2 we discuss some issues related to adaptation, development and deployment of educational videogames. In section 3, a brief description of the <e-Adventure> platform is given. In section 4 we provide a full description of the case study. In section 5 we present a direct experience with students and some evaluation of the results, and in section 6 we present some conclusions and future lines of work.

2 Games and Education: Challenges and Issues

In this section we discuss two aspects that are tightly related to the work we are presenting. First we introduce adaptive learning and how this can be achieved through videogames. Then, we describe some of the issues that must be addressed when developing educational games and game-like simulations.

2.1 Adaptation in Learning and Videogames

During the last years, there is a steadily growing trend towards adaptive learning, especially focused in online learning systems [13, 14]. The idea is to personalize the content and flow of the learning experience for each student, taking into account their individual context to maximize the effectiveness of the learning experience. This adaptation can consider different aspects, such as user preferences, different levels of prior knowledge, cultural conditions, and even learning styles (e.g. exploratory vs. guided).

In this context educational videogames can be very helpful as games are inherently adaptive. Commercial pressure pushes videogame developers to personalize the game experiences as much as possible, in order to widen the spectrum of potential customers and maximize their engagement when playing the games. Therefore it is very usual to see videogames catering for different gaming styles and skills, offering for instance diverse difficulty settings. In addition, unlike other content videogames are extremely interactive. The interaction between user and videogame can be used to gauge the game behaviour. For instance, it can be detected transparently if the user is stuck trying to solve a puzzle, and then give a clue or lessen the difficulty of the task slightly [15]. In short, adaptation mechanisms in videogames are now much more fine-grained than a simple difficulty level choice.

There are interesting works identifying the characteristics of videogames that are better for implementing adaptive behaviours and how to design adaptive videogames [16]. Nonetheless it is difficult to see authoring tools and learning models supporting the modelling and implementation of adaptive behaviours in videogames [17].

2.2 Videogame Development and Deployment

During the last years, several development tools have appeared trying to ease the production of videogames, including game engines, IDEs (Integrated Development Environment), and user-friendly authoring tools. The range of possibilities is massive, going from very simple open source projects to complex professional tools.

A great example is the *Torque*™ game engine, published by *GarageGames*™ which allows users to produce top-tier computer games for different platforms. Another good example is *Microsoft*™'s *XNA*™ development environment, which is being used in the development of numerous videogames for both PC and *XBOX*™ platforms. Besides, there are lots of authoring tools aiming to encapsulate the most complex aspects of videogame development, facilitating the production of videogames by people with no technical skills. Some good examples are the tools developed by *The Game Creators*, *Unity3D*™ or *GameMaker*™.

In spite of all these initiatives there are still open issues which have not been completely addressed yet, especially for educational gaming. On the one hand videogames are not easy to distribute and deploy in educational settings. On the other hand, these platforms do not cope with the specific needs of the educational gaming field, such as the need of tracking and evaluation of the progress of the student or adaptation to the student special requirements.

These inconveniences can be lessened by integrating the educational videogames and game-like simulations in the widely extended e-Learning environments (the so called Virtual Campus, Learning Management Systems or LMS) [18]. These environments allow instructors (i.e. teachers and professors) to organize courses and lessons for students, and are becoming a common tool not only for distance learning programmes but also as a complement in traditional classes. Besides, modern LMS do not only store content for remote students, as they are complex web applications that allow instructors to track the activity of the students and manage their learning experiences. These systems usually offer facilities to evaluate the students and to store information about their activity. This process is usually performed following standards and specifications that allow the content interoperability between the different

competing platforms [14]. Therefore the content must be developed and packaged in compliance with these standards and specifications to be deployed in a LMS. These standardized content packages are usually known as Learning Objects. Unfortunately, most game development tools lack the proper mechanisms to support the encapsulation of the games as Learning Objects.

3 The <e-Adventure> Platform

<e-Adventure> is an authoring platform for the production of point-and-click educational adventures, which has been used in the development of diverse educational games and low-cost game-based simulations in multiple contexts, as for instance, the medical education field [19]. Besides, <e-Adventure> present some additional features especially oriented to education.

Point-and-click adventure games are quite cheap to produce in comparison to other, more sophisticated game genres. This makes the production of <e-Adventure> games affordable even with small educational budgets. In addition, the <e-Adventure> platform was designed with instructors in mind, providing a friendly authoring environment [12] and an instructor-centered development process model [20]. The main advantage of this approach is that instructors can be directly involved in the production of the games.

<e-Adventure> also provides education-specific features that are not typically found in commercial games or game development tools. One of these features is the possibility to define assessment rules in the games that are triggered when a set of conditions on the "state" of the games are satisfied. The effect will be that the grade of the student is changed according to the definition provided by the author of the game (i.e. the grade is set to a value, incremented or decremented). When the game is completed an assessment report is generated with all this information. Besides, <e-Adventure> games can take advantage of the high interactivity in the games to adapt their behaviour according to a set of rules defined by the author of the game [11].

Finally, the games produced with <e-Adventure> can be packaged as Learning Objects, easing the delivery of the games to the end users. When an <e-Adventure> game is delivered through a standards-compliant LMS, the assessment and adaptation mechanisms described above can be linked to the central server. The tracking reports and the computed grades can be sent to the LMS for automatic processing; then instructors can access the results via web. Alternatively, the information can be displayed to the students as feedback. Similarly, the adaptation mechanism can be used as input for the adaptation decisions stored in the student's profile at the LMS side

4 Case Study: The HCT Blood Test Game

For a long time teachers of Human Physiology, a module taught in the second year of the Degree in Medicine at Complutense University of Madrid, have identified diverse

difficulties that students usually have when working in practical lab sessions, especially the first time they have to use the equipment. In this module students must complete various practical lab sessions where they test multiple properties of the Hematocrit (HCT) and learn to measure HCT levels through a classic HCT Blood Test. The attendance to these practical sessions is compulsory for all the students, although the results are not directly considered for the final grade of the module, which lessens the students' motivation.

In addition, in order to prevent potential infections and according to current Spanish health regulations, the blood used in these practical exercises must be drawn from laboratory rats that must be sacrificed. This means that, for ethical reasons, blood samples are scarce, while the number of students enrolled in this module every year is rather high (around 400 students). As a consequence the lab time is scant and must be administrated carefully.

We considered that creating a game-like simulation of these exercises would increase the motivation of the students. Moreover, a game-like simulation would help the students to use their limited time at the laboratory more effectively. In addition, these sessions are usually the first contact students have with the equipment and materials required for the HCT test, and the game would also provide a first contact with the equipment before the actual laboratory session.

This case study also demanded a simple delivery and deployment mechanism to provide students with free access to the game during the year, so they could use it to improve their long-term retention of the procedure and lessen the inconveniences of the limited working hours in the lab. Besides, the limited budget available for this experience restricted the range of development options.

4.1 Design, Implementation and General Description of the HCT Game

To meet all these requirements the <e-Adventure> platform was chosen for the development of the game-like simulation. During the development process, the experts of the field (in this case the teachers from the School of Medicine) were actively involved, providing advice and feedback. Additionally we profited from the instructor-oriented condition of the <e-Adventure> platform, as experts could directly open and modify the game with the <e-Adventure> editor without requiring technical background. This simplified a lot the refinement of the videogames when the situation required a high level of preciseness either of the vocabulary or the concepts.

We also used the features provided by <e-Adventure> to integrate the game in a standards-compliant LMS, which provided an easy game delivery mechanism through the Virtual Campus of the Complutense University, as well as the server-driven adaptation and assessment mechanisms provided by <e-Adventure>.

The general view of the game-like simulation produced is quite simple. It is basically a *point-and-click* navigational environment which recreates a laboratory station where the student must perform the HCT Blood Test. A good balance between cost and realism is obtained with this approach as the student is visualizing all the time the real working place but without needing costly 3D environments.

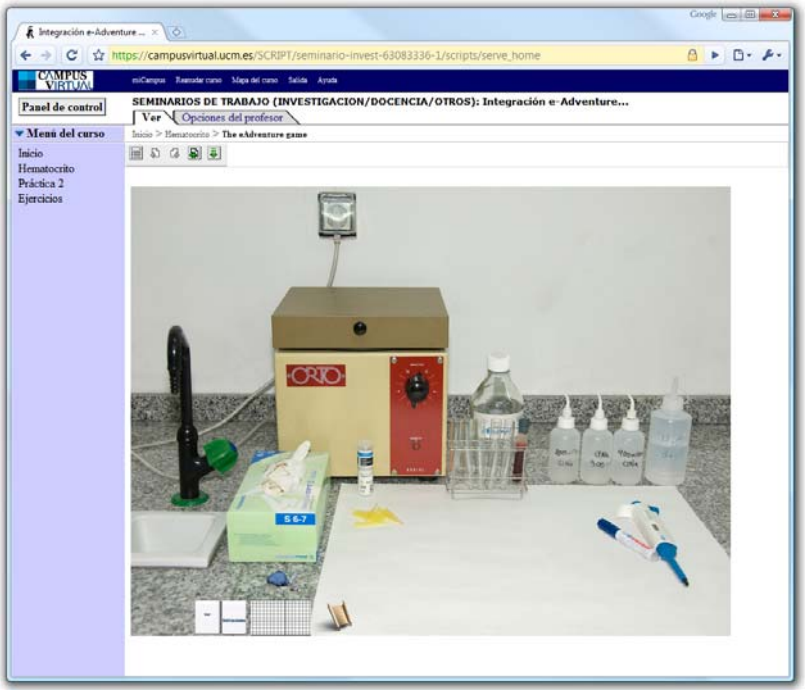


Fig. 1. The HCT Blood Test videogame deployed in the online Virtual Campus of the Complutense University

In this scenario, the students find the objects (equipment and material) they need to accomplish the game. To complete the steps of the procedure and progress in the game, students need to use or combine the right objects in the right order. Additionally, to complete some steps of the procedure, students must answer some questions about how to do it. This is special relevant to explore how just small incorrect variations of the procedure can affect the results. Besides, the preciseness of the simulation is improved with real videos of the more complex tasks.

In this manner the whole HCT blood test is simulated achieving a high level of accuracy but without compromising the cost. Besides, the attractiveness of the experience profits from a game-based approach. For instance, the consequences of some negligent acts are slightly exaggerated to capture students' attention and reinforce the redefinition of wrong suppositions.

4.2 Feedback and Assessment

In addition the game includes further interaction mechanisms for those steps of the procedure that require a more fine-grained simulation, as they cannot be properly simulated by a simple combination of objects. When it is important to tinge details about how the combination of elements must be performed, the student is prompted with a multiple-choice question with diverse options. The consequences of this choice depend on the correctness of the answer. Basically three different things can happen:

- The answer is completely right: the student can carry on with the simulation and no feedback is provided.
- The answer is partially wrong, but the mistake is not critical: the game provides feedback to the student and the error is written onto the assessment report.
- The answer is critically wrong: feedback is provided in any case, but if the negative effects are not immediate, the feedback is postponed to the end of the game (e.g. the effects of a wrong action might imply no visual consequences but influence the final determination of the HCT level). Besides, the grave error is written onto the assessment report.

In this manner, interaction is tracked and used from a pedagogical point of view. On the one hand the activity of the student is recorded for later evaluation. The successes and failures of the student are written onto the assessment report which is sent to the Virtual Campus server, which stores it to be taken into account for later executions of the game. On the other hand this activity can be used to provide feedback to the students. However, not all the actions in the game provide feedback immediately. Following instructors' recommendations, when the student fails to perform a critical step of the procedure feedback is delayed to the end of the game. In this manner students can check the real consequences of their acts, even when those are not produced immediately.

4.3 Adaptation

Another key aspect of the game is that it can be adapted according to the profile of the student in a process which is driven by the LMS. In the real HCT Blood Test some occasional events rarely occur, and most students do not have the opportunity to see them when they are in the lab. A game-like simulation like this is a perfect place to simulate these situations.

For instance, when a capillary tube is filled with blood, sometimes a blood coagulum blocks it, spoiling the whole tube. Then students must throw the tube away and start again the procedure. In our game, those rare events occur randomly, but with a much higher probability. The assessment report notifies the LMS about whether these situations have already happened so that it can keep a record of the students who have already experienced the abnormal situation in previous executions of the game. The next time those students play the game the LMS triggers a simple adaptation process which forces the normal situation. This is essential to avoid frustration in students who can see these abnormal situations as unjustified punishments [21]. Thanks to the adaptation mechanism, students will experience the effect of a coagulum with a much higher probability, but only once, which is enough illustrative but not frustrating.

In addition, there is a small adaptation layer taking account prior knowledge of the students based on the results of previous executions of the game. Students are roughly categorized in two groups: novice and intermediate. The idea is to skip some easy tasks for skilled students so that the game does not become boring. Besides reference documents, like a hints book, are only available in the game for novice users.

When the game starts it receives from the LMS the group the student belongs to; then the game is adapted accordingly. Once the game is completed the assessment report is sent to the LMS, which re-categorizes the student. Initially all students are novice until they achieve at least a 60% of performance playing the game (then they become intermediate students).

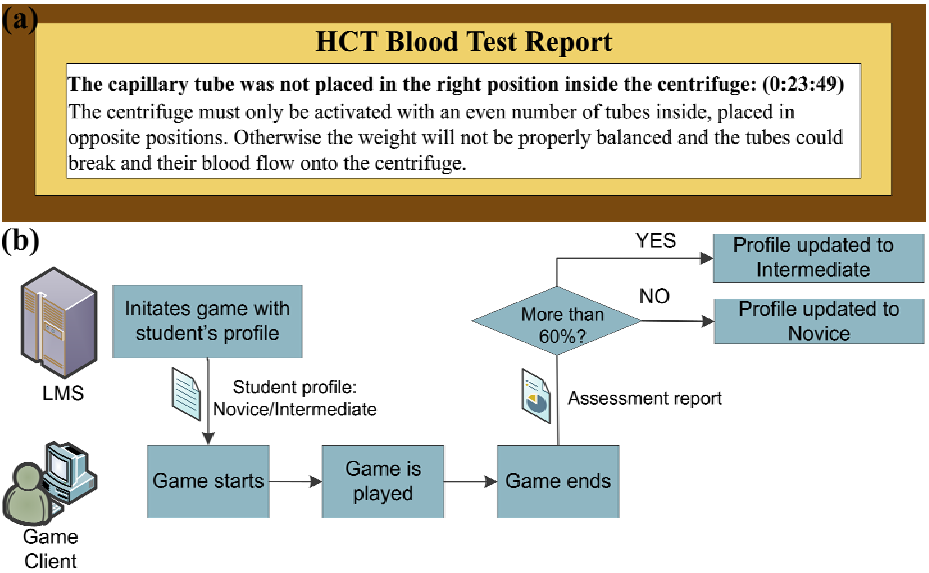


Fig. 2. (a): Fragment of an assessment report of the HCT game. (b): Full adaptive cycle implemented in the HCT game.

5 Preliminary Evaluation of the HCT Case Study

To check the effectiveness of the HCT Blood Test game-like simulation, we carried out a pilot experience with a class group of second-year students from the School of Medicine at Complutense University. The idea was to measure the effectiveness of the HCT videogame in terms of motivation towards learning and improvement of the effectiveness of the lab sessions.

The experiment was carried out with part of the students enrolled in the Physiology course (n=98). One of the laboratory groups was selected as the Experimental Group (EG, n=21) and the rest of the groups were taken as a unified Control Group (CG, n=77). The EG had the chance to play the game for 30 minutes with no guidance from their teachers beyond a brief description of the purpose of the exercise. The students from the CG attended the lab session without additional support. The objective was to test, after the real lab session, if there were any difference between the students who played and who did not play the game before going to the lab, in the following terms:

- Were students who played the game more motivated?
- Did the students who played the game understand the procedure better?
- Did the students who played the game have any advantage when using the equipment in the laboratory?

5.1 Student Satisfaction

In order to assess the subjective perception of the students, the participants from the EG completed a satisfaction survey after the practical lab session. In this survey they

were asked four questions about their perception of how the game did help them in some concerns:

- Q1: Do you think the HCT game has helped you to recognize the equipment needed?
- Q2: Do you think the HCT game eased the practical session for you?
- Q3: Would you like to use more games like this in this module?
- Q4: Would you like to have at your disposal the game during the practical session as a reference material?

The answers were in multiple-choice Likert-scale format, where 1 meant "strongly disagree" and 5 "strongly agree".

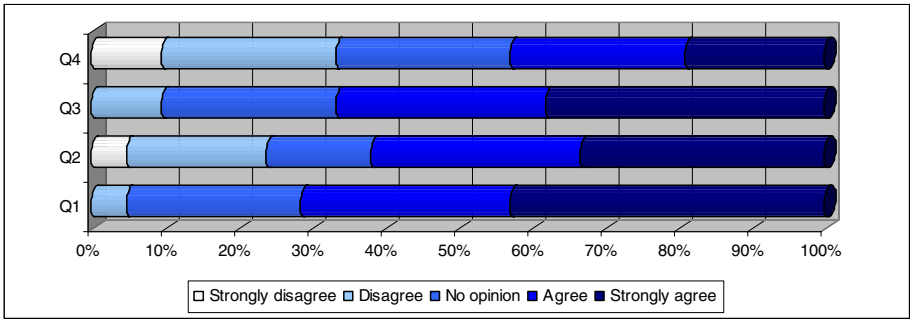


Fig. 3. Accumulative results of the satisfaction survey for students who played the game

The results are certainly positive. As figure 3 depicts, more than 70% of the students (71,43%) "agree" or "strongly agree" with the idea that the game helped them to recognize the equipment. More than 60% of the students "agree" or "strongly agree" (61,90%) with the idea that the game helped them to complete the practical session. In the same line, more than 60% of the students "agree" or "strongly agree" with having more games like this for the module (66,67%). Finally the results for question 4 are less meaningful, as over a 40% of the students (42,86%) "agree" or "strongly agree" with having the game available in the lab.

5.2 Learning Outcomes

A basic analysis of the learning outcomes was based on a second multiple-choice questionnaire that all the students (both control and example groups) had to answer about the difficulty of the practical session.

As the table above depicts, the results suggest that students who played the game found the session slightly easier. On the one hand, more students in the EG perceived the exercise as "easy" (85.71% in EG against 72.73% in CG) and less students perceived the exercise as "difficult" (0% in EG against 3.9% in CG). On the other hand, the results are similar when analyzing the students' perception of the difficulty of using the equipment. (85.95% of the students found it "easy" in EG against 77.92% in CG), although the results here are less significant when comparing the number of

Table 1. Student perception of the difficulty of the practical exercise and the difficulty of using the equipment

	Difficulty performing the exercise			**Difficulty using the equipment**		
	Easy	Normal	Difficult	Easy	Normal	Difficult
EG	85.71%	14.29%	0%	80.95%	9,52%	9,52%
CG	72.73%	23.38%	3.9%	77.92%	16.88%	5,19%

students who found the use of the equipment "difficult". This could be justified because the limited interactivity provided by the game can help students to recognize the equipment, but not how to actually use it.

6 Conclusions

As discussed in this paper, there is a growing interest of both the academic and the industry worlds on the educational gaming field. However, the integration of educational gaming (in all trends) in the educational system will not be complete until diverse issues are addressed.

These issues include development cost aspects, how to track and evaluate the performance of the students and how to use this evaluation to produce adaptive learning experiences. There are also practical issues, such as how to effectively deliver and deploy the games in educational environments, and even development models allowing the active involvement of experts in the production of the games.

In this paper we have presented the HCT Blood test game-like simulation, developed with the <e-Adventure> platform taking into account all these issues. A group of experts (teachers of the school of medicine) were actively involved in the project in order to ensure the correctness of the concepts transmitted by the videogame. Besides the game includes a full adaptation and assessment cycle which allows adapting the videogame according to the student's profile (profile which can be modified taking into account the results of the game). The game can be easily deployed and distributed through the online Virtual Campus of the Complutense University. Thus all the students can access it via a web browser as many times as desired, solving in this manner the inconveniences of the little time students can spend practicing in the real lab.

The primary analysis of the results of the game-play session suggests that the use of the videogame can have a great impact in the motivation of the students. The satisfaction survey reveals a great acceptance of the initiative and a good predisposition to use the game to improve their skills. However this may turn to be only an illusion once the novelty is gone. Further research about the usage trends for the games will provide additional insight.

Regarding the learning outcomes of the experience, the results suggest that the use of the game facilitates the first contact with the equipment and the successful accomplishment of the HCT measurement procedure. This can be interpreted as a sign of the positive effects that this kind of approaches can have not only on the motivation of the students, but also on the effectiveness of the learning experience. Our results suggest

that students who played the game learnt the procedure more easily than those who did not play the game.

Coming back to the problem of the lab availability, this also suggests that students who had the chance to play the game could use their lab time more effectively. It must be noted that the objective of this work is not to provide an alternative to the lab time. The embodiment of the full experience, where students can physically interact with the equipment in a real setting cannot be substituted by simulations (not even expensive and complex 3D simulations). Instead, the objective is to try to help the students to get more profit from their limited lab time.

From our initial results we can hypothesize that students are in fact profiting more from their lab time, because they are finding the exercise easier (and are thus focusing more on performing the task). However, it must be noted that these results are based on subjective appreciations from the students. Further work and experimentation will be required to draw more solid conclusions.

Acknowledgments. The Spanish Committee of Science and Technology (projects TIN2005-08788-C04-01, TSI-020301-2008-19 and TIN2007-68125-C02-01) has partially supported this work, as well as the Complutense University of Madrid (research group 921340) and the EU Alfa project CID (II-0511-A). Special thanks to María Dolores Comas, Julián Bustamante and Carmen Fernández for their interest in the <e-Adventure> platform and their active. Thanks to Enrique López-Mañas, Ismael Salgado and the technical staff of the computer labs of the School of Medicine for their generous help before and during the game-play session with the students.

References

1. Aldrich, C.: Learning by Doing: A Comprehensive Guide to Simulations, Computer Games, and Pedagogy in e-Learning and Other Educational Experiences. Pfeiffer, San Francisco (2005)
2. Gee, J.: Good Video Games and Good Learning: Collected Essays on Video Games, Learning and Literacy (New Literacies and Digital Epistemologies). Peter Lang Publishing (2007)
3. Prensky, M.: Digital Game Based Learning. McGraw-Hill, New York (2001)
4. Garris, R., Ahlers, R., Driskell, J.E.: Games, Motivation and Learning: A Research and Practice Model. Simulation & Gaming 33, 441–467 (2002)
5. Mayo, M.: Games for science and engineering education. Communications of the ACM 50, 30–35 (2007)
6. Malone, T.: What makes computer games fun? Byte 6, 258–276 (1981)
7. Van Eck, R.: Digital game-based learning: It's not just the digital natives who are restless. EDUCAUSE Review 41, 16–30 (2006)
8. Wexler, S., Corti, K., Derryberry, A., Quinn, C., Barneveld, A.: 360 Report on Immersive Learning Simulations. The eLearning Guild (2008)
9. Kirriemur, J., McFarlane, A.: Literature review in games and learning. NESTA Futurelab Series. NESTA Futurelab., Bristol (2004)
10. McFarlane, A., Sparrowhawk, A., Heald, Y.: Report on the educational use of games. TEEM: Teachers Evaluating Educational Multimedia (2002)

11. Moreno-Ger, P., Burgos, D., Sierra, J.L., Fernández-Manjón, B.: Educational Game Design for Online Education. Computers in Human Behavior 24, 2530–2540 (2008)
12. Torrente, J., Moreno-Ger, P., Fernández-Manjón, B., Sierra, J.L.: Instructor-oriented Authoring Tools for Educational Videogames. In: 8th International Conference on Advanced Learning Technologies (ICALT 2008), pp. 516–518. IEEE Computer Society, Santander (2008)
13. Brusilovsky, P.: Adaptive Educational Systems on the World-Wide-Web: A Review of Available Technologies. In: WWW-Based Tutoring Workshop at 4th International Conference on Intelligent Tutoring Systems (ITS 1998), San Antonio (1998)
14. Paramythis, A., Loidl-Reisinger, S.: Adaptive Learning Environments and eLearning Standards. Electronic Journal of eLearning 2, 181–194 (2004)
15. Robin, H.: The case for dynamic difficulty adjustment in games. In: Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology. ACM, Valencia (2005)
16. Peirce, N., Conlan, O., Wade, V.: Adaptive Educational Games: Providing Non-invasive Personalised Learning Experiences. In: Second IEEE International Conference on Digital Games and Intelligent Toys Based Education, pp. 28–35. IEEE Computer Society, Banff (2008)
17. Torrente, J., Moreno-Ger, P., Fernández-Manjón, B.: Learning Models for the Integration of Adaptive Educational Games in Virtual Learning Environments. In: Pan, Z., Zhang, X., El Rhalibi, A., Woo, W., Li, Y. (eds.) Edutainment 2008. LNCS, vol. 5093, pp. 463–474. Springer, Heidelberg (2008)
18. Mayes, T., De Freitas, S.: Review of e-learning theories, frameworks and models. Commissioned review report as part of the JISC-funded e-pedagogy desk study on e-learning models (2004)
19. Moreno-Ger, P., Blesius, C., Currier, P., Sierra, J.L., Fernández-Manjón, B.: Online Learning and Clinical Procedures: Rapid Development and Effective Deployment of Game-Like Interactive Simulations. In: Pan, Z., Cheok, D.A.D., Müller, W., El Rhalibi, A. (eds.) Transactions on Edutainment I. LNCS, vol. 5080, pp. 288–304. Springer, Heidelberg (2008)
20. Moreno-Ger, P., Martínez-Ortiz, I., Sierra, J.L., Fernández-Manjón, B.: A Content-Centric Development Process Model. IEEE Computer 41, 24–30 (2008)
21. Gilleade, K.M., Dix., A.: Using frustration in the design of adaptive videogames. In: ACM SIGCHI International Conference on Advances in computer entertainment technology (2004)

Motivational Factors in Educational MMORPGs: Some Implications for Education

Kuo-Hsun Hung, Charles Kinzer, and Cheng-Ling Alice Chen

Box 8, 525 W 120th Street, New York, New York 10027-6696
Location: 322 Thompson Hall
kh2203@columbia.edu, kinzer@tc.columbia.edu, cc2550@columbia.edu

During the past two decades, digital games have been acknowledged as motivational and have become a source of study for educational researchers and instructional designers who wish to maximize motivation in educational materials. Among different types of digital games, massively multiplayer online role-playing games (MMORPGs) continue to grow in popularity. Therefore, researchers have started to explore the possibilities of using MMORPGs in education. While MMORPGs have been proven to be a tool that can strengthen students' learning, to enhance their efforts educational game designers need to know more about how educational MMORPGs motivate students. To address the above need, we set out the following two objectives for the study briefly reported herein: To examine the motivational factors of playing educational MMORPGs; To discuss how educators and educational game designers could use motivational factors in designing learning activities and educational experiences within MMORPGs.

We used a self-developed educational MMORPG called Ed-Wonderland to explore the two objectives noted earlier. Twenty 5th grade students (female=10, male=10) school in KaoHsiung, Taiwan agreed to participate. We first conducted a twenty-minute session to introduce Ed-Wonderland and its game world, rules, and functions. This was followed by a one-hour play session. After the play session, each participant completed a motivation questionnaire and overall attitude questionnaire.

The results show that participants are motivated by *Achievement*, *Social, Immersion*, and *Instructional Mechanism Factors*. In addition, participants' attitudes toward Ed-Wonderland are positive.

These findings point to the following implications for both educators and educational game designer. For educators, we suggest that (1) educational MMORPGs such as Ed-Wonderland could be used to motivate students to learn; (2) educational MMORPGs such as Ed-Wonderland could be a social learning platform for after class usage; and (3) educators could utilize the four motivational factors in their learning activities. The implications for educator games designers are (1) the instructional materials and tools should be thorough; and (2) educational games could be accompanied with other materials.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 174, 2009.

Designing a Trading Card Game as Educational Reward System to Improve Students' Learning Motivations

Peayton Chen[1], Rita Kuo[2], Maiga Chang[3], and Jia-Sheng Heh[1]

[1] Dept. of Information and Computer Engineering, Chung-Yuan Christian Univ., Taiwan
peayton@hotmail.com, jsheh@ice.cycu.edu.tw
[2] Dept. Of Digital Design, Mingdao Univ., Taiwan
rita@mdu.edu.tw
[3] School of Computing and Information Systems, Athabasca University, Canada
maiga@ms2.hinet.net

Reward is the simplest way to motivate students in education. It can encourage students to learn and get immediate achievement. Moreover, it is also has potential to construct students' intrinsic motivation. However, traditional symbolic rewards like stars or stickers are often less valuable because it cannot be used by the students after the class; thus cannot keep motivating students.

This research designed cards of a self-developed computerized trading card game (TCG) as educational rewards in order to inspire students learning. The teacher can give the student cards if the student did well in either his/her homework, quiz, or exam. Also, the teacher can give the student different level cards according to his/her answers to the question the teacher asked; or according to the student's learning attitude and performance. Teachers can pre-define the relation between the learning and the reward, the system then can give appropriate cards to students automatically according to the relation. Furthermore, because of the cards and the computerized TCG is independent from the courses, teaches can map the same card to verity courses to let students get cards from any courses.

For this purpose, this research analyzed three famous TCGs and implemented a prototype computerized TCG and educational reward system to increase student's learning motivation. Students can collect cards in class and use it for play or even show-off after class, which can really encourage students to learn. These cards in the computerized TCG not only can increase the usability of rewards, but also can stimulate students' learning motivations because of more they've learned or better they've performed, more and better cards they can get and use to play the game and defeat the fellows easier. Because the computerized TCG is real game, it is fun and will not make students feel they are still "learning". Through the TCG, the rewards can hold students' interest for longer.

Keywords: Trading Card Game, Reward, Learning motivation, Competition, Game.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 175, 2009.

Where Academics Meet the Real World: Difficulties Encountered When Conducting a Project for Designing a Game-Based Learning in a Company

Eduardo Werneck and Maiga Chang

School of Computing and Information Systems, Athabasca University, Canada
eduardo_d_werneck@yahoo.com, maiga@ms2.hinet.net

Abstract. Educational games have been widely developed and tested by many researchers. Most of results show that the educational games are good to increase students' learning motivations in formal learning. It seems quite workable, however, is it also true if we want to apply the concepts to business? Or, does it still have effects to on-job-training and orientation in business? This research focuses on the first question. The experience of trying to design and test a Game-Based Learning System, with a joy component, in a real corporation is challenging and risky. This paper shows how hard was to find a company willing to do this test, the negotiations involved, the legal issues and the extensive scrutiny imposed. Constant revisions and postponing, threatening of cancellation and misinformation about company resources needs continuous diplomacy and flexibility from researchers. Prejudice against computer games may play an important barrier and an unfair advantage towards traditional training deliveries.

Keywords: game-learning learning, training, joy, computer game, educational games.

1 Introduction

According to Vossen's research in 2004, three attributes are used to analyze game category, are competitive, interactive, and physical [16]. The game features attract players are fantasy, curiosity, challenge and control [8]. Some researchers point out that playing can hold student attentions and make learning be more interesting [15][2]. For this reason, many studies use commercial games directly or design new education games and have evidences of students can get significant improvement in learning [15][11][1][13].

Several studies have been carried out on game-based learning with an educational orientation, especially for a possible use in either helping learning the traditional classroom environment, or supporting teaching activities [5], with improving techniques like the multi level challenge system [4]. Other game-bsed learning systems were, for examples, VISOLE [10], AnswerMatching [17], Shadow Box [12], and Simulation Fish Tank [14].

This decade has brought significant technological improvements to enable a level of precision for game-based learning tools, never experienced before, like the Lego Mindstorms [7] and other learning toys [6][9]. Capps et al. (2001), explained how the

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 176–183, 2009.

Department of Defence has been focussing in collaboration with the entertainment industry, in order to try to cope with the same agile pace of the industry, but taking advantage of the technology and even a postgraduate naval department was successfully created [3][18].

The objective of this paper is to inform researchers of the hard reality of conducting real life studies about game-learning in companies. Even if some company employees may open the doors to game-learning studies, researchers still have other barriers to work on.

This paper is organized into five sections, the four remainder parts of this paper exposes the process of looking for a company willing to allow the research to be done with their employees, then the project management, followed by the unexpected ending and the conclusions.

2 Finding a Collaborative Company

The process of recruiting a company willing to allow its employees to participate in an academic empiric research is not an easy task, when the subject of the study is Game-Learning. Armed with a mini-proposal and a sales plan explaining the benefits for an organization to help out with an academic study was not enough. The word *game* represents a major road blocker, even after carefully explaining factual information regarding peer review studies showing game-learning systems as a powerful and effective learning tool.

Considering the final objective was to create, design and test the learning effectiveness of a game for training purposes, in an enterprise-like environment, and analyse the learning process, engagement, and knowledge retention compared to the conventional training currently in practice, the path chosen was to adapt a current training from a company to a board game format, where the addition of joy while learning, would improve learning results and user experience. The proposal to the company would be to develop this game based on a current training material and test it among their employees. The test results would be shared with the company, as well as the game would be used by the company at any time.

Once it is understood a company will have training needs at specific dates, for specific individuals, at specific locations, it is important to consider being flexible enough, in order to match research deadlines to corporate needs. These facts lead to searching for the corporate partner as soon as enrolled in the respective course, at University, as negotiating deadlines and major deliverables could take a long time.

When already working for a company, it is natural to search for shelter within your own roof. The first approach was to contact D-Company, the current employer. Follow the protocol, contact your boss first, who in this case was a director and a game fan: he immediately sent an e-mail to one of the Human Resources Vice Presidents, who oversees training.

The Vice President forwarded the message to a human resources employee, who was quite resistant to the idea of having any test done with gaming and after a few tries, it was very clear there was going to be no cooperation. The next step was to

climb one corporate ladder step and talk to the Training Manager, who was very positive and opened to the study, collaborating with ideas and example of online games.

A couple of months later, after researching about Adobe Flash, and ready to start developing the game, several attempts to contact this manager were tried, unsuccessfully. E-mails were sent and voice mails left. Only after a couple of weeks, the manager returned the e-mail mentioning they had no more budget and therefore, the company could not go ahead with the training anymore. After inquiring about other possibilities of training with other companies from the same group, she facilitated the contact with another manager in the United Kingdom, at the head office of the parent company. This manager worked with Corporate Responsibility and she had developed a board game for *business principles* to train remote employees. However, the training had already been done and there were no more plans for another one and attempts to still try to do the research at D-Company, end at this point. Table 1 shows the contact flow at D-Company.

Table 1. Contact flow for D-Company

Contact Type	Level	Outcome
Boss	Director	positive
VP HR	VP	positive
HR Consultant	Manager	negative
Manager Training	Manager	negative
Manager Corporate Responsibility	Manager	negative

At R-Company the first contact was done through the Design Manager, a Human Resources department in charge of training. Networking made the accessibility flow better. In this case, the contact person was also directly in charge of developing training and again, in a management position.

The initial contact, over the phone, was done in November 2008 and the concept of game-learning was perceived as positive and the process moved to a company internal exploration phase, where the manager was trying to find departments willing to experiment game-learning and assign a training to it. During this process, a brief benefit analysis was sent to the manager, as per one of her director's request which were sent based on these 5 points: experts advisory to R-Company (peer review), exposure and advertisement (Conference papers), possibly new training delivery format, empiric research and low, or no cost to the company.

Fig. 1 shows the flow chart sent to the manager, so she could make use of a visual tool when presenting the project to R-Company executives.

At this time, a written agreement was sent to the manager, signed by the researchers and to be signed by the company. This agreement was sent to the company lawyers for review, which took 6 weeks to be signed, after several changes made to the original document, and dozens of e-mails exchanged between the parties. It was also necessary to sign an NDA – Non Disclosure Agreement, at that time.

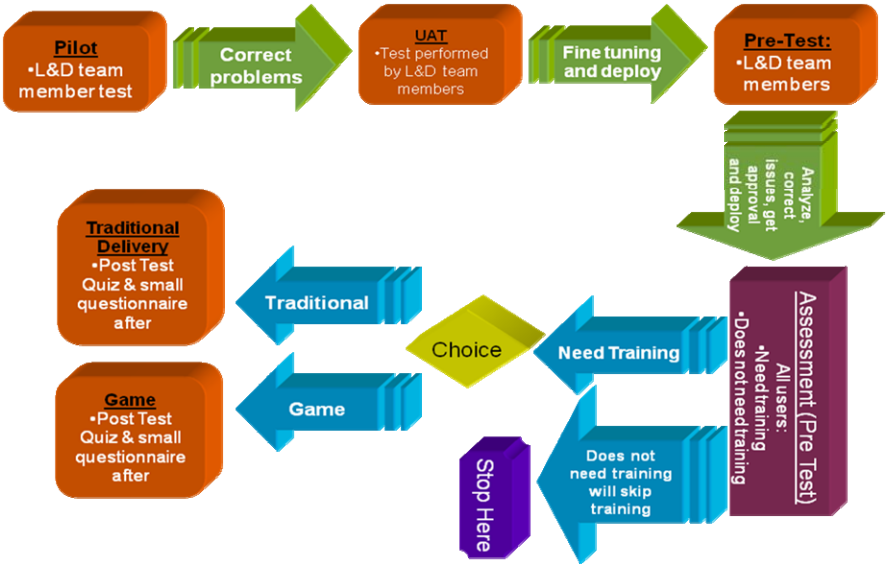


Fig. 1. Flow chart of the project at R-Company. This chart was sent to the manager in order to help selling the idea of the project to upper management.

3 Project Management and Corporate Diplomacy

No matter how important your project may be for humanity, corporate decisions will take its own course. It is up to you to manage the project the best way you can. There will be several and unexpected issues along the road and negotiation and diplomatic skills will play decisive role in the survival of your project.

From the agreement signed with R-Company, the training selected to be part of this research was the watercraft training. The initial number of employees targeted for the project was around 600, from which about 240 would have to undergo the w-craft training. These 240 would chose between the traditional online training and the game-learning module. Every single statement within this paragraph has been at stake, several times along the process. The training itself has been called off and then back again. The design manager played an important role interacting with the different departments.

The departments holding the w-craft training to its employees are basically sales oriented. If the sales targets are not being met, or if the heads of these departments decide to take any tactic, or strategic decision regarding how to better use their employees time, between taking the w-craft training for one hour, or using this time to do something else, is out of the researcher control.

Positive attitude in showing how the project would impact in helping the company was the only counter measure for the downfalls the company presented during the whole interaction with us.

Diplomacy played at its most joyful is the best advice when facing the nervous breakdown point employees in a company. While in the process of developing the

game, it was inevitable to face the company design team worried about the outcome and the process itself. Several change requests were made and they had to be negotiated and sometimes modified, or even implemented, reviewed, and modified again, until they were happy with the outcome.

The initial prototype was quite different from the final version of the game, basically due to the several changes initiated by the company. The involved employees take the project as something produced by their own department, and not an academic project. It was quite usual to receive a request to modify something related to the game, and not the training content itself. Unquestionably, the best approach was to always show the different scenarios and explain the pros and cons. If not able to convince them, the solution was to incorporate the change and try to work around it as best as possible, which was time consuming, but the only way to try to change the situation on a reasonable way. The same way, after several threats of not going ahead with the research, the efforts switched to the development of the Flash game, improving the questionnaire for the participants to measure how likely they were to adopt the game, to deploy the swf file into the University server and make sure it would work flawless, which means perform all the tests at R-Company, and not when and how many people would take part of the experiment, neither if it would even happen.

To orchestrate the company and University timelines is another extremely important task. To keep the parts involved aware of changes is key to manage this process, however it is part of the negotiation and diplomatic skills mentioned above to keep all the parties away from a panic situation.

Right after receiving the okay from upper management on January 22nd, 2009 and signing the agreement, the manager emailed the pre- and post-test questions. The content was sent about a week later, on January 23rd.

The first step was to review the documents and understand and master the content. Several messages were exchanged with the company to clarify points in the content. At the same time, the process of creating the game had already started.

February 27th or almost one month later, the prototype of the game was ready and a meeting was carried out at the company, with the design manager and the development officer in charge of this training module. Initially, it was difficult to get any consensus from the meeting. Instead of focusing on the learning content, both the manager and the officer were more worried about the game itself. Although input is extremely healthy at the development phase, it has to be constructive and avoid threatening of not launching the game, or stating the head of the target departments would not approve it, but this is how the meeting was. At this point, the manager cognitive resonance process in order started to justify how the changes they requested were going to make the experiment results lean towards the game, improving the score of game participants.

Right after the meeting the manager sent an e-mail with a list of required modifications to the game. After advising it would not be possible to meet the deadline to have the game in the company training Intranet site if all the modifications had to be implemented, the manager and the officer decided for hosting the game at the University's website and having a link posted in the company's Intranet. This arrangement extended the development phase to another 4 weeks, especially due to another bumping on the training start date, which was moved to March 24th.

These 4 weeks were extremely intense. 40 e-mails and several telephone calls were exchanged during this time. The officer revised the content 4 times. The experiment questionnaire was sent for review, but came back as the format the manager and the officer thought it would be fine for setting up at their training application could not be done, or the answers would count as official marks for the participants. The questionnaire had to be changed and the officer revised it 4 times, until acceptance.

The game was ready by March 23rd and approved by the officer, who mentioned he was quite happy with the outcome.

4 Unexpected Ending

Once the game was being tested, some follow up calls and messages had been exchanged and everything was fine. When inquired about the number of people logging into the game, the officer mentioned it could not be captured. At this point there was another corporate challenge, but this time, with the University: as the game was hosted at the University server, a request was sent to the administrators in order to retrieve the hits to the specific swf file containing the game. Larger servers as the ones used by Universities do have web statistics capabilities and it is possible to retrieve this information. However, after 3 attempts, no answer to this request has been provided.

One day after the end of the training, which was April 1st, the results started to come: 32 participants. As the initial estimate of employees taking the training was around 240, another set of e-mails started to be exchanged. Only after a phone call it was possible to understand why only a fraction of the participants took the training: it was offered to 80 participants only. From these 80, 48 passed the pre-test and did not need to do the training. Although it was unexpected that such a small amount of people would do this module, at least it was a real world project, which would show the results based on real life experience.

From the 80 employees in the department, 32 completed the training. From these 32, 23 responded the questionnaire. From these 23, 2 answers will have to be discharged, as the score is clearly incorrect: they show a score of 8, and 9, which is way too low compared to the rest of the answers (between 45 and 100).

5 Conclusions

The conclusion of the project itself is not the scope of this paper and will be presented in the thesis document. What is important to highlight is the impact of the procedures from a company in a real life experiment. Deadlines overstretched, development process convoluted and outcome unexpected. The results cannot be seen as bad, but certainly absolutely interesting from the scientific point of view, as the environment affected the course of science.

A clear recommendation for anyone who is planning to carry on a similar approach of real life research in a corporation would be to try to nail down the details in the agreement and to have all the chain of sponsors and major stakeholders sign off the document, as a project management document. A project management rigid guideline

would possibly avoid the deviations from the initial proposal and keep the focus of all the departments in their deliverables, but not in the creative process of the game.

References

1. Anderson, T.A.F., Reynolds, B.L., Yeh, X.P., Huang, G.Z.: Video Games in the English as a Foreign Language Classroom. In: 2nd IEEE International Conference on Digital Games and Intelligent Toys Based Education, pp. 188–192. IEEE Press, Banff (2008)
2. Boyle, T.: Design for multimedia learning. Prentice Hall, London (1997)
3. Caaps, M., McDowell, P., Zyda, M.: A future for entertainment-defense research collaboration. IEEE Computer Graphics and Applications Journal 21(1), 37–43 (2001)
4. Cheng, H.N.-H., Deng, Y.-C., Chang, S.-B., Chan, T.-W.: Design of Multi-level Challenges of a Digital Classroom Game. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 11–18 (2007)
5. Hsiao, H.-C.: A Brief Review of Digital Games and Learning. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 124–129 (2007)
6. Hsu, S.-H., Chou, C.-Y., Chen, F.-C., Wang, Y.-K., Chan, T.-W.: An investigation of the difference between robot and virtual learning companions' influences on student engagement. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 41–48 (2007)
7. Jormanainen, I., Zhang, Y., Kinshuk, Sutinen, E.: Pedagogical Agents for Teacher Intervention in Educational Robotics Classes: Implementation Issues. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 49–56 (2007)
8. Pivec, M., Dziabenko, O., Schinnerl, I.: Aspects of Game- Based Learning. In: 3rd International Conference on Knowledge Management, Graz, Austria, pp. 216–225 (2003)
9. Schweikardt, E., Gross, M.D.: A Brief Survey of Distributed Computational Toys. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 57–64 (2007)
10. Shang, J., Jong, M.S.-Y., Lee, F.-L., Lee, J.H.-M.: A Pilot Study on Virtual Interactive Student-Oriented Learning Environment. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 65–72 (2007)
11. Steinman, R.A., Blastos, M.T.: A trading-card game teaching about host defence. J. Medical Education 32, 1201–1208 (2002)
12. Sung, J.-Y., Levisohn, A., Song, J.-W., Tomassetti, B., Mazalek, A.: Shadow Box: an interactive learning toy for children. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 206–208 (2007)
13. Šisler, V., Brom, C.: Designing an Educational Game: Case Study of 'Europe 2045'. In: Pan, Z., et al. (eds.) Transactions on Edutainment I. LNCS, vol. 5080, pp. 1–16. Springer, Heidelberg (2008)

14. Tan, J., Biswas, G.: Simulation-Based Game Learning Environments: Building and Sustaining a Fish Tank. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 73–80 (2007)
15. Virvou, M., Katsionis, G., Manos, K.: Combining Software Games with Education: Evaluation of its Educational Effectiveness. Educational Technology & Society 8(2), 54–65 (2005)
16. Vossen, D.P.: The Nature and Classification of Games. Avante 10(1), 53–68 (2004)
17. Wu, W.M.-C., Cheng, H.N.-H., Chiang, M.-C., Deng, Y.-C., Chou, C.-Y., Tsai, C.-C., Chan, T.-W.: AnswerMatching: A Competitive Learning Game with Uneven Chance Tactic. In: The Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), Jhongli, Taiwan, March 26-28, pp. 89–98 (2007)
18. Zyda, M.: Directions in Modeling, Virtual Environments and Simulation (MOVES). In: The Proceedings of the IEEE Virtual Reality Conference (VR 1999), Houston, Texas, USA, March13-17, p. 71 (1999)

An Entertainment System Using Thermal Feedback for Increasing Communication and Social Skills

Takuji Narumi[1,3], Tomohiro Akagawa[2], Young Ah Seong[1], and Michitaka Hirose[1]

[1] The University of Tokyo,
7-3-1 Hongo Bunkyo-ku, Tokyo Japan
{narumi,hirose}@cyber.t.u-tokyo.ac.jp,
yabird@hc.ic.i.u-tokyo.ac.jp
[2] Tokyo University of the Arts,
2-5-1 Shinko, Naka-ku, Yokohama, Japan
toakmoak@gsfnm.jp
[3] Japan Society for the Promotion of Science

Abstract. Although social skills are important, to increase these skills is difficult. In this paper we propose an experimental system that lets a user "feel" the appropriate distance between him/her and another person in order for social interaction to take place in an optimal setting. We created wearable thermal devices that transmit thermal information to the person wearing them and linked them to an edutainment system called "Thermo-society". "Thermo-society" is a system that creates thermal sensory spots around people in an open space. Thermal sensory spots are generated based on the knowledge of proxemics. Through an experiment, we analyze people's behavior in the space. As a result of the analysis, we estimate the average distance between two users in the same group is 1.45meters. We noticed in our experiment that people, when playing Thermo-society, allow strangers to come in personal distance in 44.4% of the cases, which suggests that our system increases the potential for social interactions.

Keywords: Interpersonal Distance, Social Skills Support, Social Communication, Thermal Sensation.

1 Introduction

Social skills are very important to developing good human relations [1]. These are the foundation for getting along with others. A lack of social skills can lead to behavioral difficulties in school, delinquency, inattentiveness, peer rejection, emotional difficulties, bullying, difficulty in making friends, aggressiveness, problems in interpersonal relationships, poor self-concept, academic failures, concentration difficulties, isolation from peers, and depression.

Although social skills are important, to increase these skills is difficult [2, 3]. Nobody teaches us how to communicate with others. How to improve social skills is simple: by practice. We can study techniques like matching and mirroring to build rapport, and you can memorize cutesy acronyms like SOFTEN (Smile, Open posture, Forward lean, Touch, Eye contact, Nod) [4].

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 184–195, 2009.

However, we don't consider those are helpful. Those are likely to make people even more self-conscious. If a man/women is in the right frame of mind to begin with, he/she will naturally perform the correct actions like smiling and mirroring — if he/she has to think about them, he/she is in the wrong mindset.

When he/she becomes comfortable, he/she is naturally being himself/herself. And that's the basis of effective interpersonal communication — just be yourself and feel perfectly at ease with who you are and what you bring to a conversation.

When a man/woman feels totally comfortable, his/her ego dissolves. He/She is not thinking at all about himself/herself, how he/she look, how he/she sound, etc. He/She is thinking about the topics he/she is discussing and about the other people. This is true whether he/she is having a conversation with an old friend or giving a speech in front of hundreds of people. When you feel comfortable, your focus is on the content of the communication and on the other people, not on yourself.

Our research aims at creating a social skill supporting environment by presenting additional information to the users. In spatial information design, there are many studies on presenting information, including pervasive, ubiquitous and ambient computing [5]. Most of them focus on presenting additional information or information of a distant place remotely [6, 7].

In this paper we propose a method to let us know the appropriate interpersonal distance for communicating with a stranger in public space by presenting thermal information. Although thermal sensing is slow in response time and lower in resolution than visual and audio sensing, it is deeply linked to the pleasure-pain feeling [8]. Moreover, it is suitable for creating comfortable space and informing users gradually without giving a clear border of characteristics. In our method, we create a comfortable space around people by presenting thermal information with wearable device. By doing so, we generate a social skill supporting environment to let people feel themselves compelled to approach others and communicate with each other.

In the 2nd chapter, we introduce the idea of appropriate social distances for communication based on the study of interpersonal distance proxemics. In the 3rd chapter, we describe our system "Thermo-society" to feel the appropriate distance between people which made in accordance with the review in the 2nd chapter. And we report the result od an experiment to examine how the thermal feedback affects people's behavior and distance between people.

2 Appropriate Social Distances for Communication

People surround themselves with a "bubble" of personal space that they claim as their own, and they tend to become stressed when other people invade their "bubble." Our personal space protects us from too much arousal and helps us feel comfortable when we communicate with other people.

Hall called the study of interpersonal distance proxemics [9]. From observing people, Hall concluded that four interpersonal distances were important in our social interactions: intimate, personal, social, and public (Table 1).

Intimate distance is from 0 to 0.45 meters. What can be done at this close range? Vision is minimal, and we rely on our senses of smell and touch. Making love or comforting someone is an intimate activity, usually restricted to private encounters,

which can be performed comfortably at intimate distances. We tend not to get this close to people we are not intimate with, and usually try to escape if we do.

Personal distance is from about 0.45 meters to around 1.2 meters. At this distance, touch is minimal (except perhaps when shaking hands), and vision and hearing become important. This is the distance we use to interact with friends. Within this range, normal conversations can take place easily. We might allow strangers into the outer limits, but reserve the inner limits strictly for friends.

Social distance extends from approximately 1.2 to 3.6 meters, and includes the space required for more formal social interactions. Hearing and vision are the primary senses involved. The social distance is often utilized in business, for example, in interviewing new applicants for employment or negotiating for a raise. When a stranger keeps on staying in this distance, people often exchange greetings.

Public distance includes distances greater than 3.6 meters. Hall suggested that after 7.6 meters, interpersonal interaction is not possible. At this distance there is little detail involved in communication. A public speaker (actor or politician) communicates only one way with an audience.

Table 1. Four Interpersonal Distances in Our Social Interactions

Interpersonal distances	From	To
Intimate distance	0 m	0.45 m
Personal distance	0.45 m	1.2 m
Social distance	1.2 m	3.6 m
Public distance	3.6 m	7.6m

Research suggests that we feel uncomfortable when we are too close or too distant from another person [10]. How do we learn appropriate social distances? We propose an experimental system that lets a user "feel" the appropriate distance between him/her and another person in order for social interaction to take place in an optimal setting using thermal information. Users of the experimental system are influenced to stay within social distance of each other, even of strangers, by exposing them to a comfortable temperature. Since people usually greet others that are within social distance, the likelihood of social interaction taking place is higher.

3 Thermo-society

3.1 System Overview

In this section, we propose a system of controlling thermal information and discuss how thermal information affects people's behavior. Thermo-society is a system that creates thermal sensory spots around people in an open space (Figure 1). It works as a spatial partitioning system without physical walls. Instead, it displays temperatures in several grades. It makes a "virtual agora" in public space.

Fig. 1. Thermo-society

In this system, we use earmuffs like wearable devices that provide thermal sensation depending on the location of people. We choose ears to present thermal information because the cephalic part is the most sensitive to heat and cold stimuli [11]. By feeling the temperature, people distinguish different thermal areas, though there is no visual distinction between them.

In Thermo-society, space is divided into several thermal fields. Visitors are expected to walk around to find their comfortable position based on their thermal senses. Thermal sensory spots are created around people. The area between 1.25 meters and 2.0 meters around the user is defined as a warmer place. In this area, the earmuffs present a temperature of around 35 degrees. When people are in this area, many people will feel warm. It's just conceivable that people favor the warm spot as comfortable place. The area within 1.25 meters of a user is defined as a warmest place. In this area, earmuffs device presents the temperature around forty degrees. This area equals personal distance. When people are in this area, people will feel hottish.

We let users feel the edge of social distance implicitly by the difference of temperatures. We therefore thought we can gather people who don't know each other and let them enjoy communicating with others in a natural way by using our system. Through this communication, people will enjoy increasing their social skills.

3.2 Presenting Thermal Information

Thermal sensation is a kind of a haptic sensation and is a very familiar feeling. However, force and tactile feedback are the main sensory inputs presented to an operator

using a haptic display and there are few example of the utility as a thermal interface or a thermal display. For example, there has been work on incorporating thermal feedback into haptic devices [12, 13]. Thermal feedback can be used to convey information about the thermal conductivity of objects encountered in an environment which can assist in object identification, or in the creation of a more realistic image of the object [12].

A thermal characteristic has a larger ambiguity than that of visual and audio information. And the response time is longer than visual and auditory sensation [14]. These are the reasons why it is difficult to realize a thermal display which gives realistic thermal feedback. Alternatively, thermal feedback could be used as a new channel for the transmission of imaginary characteristics.

In this paper, we present thermal information to characterize the space. Thermal sensing is suitable for informing users gradually, without giving a clear border. By utilizing these characteristics, we inform users on the appropriate interpersonal distance and encourage them to communicate with each other.

3.3 Hardware Configuration

The experimental device is designed to be controlled by a computer as an operating unit via wireless communication, and all electronic modules that control temperature are installed in the earmuffs.

This system consists of several earmuffs like wearable devices (Figure 2) and a control unit that controls the wearable devices and recognizes their locations. Figure 3 shows the configuration of devices.

An IEEE 1394 camera with an infrared filter for earmuffs tracking is attached to the ceiling about 12 meters above the floor. Infrared LEDs are attached to the top of the earmuffs device for camera tracking. Sensing with a camera is easy to install if the camera has a clear line of sight to all wearable devices. Figure 4 depicts the

Fig. 2. Earmuffs device

system layout. When the control unit requests locations of the wearable devices, the camera detects their positions by capturing blinking infrared LEDs mounted on their tops.

To build a wearable device that displays warm temperatures, we use an Arduino Nano [15] as a microcontroller. It controls two Peltier devices in each side of the earmuffs. It also controls infrared LEDs. There are three heating levels on the Peltier device control. Two of them are heating and one is without heating level. The temperatures heated by the Peltier devices are about thirty five degrees and about forty degrees. We decide the temperatures as pleasant ones based on the knowledge about how we feel temperatures [16].

The control unit and the earmuffs device communicate via a Zigbee network. If the position is detected, the control unit generates thermal field based on all users' position, determines the heating level according to the thermal field, and sends the temperature level to the earmuffs device. Because the thermal fields are defined by the position of all users, the field changes dynamically.

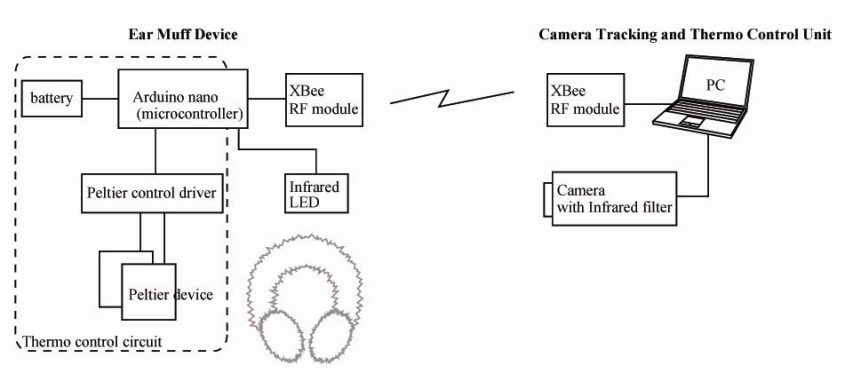


Fig. 3. Configuration of Earmuffs Devices and Control Unit

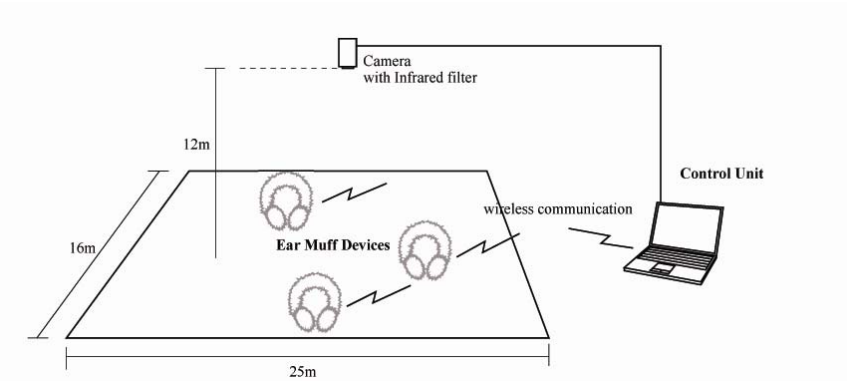


Fig. 4. System Layout

4 User Behavior

4.1 Experimental Settings

An experiment was performed to examine how the thermal information affects people's behavior and distance between people in open space. There were six earmuffss, which allowed six people to experience the system at the same time. This experiment was conducted in December 2008 at the University of Tokyo as an art exhibition. The air temperature during the experiment ranged from a low of 8 degrees to a high of 12 degrees in Celsius, averaging 10 degrees.

Approximately a total of 400 people ranging from teens to 60s experienced this system. All of them were told to put on the earmuffs device and walk around in the open space to find comfortable areas. The dimensions of the open space were about 25m x 16m. In order to examine the trajectories of people in that space, the system was programmed to record logs of positions detected by the control unit. Figure 5 and Figure 7 shows the gathered people by playing "Thermo-society." And Figure 6 shows the trajectories of gathered people shown in Figure 5 and the generated thermal field.

4.2 Analysis and Discussion

In this section, we present analysis of recorded data and discuss people's behavior in the space. In the experiment, we often observed that people who didn't know each

Fig. 5. Gathered People by Playing "Thermo-society" in public space

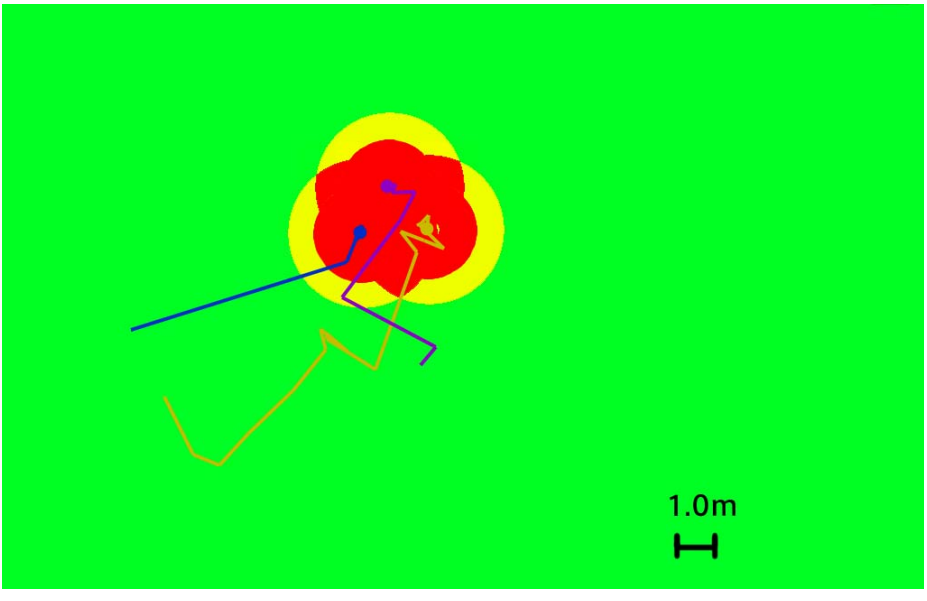


Fig. 6. The Trajectories of Gathered People in Figure 5. In this map, red areas are warm, yellow areas are slightly warm and green areas are at a regular temperature area. All people are standing in red area.

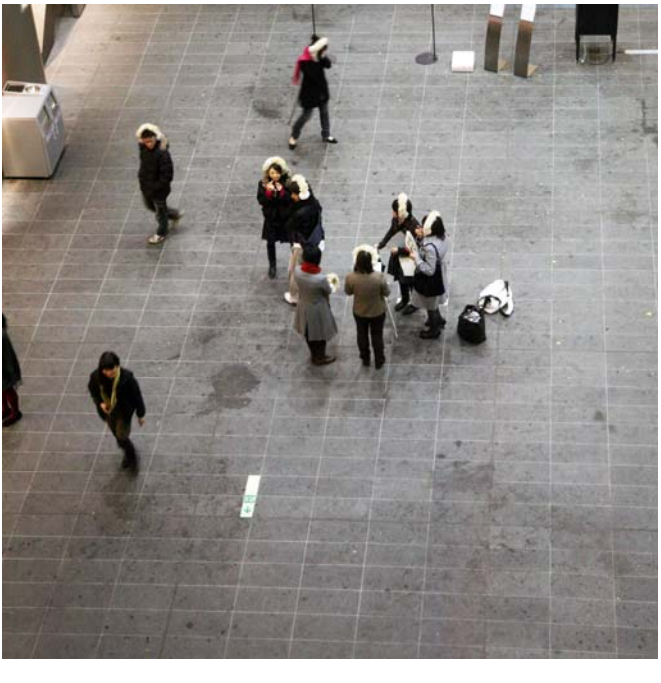


Fig. 7. A Bird's-Eye View of Gatherd People in “Thermo-society”

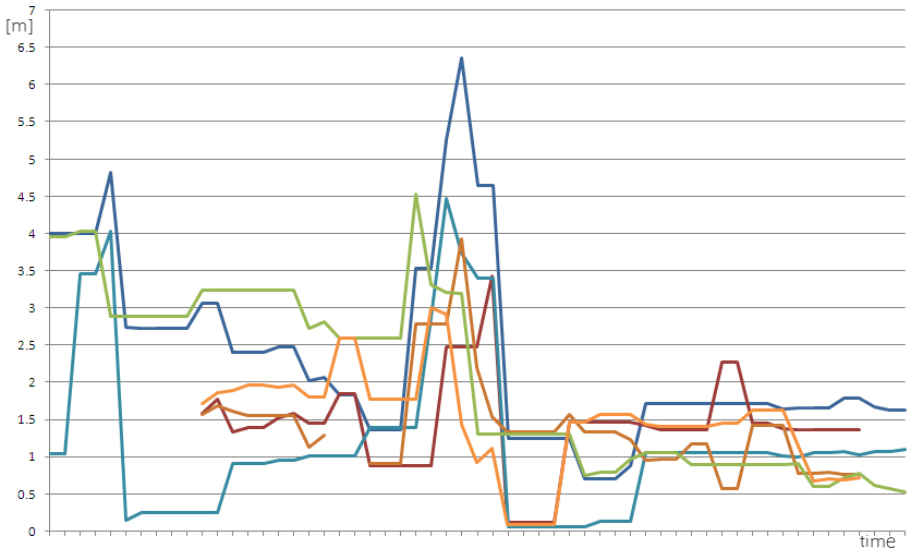


Fig. 8. Example Time-Series Data of Distance between Two Users

other gathered, formed groups and talked to each other in the groups. Then we analyzed the distance between two users to measure influences of our system.

Figure 8 shows example time-series data of distance between two users. Each line represents the distance between two users. When three users (USER A, B, C) played our system, three lines appear in the graph like the lines at the beginning of example time-series data shown in Figure 8. One is the distance between USER A and USER B, one is the distance between USER A and USER C, the other is the distance between USER B and USER C. When users walked around, the line went up and down severely like the lines in the middle of Figure 8. When users were standing still, the line went sideways and stable like the lines in the right of Figure 8.

To analyze the characteristic of the user behavior in a group composed of users, we extract the data of distance between two users when all the data are stable at the same time. We use a 6.5 hours data including 66 people for this analysis. We defined a person was "standing still" when he/she moved within 2.5 cm per second in this analysis. While members of a group don't change, distances among users will converge. When distances among users converged and all people standing still at the same time for over 15 seconds were found 34 times. The number of extracted data of converged distance between two users standing still is 104. Figure 9 shows the distribution of the extracted data.

Average distance between two users is 1.90 meters. In these data, we found some outlier. These are shown in the right side of the Figure 9. These data are no fewer than 6.5 meters, nor more than 13.5 meters. Figure 10 shows an example data of distance between two users including outlier data.

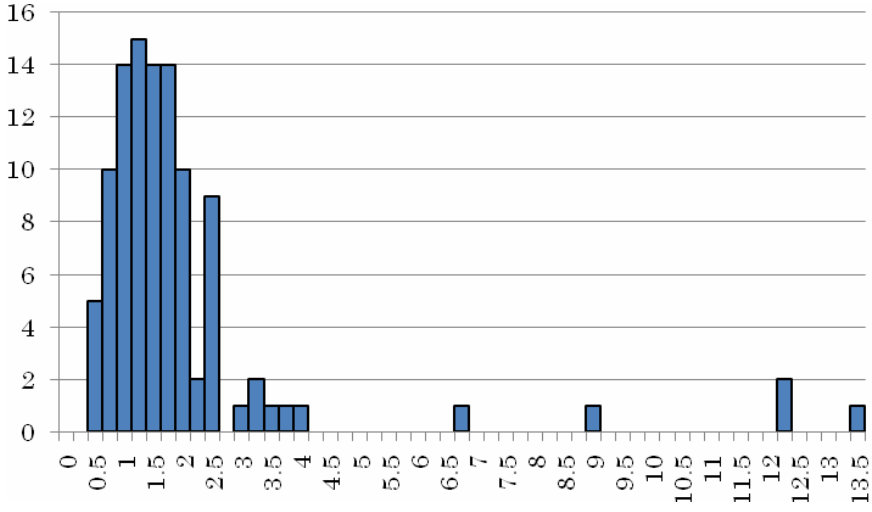


Fig. 9. Distribution of Converged Distance between Two Users Standing Still

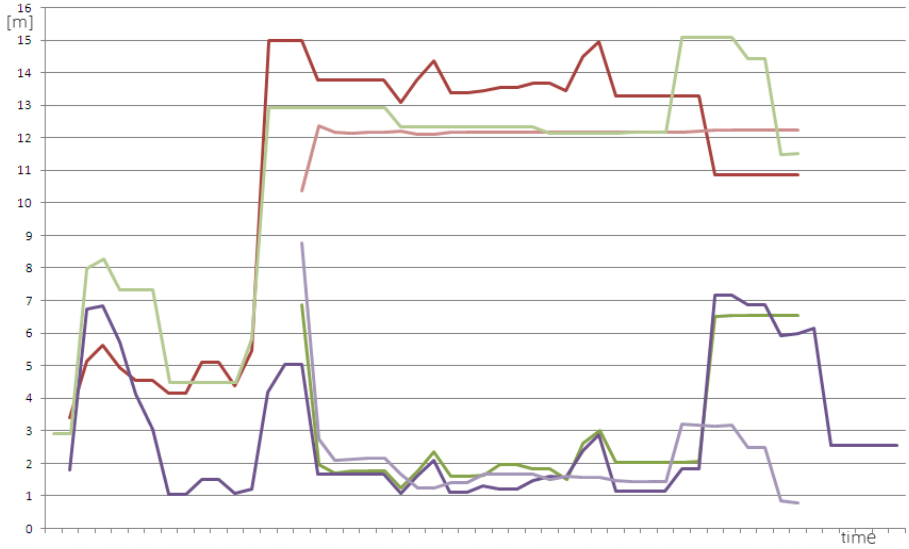


Fig. 10. An Example Data of Distance between Two Users Including Outlier Data The Data in center of this graph show users gather in two groups

We found that users gather in two groups when the outlier data occurs by observing the trajectories. The outlier data means the distance between two groups.

Since the distance between two groups is not the characteristic of the user behavior in a group, we remove the outlier data. As a result, average distance between two users in the same group is 1.45meters. This is in social distance and near the edge of personal distance.

Moreover 44 data (44.4%) of distance between two users standing still are within 1.2 meter. In the area of personal distance, we might allow strangers into the outer limits, but reserve the inner limits strictly for friends. However people allow strangers to come in personal distance in 44.4 percent cases by playing “Thermo-society.” We believe that this is because our system is effective to get friendly with strangers and works well as edutainment system for training social skills.

5 Conclusion

In this paper we propose a method to let us feel the appropriate interpersonal distance for social interaction by presenting thermal information. We created wearable thermal devices that transmit thermal information to the person wearing them and linked them to an edutainment system called "Thermo-society". “Thermo-society” is a system that creates thermal sensory spots around people in an open space. Thermal sensory spots are generated based on the knowledge of proxemics.

Through an experiment, we estimate the average distance between two users in the same group is 1.45meters. We noticed in our experiment that people, when playing Thermo-society, allow strangers to come in personal distance in 44.4% of the cases, which suggests that our system increases the potential for social interactions.

There is obviously a need for further improvement of the system and experiment. We need further investment about how people’s behavior changes if the thermal mapping to the corresponding interpersonal distances changes.

Acknowledgement

We would like to thank Taro Suzuki, Tomohiro Tanikawa, Takashi Kiriyama, Takeshi Naemura and Hiroshi Harashima. This research is supported by JST (Japan Science and Technology Agency), CREST (Core Research for Evolutional Science and Technology) and by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for JSPS (Japan Society for the Promotion of Science) Fellows.

References

1. Shigenori, T., Nagisa, H., Tomoki, M., Hiroshi, O., Hideaki, T.: Fundamental Study on Stress Management in Children (Second Report): The Effects of Social Skills on Stress Reduction in Children. Japanese Journal of Psychosomatic Medicine 43(3), 185–192 (2003)
2. Riggio, R.E.: Social interaction skills and nonverbal behaviors. In: Feldman, R.S. (ed.) Applications of Nonverbal Behavioral Theories and Research, pp. 3–30. Lawrence Erlbaum Associates, Hillsdale (1992)
3. Gresham, F.: Best Practices in Social Skills Training. In: Thomas, Grimes (eds.) Best Practices in School Psychology, pp. 1021–1030. The National Association of School Psychologists, Washington (1995)
4. Gupta, R.: BEST: a communication model. British Medical Journal (2006)
5. Weiser, M.: The computer for the 21st century. Scientific American (1991)

6. Wisneski, C., Ishii, H., Dahley, A., Gorbet, M., Brave, S., Ullmer, B., Yarin, P.: Ambient displays: Turning architectural space into an interface between people and digital information. LNCS, pp. 22–32. Springer, Heidelberg (1998)
7. Redström, J., Skog, T., Hallnäs, L.: Informative art: using amplified artworks as information displays. In: DARE 2000: Proceedings of DARE 2000 on Designing augmented reality environments, pp. 103–114. ACM, New York (2000)
8. Vernon, H.M.: Is effective temperature or cools power the better index of comfort? J. Industr. Hyg. 8, 592–601 (1926)
9. Hall, E.T.: The Hidden Dimension. Doubleday & Company, New York (1966)
10. Jones, E.E., Farina, A., Hastorf, A.H., Markus, H., Miller, D.T., Scott, R.A.: Social stigma: The psychology of marked relationships. W. H. Freeman and Co., New York (1984)
11. Nadel, E.R., Mitchell, J.W., Stolwijk, J.A.J.: Differential Thermal Sensitivity in the Human Skin, Pflugers Archiv. European Journal of Physiology, Pflfigers Arch. 340, 71–76 (1973)
12. Ino, S., Shimizu, S., Odagawa, T., Sato, M., Takahashi, M., Izumi, T., Ifukube, T.: A tactile display for presenting quality of materials by changing the temperature of skin surface. In: Proc. 2nd IEEE Int. Workshop on Robot and Human Communication, pp. 220–224 (1993)
13. Yamamoto, A., Cros, B., Hashimoto, H., Higuchi, T.: Control of Thermal Tactile Display Based on Prediction of Contact Temperature. In: Proc. IEEE Int. Conf. on Robotics and Automation, pp. 1536–1541 (2004)
14. Shklovski, I., Chang, M.: Guest editors' introduction: Urban computing.navigating space and context. Computer 39(9), 36–37 (2006)
15. Arduino, `http://www.arduino.cc/`
16. Chatonnet, I., Cabanac, M.: The Perception of Thermal Comfort. Int. J. Biometeor 9(2), 185–195 (1965)

Student Attitudes towards Using Culturally-Oriented Educational Games to Improve Programming Proficiency: An Exploratory Study

Phaedra Mohammed and Permanand Mohan

Department of Mathematics and Computer Science, The University of the West Indies, St. Augustine, Trinidad and Tobago
phaedra.mohammed@gmail.com, Permanand.Mohan@sta.uwi.edu

Abstract. This exploratory study investigates student attitudes towards culturally-oriented educational games for practicing computer programming, where the mainstream culture appeals to all of the students irrespective of their cultural background. We show that a shared appreciation of culture along the lines of humour promotes positive student attitude towards culturally-aware game based learning which in turn is useful for developing proficiency in specific programming skills such as error detection and correction. Details of the exploratory study undertaken using culturally-oriented educational game prototypes are described, along with the results of the study.

1 Introduction

Recruitment and retention are among the top reasons for using games in introductory Computer Science courses. With high drop-out and failure rates among first year programming students in many universities, a lot of attention has been given to finding better ways of improving student performance with particular emphasis on the use of educational/serious games. According to Bayliss and Bierre [2], games have been used to strengthen students' computing skills through practice and for gaining skills in software engineering with 'the common result of…more motivated students'.

Design principles for effective digital game based learning have been described in the literature from various perspectives and these principles have been used to guide the development of many educational games. Well defined learning goals, immersive storylines, achievable challenges, informative feedback, principled pedagogy, proper player profiling, and sound game mechanics are some of the frequent design recommendations advocated by researchers which align with mainstream ideas in instructional design and game design. The impact of each of these design considerations on the quality and the extent of learning resulting from these games has been the focus of many experiments and research projects; however one important dimension has not received as much scrutiny: the player's/learner's cultural background.

Culture is rapidly becoming an important consideration in the design of educational software firstly because of the increase in the number of users accessing software over the Internet, and secondly because of the sheer diversity in the cultural

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 196–207, 2009.

backgrounds of these users. Furthermore, culture significantly affects the way students learn, it defines their attitudes, strategies and general learning styles, and above all it gives insight into the source(s) of their motivational triggers ([5], [7], [16]). Despite these connections to the learning process, culturally aware learning environments are limited in practice largely because of the complexities in representing culture computationally since current instructional designs lack cultural sensitivity ([12]). Consequently, few educational games (with the exception of games for language learning [9] and development of intercultural skills [10]) take advantage of the utility of culture when leveraging and prolonging motivated student behaviour.

Computer Science has been traditionally considered to be culturally-neutral field [4] and as such, the large majority of the games developed for teaching/learning programming has been culturally-neutral as well. New studies in the upcoming field of Ethnocomputing, such as the work by Duveskog et al. [4], show that a culturally relevant context increases student motivation and triggers the creativity and self-directed learning of the students in a Java programming class in a Tanzanian secondary school. Eglash et al. [6] report similar increases in self-initiated learning when culturally-situated learning environments are used to teach students in African-American, Native-American, and Latino contexts. So far most of these studies leverage the benefits of computer-based instruction but very little (if any) work has been done using culturally-oriented educational games. Furthermore, most of these studies have focused on underprivileged or minority groups in societies where the mainstream culture clashes with the traditions and practices of these groups.

In light of this, we intend to investigate student attitudes towards culturally-oriented educational games for practicing computer science programming, where the mainstream culture appeals to all of the students irrespective of their cultural background. We believe that a shared appreciation of culture is useful for promoting positive student attitude towards culturally-aware game based learning which in turn is useful for developing proficiency in specific programming skills such as error detection and correction. The study focuses on the first year programming students at the University of the West Indies (U.W.I.), St. Augustine campus, and examines the issues involved in designing and developing cultural game prototypes which were used to evaluate these ideas. Details of the exploratory study undertaken, using these prototypes, are described along with the results of the study. The significance of these results in relation to our ideas regarding culture and learning is analysed, and the next set of steps to be taken to advance these ideas and the prototypes are discussed.

2 Cultural Context

The University of the West Indies is a multiple-campus institution spread across three Caribbean islands: Jamaica, Barbados, and Trinidad and Tobago. The majority of undergraduate students enrolled in the Computer Science degree program at the St. Augustine campus in Trinidad and Tobago are therefore native to the English-speaking Caribbean region with a predominant percentage originating from Trinidad itself. Many of these students are technological savvy indicated by their widespread usage of mobile phones, and constant preoccupation with online social networking tools and games. Their digital native status works to their disadvantage however since

the first year programming courses employ traditional instructional methods such as lectures, written coursework and final exams. Consequently, these courses have very low pass rates of less than 60%. In addition, few of these undergraduate students have prior programming experience, and many exhibit underdeveloped problem solving skills along with a halfhearted attitude towards practice. The cultural background of the students gives some explanation for this since rote teaching methods are commonly used in secondary/high school which discourages independent thought and creates an overindulgent reliance on oversimplified instruction. Furthermore, Trinidadian and Tobagonian (referred hereafter as Trinbagonian) culture encourages an easy-going attitude towards work which can be detrimental to the learning process, and often results in frustration for many of our first year students who expect the same or better academic results as in high school.

In spite of these challenges, there are useful aspects of Trinbagonian culture which, when harnessed properly, enhance and promote learning. The local vernacular is of particular interest since influences from the languages and cultures of East Indian, Chinese, African, Spanish, French, Amerindian, and British populations (as a result of colonization and indentureship) have been integrated to form a unique language, formally referred to as Trinidad English Creole (TEC), which sounds comical and is often satirical in a humorous way. The phonology of TEC adds even more dimension to the language since the pronunciation of a word can change its meaning. When TEC is used to describe the customs and everyday events characteristic to Trinidad, the local culture can be represented as a narrative that has comedic appeal especially when represented as an educational game.

Humour plays an important role in learning environments because it promotes a lighthearted and memorable learning experience, enhances a student's mood through affective learning and also commands the student's attention and encourages retention of material as a result of comical moments [3]. Humour also promotes greater student interaction and social discussion of amusing anecdotes used in the learning process. Dormann and Biddle [3] go on to add that humour can be used to diffuse frustration and hostility because it decreases the pressure (on the student) to learn and perform. This is valuable especially for the Computer Science discipline where academic competition is stressful and where the material being learnt is difficult or abstract. Cultural humour, featured in an educational game, therefore opens up many possibilities for stimulating motivation, and increasing interest.

3 Game Design

Three designs were created for testing student attitude towards culturally-oriented learning games. Familiar aspects of Trinbago culture, such as real-life events, were selected for the designs based on how easily they could be implemented in a game with an acceptable level of authenticity. Believable and convincing mimicry of cultural events is important because it stimulates player engagement by appealing to the player's curiosity [11]. Queiroz [14] states that by using gameplay rather than graphics, the cultural elements in a game become more authentic. Consequently, references to comical cultural behaviour were chosen for developing the humour of the games, and this mainly took the form of phrases and terminology expressed in TEC language.

The learning objectives featured in the game designs were restricted to developing specific programming skills such as attention to and recall of proper syntactic details through continuous practice. This decision was based on research suggesting that games are helpful for developing accuracy and fluency in analytical skills [1], and also because of the weak error detection and error correction skills possessed by the target student audience. Therefore, the learning activities were structured as snippets of code riddled with syntactic errors which students had to repair. Now since most educational game designs stand the risk of becoming boring drill exercises, Habgood et al. [8] suggest that the most enjoyable parts of the games should be used as the learning activities. This advice was followed in our designs, and the learning activities were delivered in such a way that the outcome of the activities had a direct effect on the events in the games. All three game designs had different cultural elements, different storylines, and different game objectives. The learning objectives however were maintained across the designs, as were the overall structure and form of the learning activities. A brief description of the ideas behind the three designs is given below.

3.1 Game Design Ideas

Food, language, and local events are the main cultural elements in these designs which are based on a larger design described in [13].

KFC Delivery Driver. In this game, the player has to deliver Kentucky Fried Chicken (KFC®) food products to a customer by programmatically controlling the features/functionality of his/her vehicle. In Trinidad and Tobago, KFC® is a popular fast food choice, and a common discussion point is the tardiness/absence of local delivery drivers. In this game, the player is guided to the customer's location by a series of navigational instructions, and along the way the player must try to avoid road obstacles or risk damage to his vehicle's functionality. When programming exercises related to a specific car operation are completed correctly, the respective functionality of the car is activated otherwise it is deactivated or partially restored. Common road obstacles in Trinidad include animals crossing the road randomly (cows, goats, dogs), large potholes (often filled with strange debris to alert drivers of the impending danger), and abrupt stops made by local taxi drivers**.**

Lazy Earl. In this game, the player takes on the role of Earl, a young boy who has to search for and collect items on a shopping list given to him by his mother. Local items with laughable uses and amusing names are featured on the list. Earl is a forgetful, lazy child so his mother hires a taxi to drive Earl around, help with the collection of the shopping, and then bring him home safely. Earl being far lazier than his mother believes equips himself with a faulty audio device which speaks on his behalf when certain buttons are pressed. (This is a reference to the improvisational, behaviour of Trinbagonians where short cuts are often taken to reduce the amount of work to be done.) Not having a clue as to where to find the items, Earl goes to the market, the grocery and the hardware store where he has to interact with the shopkeepers in order to get the items. In the game, Earl poses questions to the shopkeepers using his audio device if he wants an item or if he wants to know where to find the item, or the price of an item. TEC language is featured strongly in this game, and players must fix the device when it speaks incorrectly by fixing the errors in the code controlling the

functionality of the specific buttons; the respective functionality of the device is restored otherwise it is remains faulty and produces garbled phrases.

Home Food. In this game, players have to collect food items by programmatically controlling the features/functionality of their game character (hero) in a side-scroller game. Players must fight thieves and collect items which are presented at the end of the game to the chef. With these items, the chef prepares a home cooked meal for the player. In order to control the behaviour of their character, errors in the code controlling a specific hero operation must be repaired correctly so that the respective functionality of the hero is activated otherwise it is deactivated. Local food and raw ingredients are the main cultural elements in this game; the various combinations of the ingredients collected by the player result in unexpected dishes which are amusing but authentic. In addition, the behaviour of the chef reflects the cultural attitude of Trinbagonian in rewarding and admonishing the player with bantering comments.

4 Development of Game Prototypes

4.1 Game Programming Course

From September to November 2008, the game programming course, COMP3900, was run at U.W.I. with 16 final year undergraduate students. The batch of students enrolled in the course were proficient Java programmers and so they were required to build games for the course and many succeeded in creating two complete non-educational games for their first and second assignments within a short period of time. Their third assignment focused on building an educational game based on the game designs described in the previous sections. Using Java, the students were given three weeks to build a fully functional game based on any of the three designs described earlier. In addition, the students were given the choice of modifying the designs so long as the presence of cultural elements and the design of the learning activities were maintained. Only two students were able to deliver complete, working games suitable for testing. These prototypes are described in the next subsection.

4.2 Prototypes

Caribbean Conquest. This single-player, turn-based game features two islands of the Caribbean, where the player (representing Trinidad and Tobago) has to conquer unsettled islands before the enemy (Barbados) by sending people to settle the island within a specific time as shown in Figure 1 below. For this game, the student developer chose his own game design which incorporated the desired learning activity design. However, the use of culture was too subtle and failed to establish the humour required as in the original designs. Nonetheless, the graphics and use of sound produced a high quality gaming experience. Players have to solve the programming problems during the game and if they succeed their islands' defenses are strengthened otherwise the enemy gets a boost in defense. The problems followed the design criteria by testing the player's skill in error detection and correction of C code where the player has to select the line of code with an error and then type in the correction. Figure 1 also shows a sample of the exercises presented to the player.

Fig. 1. Caribbean Conquest screenshots: Example of a learning activity (left) and Uncaptured islands being settled by Barbados (right)

Fig. 2. Screenshots of the grocery (left) and hardware (right) scenes in the culturally-oriented educational game, Lazy Jim. In these scenes, Jim and the shopkeepers interact using the local dialect of Trinidad and Tobago

Lazy Jim. As shown in Figure 2 below this game closely follows the design laid out in Section 3.1 with some modifications introduced by the student. Here, the student opted to have the main protagonist (Jim) speak clearly at times and distortedly at times. The TEC language phrases are used in the game to give feedback to the player concerning the location of the shopping items. The grocery scene in Figure 2 illustrates the use of a common Trinbagonian expression, "Ehh?" by the shopkeeper after Jim asks a garbled question which in this context means "What did you say?" The shopkeeper in the hardware scene also uses TEC when he says "I doh have that here nah" which means "I don't sell any of that here". The word 'nah', also a common expression, is used for emphasis in this context. The student combined some of the design features of the games described in Section 3.1 in this game since some of the shopping items in *Lazy Jim* are clearly referred to using local terms. Examples include a jooking board (a wooden washing board used for scrubbing clothes), conchs (shellfish), Crix (a local biscuit/cracker), Powermint (a local brand of mint candy) and so on. Pictures of some of these items were even included in the game as shown in Figure 2. The learning exercises in *Lazy Jim* are similar to those

of *Caribbean Conquest* where the player has to identify the line of code with an error and then suggest the correct substitution. Incorrect answers did not have any disadvantageous effects on Jim's abilities in the game other than not getting any additional information from the shopkeeper in question. As such this game was more slowly paced than *Caribbean Conquest*.

5 Exploratory Study and Evaluation

An exploratory evaluation of the two game prototypes was conducted with the first year programming students in order to evaluate their attitudes towards the use of culture for practicing programming. The study was broken up into two parts: participation in a game day, and completion of a questionnaire. Twenty-four students, 21 males and 7 females, aged between 18 to 22 years were involved in the study. Of these students, 13 were of East-Indian descent, 3 were of African descent, 7 were of mixed ethnicities, and 1 student did not specify her ethnicity on the questionnaire. This student stated that she never played video games while the remaining 23 students indicated that they played games several times monthly confirming the digital native prevalence among our students.

5.1 Method

A game day was scheduled on November 27, 2008 where the students were allowed to play, from 1 p.m. until 4 p.m., with all of the games developed by the game programming students. Over thirty non-educational games were showcased that day along with the two cultural prototypes described in Section 4. Questionnaires were given to the students who participated in the game day to gauge their interest in digital game based learning, to find out what they thought about using culture and games, and to get their opinion concerning the effectiveness and utility of the culturally-oriented game prototypes. Demographic data and details about the students' gaming behaviour were also collected. The questionnaire consisted of a series of close-ended questions patterned as five-point Likert items along with several open-ended questions and space for additional comments

5.2 Evaluation Results

Student Prototype Preferences. Analysis of the information collected in the questionnaires revealed several interesting results. Nearly all of the players who played with *Lazy Jim* liked the game whereas almost half of those who played with *Caribbean Conquest* did not like the game. This happened even though *Caribbean Conquest* had better graphics and sound compared to *Lazy Jim*. Students liked to play *Lazy Jim* because it was entertaining, comical, and they took delight in the dialect (use of TEC). Some even gave examples of what they found to be funny, citing "Chan is d man" which is an advertisement slogan for a local hardware store (referred to in the game) made popular by a Trinidadian comedian. One student rated the use of culture in *Lazy Jim* as 'very enjoyable' and elaborated that "my friend learned what a jooking board was"; this shows that the students' curiosity about their own culture promotes an enjoyable experience especially when in a group. Another student

reported that she liked *Lazy Jim* the best but the programming problems could have been more challenging (she rated her programming proficiency as somewhat strong). This student however enjoyed the problems in *Caribbean Conques*t but the confusing gameplay caused her to discontinue playing. In fact, a survey of the responses of all of the students who did not like *Caribbean Conquest* indicated that the main reasons were the confusing gameplay and difficult learning activities even though tutorial and instruction menu options were included in the game by the student developer. Despite this, most students said that the game helped with syntactical error detection which was one of the original instructional objectives. In general, the students highlighted *Lazy Jim* as being more enjoyable for this activity though.

Student Attitudes towards Culture and Learning. The graphs in Figure 3 illustrate student opinions expressed in the questionnaire regarding the use of culture and learning and their preferences concerning the extent to which culture should be used. Few students (less than 10%) were actually opposed to using culture and most of the students were either neutral to the use of culture (33%) or enjoyed the use of culture (42%) as shown in the upper graph. The lower graph in Figure 3 gives further support for this observation where the large majority of students (83%) approve of the use culture in an educational game whereas only a small minority (8%) disapproves.

A finer-grained analysis of reasons behind the students' preferences for and against the use of culture is summarised in Table 1. Consistent with the trends shown in the graphs above, the table reinforces the observation that the majority of students support the use of culture. 87% of the responses stemmed from positive student attitude towards the relationship between their culture and their learning experiences. Enriching learning experiences, national pride, and humour were the top reasons cited by students for

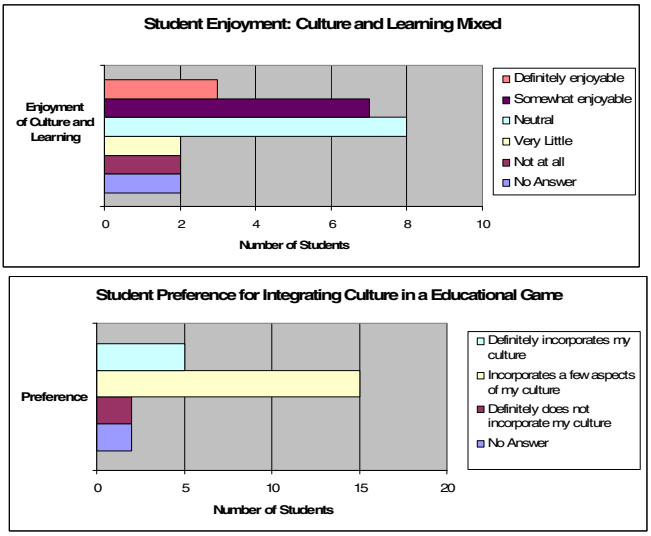


Fig. 3. Two graphs showing student opinion concerning mixing culture and learning (top) and student preference for integrating culture in an educational game (bottom)

Table 1. Percentage of student responses for and against using culture in an educational game

Student reason	Responses
I would feel proud to see my culture represented in an educational game	30%
My culture enriches my learning experience and I would remember things more	23%
My culture makes me laugh	20%
I would enjoy my learning experiences more	14%
There are more interesting characters and storylines for a game than my culture	2%
Culture has nothing to do with learning	2%
Culture doesn't go well with a game	2%
My culture has its merits, but some of its aspects are better left out of the classroom	0%
I am ashamed of everything in my culture	0%

which they would use a culturally-oriented educational game. 7% of the students did not respond at all, but 6% opted against using culture in an educational game mainly because of the perceived disconnect between culture and an educational game.

6 Discussion of Results

When designing a culturally-oriented educational game, design issues relevant to the introduction of cultural elements need to be examined. Particular attention must be paid to the authenticity and relevance of the cultural elements to the target audience. In the case of *Caribbean Conquest*, the use of culture was too general to have any lasting effect on the first year students. *Lazy Jim* on the other hand featured specific cultural aspects which had considerable impact because of their familiarity to the students. Simple use of small elements of culture such as a common expression of puzzlement ("Ehh") and images of everyday items gave *Lazy Jim* an edge over *Caribbean Conquest* because of the subtle use of humour. Furthermore, since these games were educational, the learning exercises affected the students' gaming experience. Unlike in *Lazy Jim*, poor performance in the learning activities in *Caribbean Conquest* strengthened the player's opponent which was not the best design choice since the odds of the player achieving success in the game were reduced. It was very much like a penalty for getting an answer wrong. This clearly reduced the students' interest to continue playing as reported in subsection 5.2. Though not a cultural design consideration, this result stresses the importance of maintaining the core feature of a game: games should be fun to play. With respect to the confusion experienced by the students when playing *Caribbean Conquest*, admittedly the gameplay was somewhat difficult to follow primarily because of the strength given to the opponent when the player gave a partially correct answer or an incorrect answer. Nonetheless, the students who played both these games all noted that the games were helpful for increasing their error detection and correction proficiency; this is a purely self-reported observation but it is a useful indicator for future study. Although the ethnicity range in the sample was not a true representation of the diversity in Trinidad and Tobago, generally the use of culture had broad appeal across ethnicity. No ethnic group showed a stronger or a weaker preference for culture over another. Gender

preferences for culturally-oriented learning were slightly skewed towards female students who all reported either neutral or positive attitudes towards culture. Male students had a larger variation in their attitudes to culture and learning which ranged from mostly negative to very positive. However, we must state that this evidence is anecdotal at best because of the small sample size.

Another weakness in this study related to the sample size is that a small number of students played with the cultural prototypes because of the sheer number of games available during the game day. A restriction should have been placed on the students so that they would all have been exposed to the cultural prototypes. One of the questionnaire items asked the students to identify their favourite educational game, and many students named several of the non-educational games showcased on the game day. An interesting side-effect of this flaw was that several students identified a non-educational game, Space Rasta (shown in Figure 4 below), as their favourite. This game is filled with cultural Rastafarian symbols (commonly understood in Trinidad and Tobago) used in an entertaining, witty manner which attracted the attention of more than a few students who ended up laughing. For example, power-ups for the hero in the space ship (a Rasta complete with dreadlocks and the representative Ethiopian colours in his hat) took the form of 'spliffs'- bundles of marijuana ready for smoking. Although this game was not meant to be evaluated in the study, it provides further evidence that our students already have the propensity towards developing and using culturally charged material since the use of culture in this game's design was entirely voluntary on the part of the student developer. In addition, the student built this game for an earlier assignment prior to the introduction of the cultural game designs. This raises some interesting questions concerning the extent and the reasons for which our Computer Science students currently integrate cultural aspects into their learning experiences on a purely self-regulated basis.

Fig. 4. Side-scroller action game: Space Rasta

7 Conclusion and Future Work

The exploratory study revealed that the first year programming students at U.W.I. are receptive and interested in the use of culturally-oriented games for practicing and gaining skill in programming. Over 80% of the students appreciated the use of culture in the game prototypes and were especially engaged when humour was involved. The

feedback received on these prototypes gives encouraging evidence that culture can indeed be represented with an acceptable level of authenticity in an educational game. Since the primary aim of this study was to evaluate student attitudes towards culturally-oriented educational games and not measure actual learning gains at this time, future work is planned for the refinement of these prototypes to measure and track learning gains resulting from cultural influences during gameplay. Specifically, improvements are planned for the learning activities, game mechanics, and motivational tactics used in the game. A limited amount of cultural elements were used in the prototypes, so expansion of the cultural coverage in the games is also necessary. Studies will also be conducted using larger sample sizes in order to confirm the results of this exploratory study. We will also like to examine whether culturally-oriented games have an impact on student learning gains in comparison to culturally-neutral games, and whether certain aspects of culture produce greater effects than others.

References

1. Baker, R.S.J.d., Habgood, M.P.J., Ainsworth, S.E., Corbett, A.T.: Modeling the Acquisition of Fluent Skill in Educational Action Games. In: Conati, C., McCoy, K., Paliouras, G. (eds.) UM 2007. LNCS, vol. 4511, pp. 17–26. Springer, Heidelberg (2007)
2. Bayliss, J.D., Bierre, K.: Game Design and Development Students: Who are they? In: Young, M. (ed.) Proceedings of Third International Conference on Game Development in Computer Science, pp. 6–10. ACM, New York (2008)
3. Dormann, C., Biddle, R.: Humour: Why are Serious Games so Serious? In: Taisch, M., Cassina, J. (eds.) Proceedings of Learning with Games LG 2007, pp. 449–456 (2007)
4. Duveskog, M., Sutinen, E., Tedre, M., Vesisenaho, M.: In Search of Contextual Teaching of Programming in a Tanzanian Secondary School. In: Frontiers in Education 2003, vol. 2. IEEE, Los Alamitos (2003)
5. Economides, A.A.: Culture-Aware Collaborative Learning. Multicultural Education & Technology Journal 2(4), 243–267 (2008)
6. Eglash, R., Bennett, A., O'Donnell, C., Jennings, S., Cintorino, M.: Culturally Situated Design Tools: Ethnocomputing from Field Site to Classroom. American Anthropologist 108(2), 347–362 (2006)
7. Gilbert, J.E., Arbuthnot, K., Hood, S., Grant, M.M., West, M.L., McMilllan, Y., Cross, E.V., Williams, P., Eugene, W.: Teaching Algebra Using Culturally Relevant Virtual Instructors. The International Journal of Virtual Reality 7(1), 21–30 (2008)
8. Habgood, M.P.J., Ainsworth, S.E., Benford, S.: Endogenous Fantasy and Learning in Digital Games. Simulation and Gaming 36(4), 483–498 (2005)
9. Johnson, W.L., Wu, S.: Assessing Aptitude for Learning with a Serious Game for Foreign Language and Culture. In: Woolf, B.P., Aimeur, E., Nkambou, R., Lajoie, S. (eds.) ITS 2008. LNCS, vol. 5091, pp. 520–529. Springer, Heidelberg (2008)
10. Lane, H.C., Hays, M.J.: Getting Down to Business: Teaching Cross-Cultural Social Interaction Skills in a Serious Game. In: Proc. of the Workshop on Culturally Aware Tutoring Systems, pp. 35–46
11. Malone, T.W., Lepper, M.R.: Making Learning Fun: A Taxonomy of Intrinsic Motivations for Learning. In: Snow, R.E., Farr, M.J. (eds.) Aptitude, Learning and Instruction: III. Conative and Affective Process Analyses, pp. 223–253. Erlbaum, Hilsdale (1987)

12. McLoughlin, C., Oliver, R.: Designing Learning Environments for Cultural Inclusivity: A Case Study of Indigenous Online Learning at Tertiary Level. Australian Journal of Educational Technology 16(1), 58–72 (2000)
13. Mohammed, P., Mohan, P.: Using Culture to Motivate Learning in a Digital Game based Learning Environment. In: Proc. of Workshop on Culturally Aware Tutoring Systems, pp. 59–70 (2008)
14. Queiroz, C.: Placing Cultural Elements in Gameplay (2006), http://www.nongames.com/articles/pceg/
15. Robbins, C.: Providing Cultural Context with Educational Multimedia in the South Pacific. Educational Technology & Society 9(1), 202–212 (2006)
16. Savard, I., Bourdeau, J., Paquette, G.: Cultural Variables in the Building of Pedagogical Scenarios. In: Proc. of Workshop on Culturally Aware Tutoring Systems, pp. 83–94 (2008)

Towards Intelligent Computer Assisted Educational Role-Play

Mei Yii Lim[1], Ruth Aylett[1], Sibylle Enz[2], Michael Kriegel[1], Natalie Vannini[3], Lynne Hall[4], and Susan Jones[4]

[1] School of Mathematical and Computer Sciences,
Heriot Watt University,
Edinburgh, EH14 4AS, Scotland
{myl,ruth,michael}@macs.hw.ac.uk
[2] Otto-Friedrich-Universitaet Bamberg,
Kapuzinerstrasse 16,
D-96045 Bamberg, Germany
sibylle.enz@uni-bamberg.de
[3] Universitaet Wuerzburg
Lehrstuhl für Psychologie IV
Roentgenring 10, D-97070 Wuerzburg
natalie.vannini@psychologie.uni-wuerzburg.de
[4] School of Computing and Technology,
University of Sunderland
{lynne.hall,susan.jones}@sunderland.ac.uk

Abstract. This paper investigates how graphically displayed intelligent virtual actors, mobile devices and innovative interaction modalities can support and enhance educational role-play as well as deepen the sense of engagement and presence in participants to produce more successful learning. The discussion will be presented using a showcase from the eCIRCUS project, ORIENT, an application combining virtual and real life role-play for social and emotional learning.

Keywords: Educational role-play, social and emotional learning, intelligent virtual actors, innovative interaction modalities.

1 Introduction

Role-play (RP) is a vital tool across a wide range of education and training scenarios, from adults in organisational or therapeutic contexts to children in schools. RP has been proposed as an engaging way to help solve inter-personal problems and increase team cohesion (eg. [1,2]). It covers several aspects of Bandura's Social Learning Theory [3], for example, in emphasizing the difference between the acquisition and the performance of behaviour as well as the importance of providing secure settings for the experimentation with new behavioural strategies. Role-play supports the creation of knowledge and meaning from concrete - though imagined - experiences ("prehearsal", [4]) and uses social

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 208–219, 2009.

interaction and emotional engagement as mechanisms for a learner-centred constructivist approach. It can be used for organisation-based learning where more conventional eLearning approaches are not effective given that the social setting may be a crucial factor to the success of the learning process.

If RP is embedded in an educational setting and is guided by a facilitator, the testing of new behavioural strategies is immediately followed by feedback from the social environment (the facilitator and the other players) serving as a source of information for the role-player about the appropriateness or suitability of their actions. Social interaction is used as the stimulus for challenging and changing existing beliefs and can result in significant behavioural changes because it is easier to empathise with another person under certain circumstances if one has experienced something similar. Therefore, through RP, empathy can be evoked when an individual attempts to understand another by imagining the other's perspective. It consequently influences the subjective evaluation of a person regarding his or her social skills and accordant self-efficacy.

The educational impact of role-play draws on the 'willing suspension of disbelief' by participants who commit to the roles they have been asked to play. Producing this feeling of social presence in the role-play world involves willingness to participate, the production of supporting materials, skilled facilitation and often the use of extra supporting actors. None of this is easy. For these reasons, the use of virtual worlds, providing opportunities for exploration, practice, experiments and construction, seem a desirable way of augmenting traditional learning tools. These allow for experiential learning in safe and secure learning environments, in particular for social and emotional learning in complex social situations without the risks that the learner faces in a real social situation. This paper presents an attempt to take advantage of the aforementioned benefits of role-play in cultural awareness education.

2 State-of-the-Art

The obvious example of technology-based role-play is of course massively multiplayer online games such as World of Warcraft and Everquest. These are however entirely computer based and do not take advantage of new generations of interaction technology allowing the role-play to take place in the real rather than the virtual world. Though strongly social in nature, the rich human interaction modalities of voice, face, body are severely limited by the impoverished repertoire of graphical avatars, the use of keyboard and mouse as the interaction mechanism, and the lack of geographical co-location.

One of the earliest attempts to deal with these issues was the so-called Alternate Reality Game, Majestic, launched by Electronic Arts in 2001. It aimed at blurring the lines between fact and fiction, and players were given clues via mysterious midnight phone calls, anonymous e-mails and faxes, and fake websites. It failed as a game, but subsequently a distinct genre of pervasive games both for entertainment and education has come into being, often drawing on the wide

availability of mobile devices. Educational examples include Virus [5], Paranoia syndrome [6], Virtual Savannah [7] and Environmental Detective [8].

A challenge for a technology-supported role-play lies in the role usually played by the human facilitator (often referred to as game master) in shaping the narrative experience and the pedagogical outcomes, which usually depends on post-role-play reflection or debriefing. Without feedback prompting reflection on the role-play, the transfer to real-world settings cannot be ensured. Current work in Interactive Narrative divides into 'plot-based' approaches, in which events are pre-authored, and 'character-based' approaches, in which narrative structure is generated by interaction - emergent narrative [9]. An example of work that adopted the 'character-based' approach is the software FearNot! [10]. In FearNot!, characters run the FAtiMA [11] architecture, including a generative planner. Plot-centred approaches may also involve generative planning [12] but risk conflict between pre-determined outcomes and character freedom-to-act, problematic in role-play where human actors require interactional freedom with each other and the virtual actors.

Our software showcase for the eCircus project, ORIENT addresses issues mentioned above and takes a first step towards intelligent computer assisted educational role play. In the following sections we are going to discuss this project in detail.

3 Role-Playing in ORIENT

The motivation for creating ORIENT was to transfer the empathic learning concepts applied in FearNOT! for anti-bullying education to the domain of intercultural empathy. ORIENT (Overcoming Refugee Integration with Empathic Novel Technology) provides a RP and story framework for virtual actors that establish credible and empathic relations with the learners. It aims to develop models within which narrative engagement and empathy can be used to understand social, cognitive and emotional learning processes through RP. Its focus is on integration of refugee/immigrant children in schools. It attempts to create an environment to support affective engagement in social and emotional learning by investigating methods that allow individuals and groups to interact in physical as well as the virtual world, with user roles including both spectator and actor.

Although there has been plentiful research on empathy, there is limited knowledge and understanding of the role of empathy for technology-enhanced learning processes. This problem is exacerbated by a lack of holistic models for the social and emotional process that consider intrapersonal (cognitive, affective), interpersonal (role-play), and situational variables that are at the basis of learning processes. ORIENT tries to address this issue. Its innovative approach offers the possibility to explore physiological, psychological and cognitive aspects of social and emotional learning provided through interactive educational RP to reach an improved understanding of learning processes on an intrapersonal as well as an interpersonal level.

3.1 The Game

ORIENT is designed to be played by a group of 3 teenage users between the age of 13 and 14, each a member of a spaceship crew. Their mission takes them to a small planet called ORIENT, which is inhabited by an alien race, the nature loving Sprytes. These are autonomous affective characters with individual personalities able to express emotions.

The Sprytes culture has been defined based on a subset of Hofstede dimensions [13]. The dimensions of cultural variability according to Hofstede - individualism-collectivism; uncertainty avoidance; power distance; and masculinity-femininity - exist in all cultures at the cultural and individual level and one characteristic within each dimension tends to predominate. Individualism pertains to societies in which the ties between individuals are loose while collectivism pertains to societies in which people from birth onwards are integrated into strong cohesive ingroups. The dimension of uncertainty avoidance deals with the degree, to which members of a culture try to avoid uncertainty. The power distance is the extent to which the less powerful members of institutions and organisations accept that power is distributed unequally. Lastly, masculine and feminine cultures are particularly differentiated through gender role distribution. The Sprytes are collectivistic, being largely compassionate with each other and live in a group where the majority holds power. They are hierarchically organised (high power distance) hence believe in using force to influence others and they take uncertainty as threat (high uncertainty avoidance). Gender is absent in the culture and their graphical representation as can be observed in Figure 1(a) and Figure 1(b). Additionally, they are gestural creatures where gestures form an important mean of communication as shown in Figure 1(b) where one of the Spryte is scolding the users while the other is expressing its anger through a gesture, unique to the Spryte culture.

According to Baylor and Ryu [14], a social relationship between learners and agent builds a key mechanism to foster interaction and promote learning within

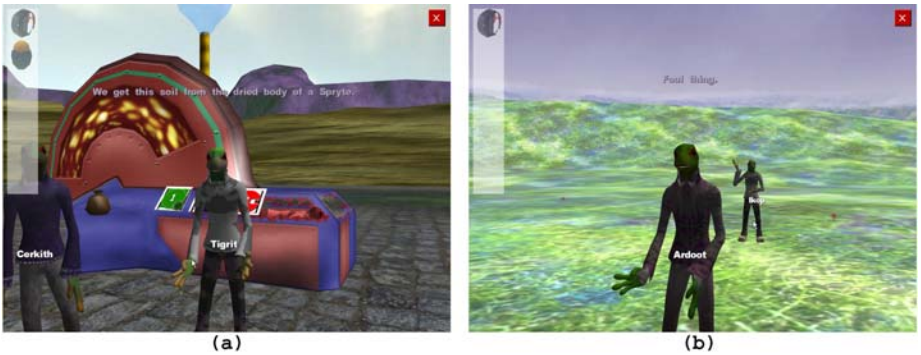


Fig. 1. (a)A Spryte explaining their life cycle; (b)Angry gesture to the user for stepping on a little tree

a computer-based learning system. The users task in ORIENT is to prevent a catastrophe in the form of a meteorite that is on destruction course with the planet. During the mission, the users will have a chance to witness the Sprytes eating habits, life cycles - recycling the dead (Figure 1(a)), educational styles, family formation and value system - trees are sacred (Figure 1(b)). This general story framework allows the users to appreciate cultural differences by trying to integrate themselves into an alien culture in order to gain the aliens' trust and eventually work together with them to save the planet. They can achieve this by empathising and exhibiting acceptable social conduct at different stages of the interaction to help and avoid enraging the Sprytes. Once a positive relationship is established between agents and users, motivation and interest are enhanced, hence constructive learning is possible [15].

In addition to the cultural-awareness function, ORIENT can be seen as a team building exercise where users play as a single entity rather than as individuals, distinguishing the application from other role-playing games. Although each user has a different role, these roles are closely related and all users have the same goal in the game. The main purpose of communication is to engage in social interaction as opposed to accomplish a task as efficiently as possible. Attitudes, emotions and behavioural reactions are prompted through the Sprytes that are reflected upon and discussed in the team of learners that collaboratively try to meet a common goal through understanding and empathising with members of this other culture.

The virtual world setting is of crucial importance here: it encourages the experimentation with different behavioural strategies and thus leads to the exploration of other experiences, behaviour and ways of thinking. The setting presents a possibility for the users to experience encounters and relations with members of another culture and engage affectively. The users can learn in safe and secure environments without the risks that they might face in real complex social situations, allowing them to experience the character's emotions and problems in a distanced way, while being at the same time engaged in what happens to the characters.

Running real life role-plays can be very expensive with respect to manpower and time for developing appropriate scenarios, for executing and facilitating them, analysing them and providing proper feedback for the learner. The use of virtual actors in ORIENT both reduce the expense and complication of organising role-play where real actors might otherwise have to have been used, and help to reinforce 'in-role' behaviour in learners by supporting the believability of the role-play world.

3.2 The ORACLE

Moreover, ORIENT includes the ORACLE (Onboard Resource Agent for Cultural and Liaison Engagements Figure 2), an embodied computer character running on a mobile phone device that plays the role of a human facilitator. The ORACLE performs its pedagogical function by asking appropriate questions and providing help during the mission to motivate and keep the users engaged. It

stimulates users' reflection on events and experiences in ORIENT by commenting on users' actions and by encouraging the recording of both personal and collective diaries. It can interact with the users reactively (users ask a question and ORACLE replies) or proactively (intervenes when necessary to help the users fulfil a task). When the mission is completed, the ORACLE carries out a "debriefing" session with the user where they report on the information collected during the mission, allowing transfer of acquired experiences to real world situations.

4 Technology

4.1 System Components

Figure 2 gives an overview of the main components that constitute the ORIENT system. At the core of the system is a world model that stores various elements of the virtual world using logical representations. The virtual world is presented to the user as 3D graphics rendered in the Ogre3D graphics engine. The users

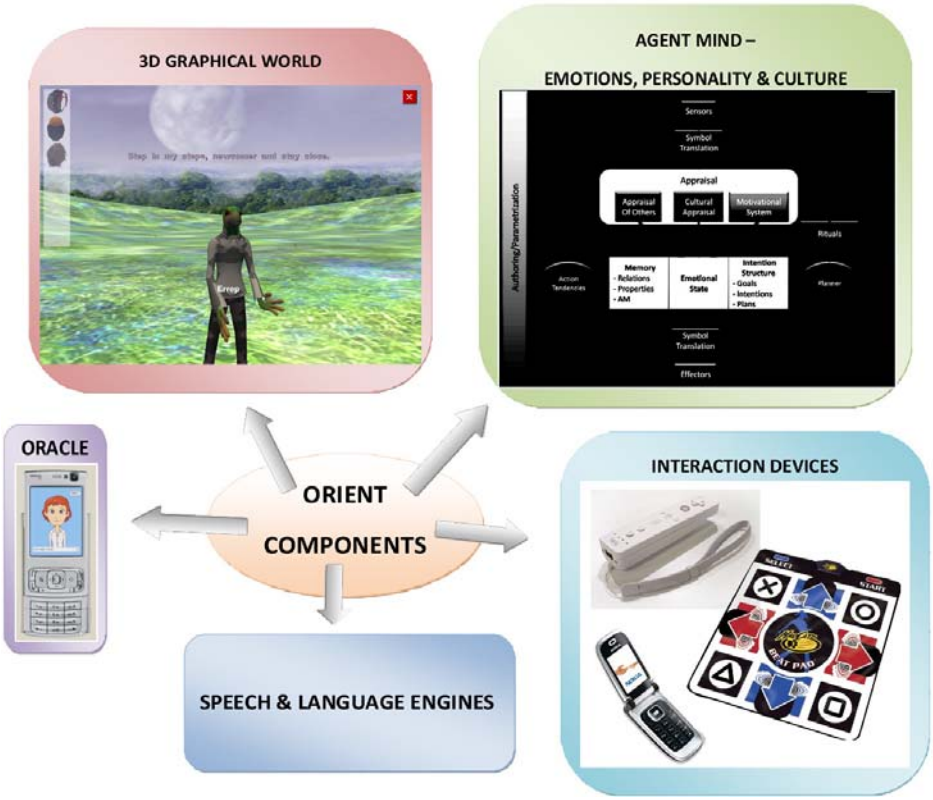


Fig. 2. ORIENT system components

can interact with the world through a variety of tangible interaction devices (see section 4.2). The characters inhabiting this world are represented by autonomous agents, each of whose cognitive processes are simulated by a separate agent mind program that receives perceptions from and sends actions for execution to the global world model. These characters have autobiographical memory, individual personalities, a model of the Spryte culture, and improvisational capabilities to enable social and emotional learning through RP and affective engagement in a complex social environment. The affective mind is being built upon FAtiMA [11] combined with the PSI [16] model. Affective models are seen here as a key component of virtual actors given the need to affectively engage participants and spectators in the dramatic environment. For more information on the agent mind, please refer to [17]. A language engine transforms speech-acts into utterances and subsequently a speech synthesizer creates gibberish speech that matches the utterance. Similar to the agent mind, the ORACLE perceives events in the world and responds to them by displaying feedback and help to the users.

4.2 Interaction Modalities

Empathic engagement can be enhanced through the use of innovative interaction devices to provide children with more intuitive interfaces to express affect. An empirical study showed that sensor-equipped toys, for example, SenToy [18], provide an affective means of self expression which is an essential requirement for successful RP. The work by Fails and collegues [19] who investigated different versions of the Hazard Room Game that contains elements of RP and interactive story telling indicated that interacting in a physical interactive environment may increase the learner's interest and understanding compared to a traditional desktop-based version. Additionally, Dow and colleagues [20] found that Augmented Reality contributed to an enhanced sense of presence as opposed to a desktop-based or speech-based interface.

Another issue of concern in ORIENT or any other educational RP applications is how interfaces can help to foster social interaction between learners. Inkpen and colleagues [21] observed that by giving each learner an input device, a positive effect on collaboration when solving a puzzle can result even if only one learner could interact at a time. A study by Mandryk and colleagues [22] revealed that learners preferred to play the game with friends than by themselves and that the learners spent a great deal of time interacting with each other. Another study exploring different multi-user settings for pervasive games [23] revealed that a positive effect on collaboration in RP can be achieved through an appropriate distribution of interaction devices. Clear evidence was observed that organised interaction within a group is possible through a setting where each user was assigned a role via an interaction device with a dedicated function, hence, balancing the level of interactivity and avoiding dominant users. Overall, there is empirical evidence that learners seem to be more engaged and more active when playing on a computer with multiple input devices than when using a computer by themselves.

Fig. 3. Interactions: (a)performing a gesture using the WiiMote, (b)navigating using the Dance Mat and (c)RFID scanning

Based on these studies, ORIENT's user interface was designed to be physical and tangible as shown in Figure 3. Full body interaction and movement in the physical space, particularly important in social behaviour and culturally specific interaction are supported. Each user is assigned a role which relates to a specific interaction device that has unique functions. These devices are a mobile phone, a Dance Mat and a WiiMote. All these devices are necessary to achieve the overall goal of the game. Bluetooth communication is utilised for both the mobile phone and the WiiMote while the Dance Mat is connected to the computer through USB.

The interaction techniques supported by the mobile phone, a Nokia NFC 6131 include RFID-based input and speech recognition. RFID tags are embedded in real world objects that also have existence in the virtual world. The user who is assigned to use the mobile phone selects objects by touching them and uses a "magic word" (character's name) to grab a character's attention. In response, the Sprytes speak an alien gibberish language, which is generated on the fly by a speech synthesizer and appears as translated subtitles on the screen. Navigation in the virtual world is achieved through the Dance Mat which is operated by a second user. The user can move forward, backward and turn left or right allowing them to explore the virtual world.

The WiiMote is used for three-dimensional gesture recognition based on motion data derived from accelerometer sensors. As aforementioned, the Sprytes are gestural creatures, thus, the third user performs different gestures for expressing communicative content. With interaction supported through large and micro screens, physical interfaces and multi-modal interaction devices, we hope the users' motivation to learn about the Sprytes' culture, their engagement in the interaction and collaboration between them can be enhanced.

5 Evaluation

The evaluation of ORIENT was designed as an in-role experience for adolescent users in UK and Germany: Four groups of three adolescents in each country interacted with ORIENT. Participants were given the roles of applicants to a mission of Space Command with the aim of exploring the alien planet of ORIENT, while the evaluation team played the roles of members of Space Command.

Table 1. Constructs and Corresponding Instruments

CONSTRUCTS	INSTRUMENT/MEASUREMENT APPROACH
Demographic characteristics & Cultural Profile	Participant Questionnaire
Cultural Intelligence	Cultural Intelligence Scale [24]
Perception & expectations of game play	Qualitative/open instrument to assess pre-interaction views
Knowledge about the Sprytes/ORIENT	Story/Task Comprehension exercise
Outgroup/cultural view (with regards to the outgroup "Sprytes")	Cultural Activities Questionnaire (amalgamating the Intergroup Anxiety Scale [25] & the General Evaluation Scale [26])
Device Use	Usability evaluation questionnaire with closed questions/discussion
Response to ORIENT & Sprytes	Based on the Character Evaluation Questionnaire [27] and by interaction observation
Feedback on interactions with ORIENT (e.g. graphics, speech, storyline, agent believability, etc.)	Questionnaires, discussion groups, creation of diaries / storybooks

One session comprised a duration of approximately two hours. The evaluation of ORIENT focused on two inter-related themes: participants' inter-cultural awareness and behaviour; and their immersion and engagement in interactions with ORIENT. The pedagogical and psychological evaluation aimed to investigate the effectiveness of ORIENT in fostering cross-cultural acceptance through the promotion of collaborative practices and the appreciation of similarities and differences between cultures. In addition to the psychological and pedagogical aims of evaluating ORIENT, our aim was also to evaluate the technology, focusing on intelligent computer assisted RP and our approach to accessing it using unusual interaction devices. Table 1 details the constructs that we aimed to measure and the approach taken to achieve this.

The main findings from the evaluation were that:

- Overall participants rated the prototype positively and readily engaged with it and with one another, with interactions indicating that this approach has the potential to foster cooperation among the user group. However, the prototype needs additional content and structure to make the encounter with the Spryte culture a pedagogically meaningful experience.
- Participants were able to identify similarities and differences between their own and the culture of the Sprytes. The Sprytes and their culture were considered to be engaging, the differences appeared to be believable and credible with participants interested in participating in Spryte activities.
- Sprytes have no obvious individuality at present but appear as cultural stereotypes thus reducing the potential of the formation of empathic relationships between users and Sprytes. This lack of individuality also reduces the coherence of the storyline and the believability of the characters.

- Differences were seen between the German and UK samples. Although UK teenagers had an increased awareness of intercultural norms and experiences, they were more negative than German teenagers towards the Sprytes. UK participants felt that the Sprytes considered them to be enemies, whilst German teenagers felt that the Sprytes thought they were friends.
- Participants found the interaction devices and approach challenging but engaging. However, the effort and challenges of such interactions frequently absorbed more user time than the Sprytes and ORIENT did, with an inappropriate focus on devices rather than interaction. In order to enable the users to explore, understand, and flexibly react to the cultural encounter with and the specific problems of the Spryte culture, the interaction with the virtual world should be more intuitive and seamless as is currently the case.

These findings highlight the potential of ORIENT to foster cooperation amongst the participants and that participants could readily identify differences and similarities between the virtual culture of ORIENT and the participants' own culture. However, although participants could appreciate the distinct culture of the Sprytes they were unable to distinguish between the individual Sprytes themselves. This provides the challenge of making the agents individual and discrete personalities and behaviours within a coherent culture more obvious. The user experience would also be improved through making the interaction more intuitive and easier to control, and by adding content to the story in order to provide more room for exploration.

6 Conclusion

ORIENT provides a novel approach to social learning through RP by integrating pedagogical self-learning and learning in a collaborative environment providing individuals with new ways to acquire, contribute and exploit knowledge and thereby learn. It presents a model of narrative engagement and empathy. Novel interaction modalities have also been applied to improve user engagement. Some evidence has been observed from the initial evaluation that ORIENT enhances collaboration among learners and learners are able to see a distinct culture in the Sprytes.

Acknowledgements

This work was partially supported by European Commission (EC) and is currently funded by the eCIRCUS project IST-4-027656-STP with university partners Heriot-Watt, Hertfordshire, Sunderland, Warwick, Bamberg, Augsburg, Wuerzburg plus INESC-ID and Interagens. The authors are solely responsible for the content of this publication. It does not represent the opinion of the EC, and the EC is not responsible for any use that might be made of data appearing therein.

References

1. Marsh, D.T., Serafica, F.C., Barenboim, C.: Effect of perspective-taking training on interpersonal problem solving. Child Development 51(1), 140–145 (1980)
2. Lane, C., Rollnick, S.: The use of simulated patients and role-play in communication skills training: A review of the literature to august 2005. Patient Education and Counseling 67, 13–20 (2007)
3. Bandura, A.: Social foundations of thought and action: A social cognitive theory. Prentice-Hall, Englewood Cliffs (1986)
4. Kanfer, F.H.: Self-management strategies and tactics, 195–224 (1979)
5. Collella, V., Bororvoy, R., Resnick, M.: Participatory simulations: Using computational objects to learn about dynamic systems. In: SIGCHI conference on Human factors in computing systems (CHI 1998), Los Angeles, USA (1998)
6. Heumer, G., Carlson, D., Kaligiri, S.H., Maheshwari, S., Hasan, W.U., Jung, B., Schrader, A.: Paranoia syndrome - a pervasive multiplayer game using pdas, rfid, and tangible objects. In: Third International Workshop on Pervasive Gaming Applications on Pervasive Computing 2006. Dublin, Ireland (2006)
7. Benford, S., Crabtree, A., Flintham, M., Drozd, A., Anastasi, R., Paxton, M., Tandavanitj, N., Adams, M., Row-Farr, J.: Can you see me now? ACM Trans. Comput.-Hum. Interact. 13(1), 100–133 (2006)
8. Klopfer, E., Squire, K.: Environmental detectives: the development of an augmented reality platform for environmental simulations. In: Educational Technology Research and Development, pp. 203–228 (2008)
9. Aylett, R.: Narrative in virtual environments: Towards emergent narrative. In: Press, A. (ed.) Fall Symposium, Technical report FS-99-01, pp. 83–86 (1999)
10. Paiva, A., Dias, J., Aylett, R., Woods, S., Hall, L., Zoll, C.: Learning by feeling: Evoking empathy with synthetic characters. Applied Artificial Intelligence 19, 235–266 (2005)
11. Dias, J., Paiva, A.: Feeling and reasoning: A computational model for emotional agents. In: Bento, C., Cardoso, A., Dias, G. (eds.) EPIA 2005. LNCS, vol. 3808, pp. 127–140. Springer, Heidelberg (2005)
12. Riedl, M., Young, R.M.: An intent-driven planner for multi-agent story generation. In: Proceedings of the 3rd International Conference on Autonomous Agents and Multi Agent Systems (2004)
13. Hofstede, G.: Cultures and Organisations. McGraw-Hill, London (1991)
14. Baylor, A.L., Ryu, J.: Evidence that multiple agents facilitate greater learning. In: International Artificial Intelligence in Education (AI-ED), Sydney, Australia (2003)
15. Moreno, R., Mayer, R.E., Spires, H., Lester, J.: The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? Cognition and Instruction 19, 177–213 (2001)
16. Dörner, D.: The mathematics of emotions. In: Frank Detje, D.D., Schaub, H. (eds.) Proceedings of the Fifth International Conference on Cognitive Modeling, Bamberg, Germany, April 10-12, pp. 75–79 (2003)
17. Lim, M.Y., Dias, J., Aylett, R., Paiva, A.: Improving adaptiveness in autonomous characters. In: Prendinger, H., Lester, J.C., Ishizuka, M. (eds.) IVA 2008. LNCS, vol. 5208, pp. 348–355. Springer, Heidelberg (2008)
18. Paiva, A., Prada, R., Chaves, R., Vala, M., Bullock, A., Andersson, G., Höök, K.: Towards tangibility in gameplay: building a tangible affective interface for a computer game. In: ICMI 2003: Proceedings of the 5th international conference on Multimodal interfaces, pp. 60–67. ACM, New York (2003)

19. Fails, J., Druin, A., Guha, M., Chipman, G., Simms, S., Churaman, W.: Childs play: A comparison of desktop and physical interactive environments. In: Conference on Interaction Design and Children, pp. 48–55 (2005)
20. Dow, S., Mehta, M., Harmon, E., MacIntyre, B., Mateas, M.: Presence and engagement in an interactive drama. In: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 1487–1484 (2007)
21. Inkpen, K., Ho-Ching, W., Inkpen, K.H.C., Scott, S., Shoemaker, G.: This is fun! we're all best friends and we're all playing: supporting children's synchronous collaboration. In: Proceedings of the 1999 conference on Computer support for collaborative learning (1999)
22. Mandryk, R., Inkpen, K., Bilezikjian, M., Klemmer, S., Landay, J.: Supporting children's collaboration across handheld computers. In: Proceedings of the SIGCHI conference on Human factors in computing systems, New York, USA (2001)
23. Leichtenstern, K., André, E., Vogt, T.: Role assignment via physical mobile interaction techniques in mobile multi-user applications for children. In: European Conference on Ambient Intelligence, Darmstadt, Germany (2007)
24. Ang, S., Van Dyne, L., Koh, C., Ng, K.Y., Templer, K.J., Tay, C., Chandrasekar, N.A.: Cultural intelligence: Its measurement and effects on cultural judgment and decision making, cultural adaptation and task performance. Management and Organisation Review 3, 335–371 (2007)
25. Stephan, W.G.: Intergroup relations. In: The Handbook of Social Psychology, pp. 599–659 (1985)
26. Wright, S.C., Aron, A., McLaughlin-Volpe, T., Ropp, S.A.: The extended contact effect: Knowledge of cross-group friendships and prejudice. Journal of Personality and Social Psychology 73, 73–90 (1997)
27. Hall, L., Woods, S., Aylett, R., Paiva, A., Newall, L.: Achieving empathic engagement through affective interaction with synthetic characters. In: Tao, J., Tan, T., Picard, R.W. (eds.) ACII 2005. LNCS, vol. 3784, pp. 731–738. Springer, Heidelberg (2005)

Reflective Learning through Playing Digital Game The Sims 2

Hui-Chun Hsiao

2F., No.2-1, Lane 39, Sec. 2, Zhongshan N. Rd., Zhongshan District, Taipei City 104 Taiwan
hsiao888@gmail.com

Abstract. Containing too many actions and only a little time for reflection, earlier games were reflexive rather than reflective. Most of the research literature on game play emphasized the learning that occurs through game actions but relatively few concern the potential for emotional experiences and reflection that occur within game play. In combining artificial intelligence (AI) techniques and advanced simulation systems, the digital game *The Sims 2* (*TS2*), provides a life-like narrative structured environment for player exploration, making it one of the most powerful and dynamic interactive narrative environments ever created. The *TS2* player online community provides artistic creations, fictional narratives, ongoing in-depth discussions of play experiences, and descriptions of real-life experiences that have intermingled to become a firm network that supports social interactions and learning. In this study, I investigated the reflection that occurred via playing the digital game *TS2* to see if such experience and reflection could lead players to generate new understanding and learning.

Keywords: digital game, reflective learning, the Sims 2, reflection.

1 Introduction

Ever since *Spacewar*[1] was first invented in an MIT lab in 1962, digital games, which are generally known as video games and computer games, have been part of popular culture for over 40 years and have had a significant social, economic, political, and technological impact on society (Newman, 2004). Entertainment Software Association's 2008 annual report also showed that playing digital games now cuts across age and gender lines and has become a vital part of contemporary culture and society. As a result, today digital games have caught the attention of scholars from fields as diverse as the social sciences, computer science, media design, literature, and education—studies in all of these areas are contributing to understanding this emergent medium and its phenomena.

During more than 20 years of discussion, academic interest in digital games has slowly shifted from early 'do-games-induce-violent-behavior [2] studies, to more relevant discussion of the potential of this new medium for other purposes, such as learning rather than entertainment. With digital games becoming a growing, developing, and progressing medium, many researchers have taken an interest in the

[1] *Spacewar* (1962) can be viewed as the first invented digital game.
[2] I use Gonzalo Frasca's (2001) term.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 220–227, 2009.

effects of these games on players, and how some of the motivating aspects of games might be utilized to help facilitate learning, such as learning about problem solving, numbering and time management, social collaboration, structures, history or cause and consequences (Alman, 1992; Garris, Ahlers, & Driskell, 2002; Millians, 1999; Prensky, 2001; Salies, 2002).

In terms of learning, digital games in the early part of the 21st century are not seen as merely involving low-level skills, such as hand-eye coordination and fast reflexes (Greenfield, 1984), but as powerful emerging tools for higher-order learning, such as information analysis and synthesis, decision making, and problem solving. A growing body of studies has reported that digital games are powerful contexts for learning because they offer opportunities for players to immerse themselves in another world in which players take on different identities, and learn through the experiences associated with these identities as well as the surrounding content of the games (Asgari & Kaufman, 2005; Gee, 2003). This immersion, and the engagement engendered through gameplay, is often cited as a compelling reason for introducing game formats into the learning environment (Ulicsak, 2005).

While digital game play has the potential to provide meaningful learning experiences, most game studies concern learning within game activities. Relatively few studies concern the emotional engagements, narrative experiences and reflections that occur from and following gameplay. Some approach game research from a belief that games are a reflexive system rather than a reflective environment, containing too many actions and requiring immediate responses and reactions, and as a result allowing little time for reflection. However, today's games, such as role playing, adventure, simulation, strategy, and puzzle games, often proceed at a slower pace that offers more built-in reflective 'space' and 'time' for reflection (Prensky, 2003; Squire, 2004). More and more studies take the stance that game-based learning is experiential learning, and therefore learning from the experience of gameplay must include reflection (Gee, 2003, 2005; Prensky, 2005; Squire, 2004; Squire & Jenkins, 2003; Vaupel, 2002; Wallace, 2005). However, these studies that emphasize the importance of reflection in learning most often focus attention on the reflection that occurs as a game player consciously and purposefully applies ideas while strategizing and implementing each phase of problem solving. The reflection through gameplay and narrative may promote a type of learning that is more significant than that which may occur through play. This perspective has not yet been seriously examined in detail.

Using the digital game *The Sims 2 (TS2)* as an example, this study was designed to advance understanding of how digital game play provides an interactive narrative interface through which players may play, explore, and express themselves, via ludic narrative to encourages reflective learning.

2 Description of *The Sims 2*

Developed by Maxis and published by Electronic Arts in August 2004, the digital game *The Sims* is a life-like social simulation game that imitates aspects of the real world for players to build, maintain the characters, families, and neighborhoods over an entire simulated lifetime. The realistic three-dimensional images, interesting storylines and a creative simulated playing environment have led to the purchase of

one million copies of *The Sims 2* worldwide within the first ten days.[3] More than 55 million copies of *TS2*, including expanded packs[4], were sold by May 2006 (Water, 2006), making it one of the best selling games in game history.

Within the digital game genre, *The Sims 2* (*TS2*) is recognized as a life-like simulation game. The foundation of this game is the concept of a dollhouse, where little people live out their day-to-day lives inside a virtual world in one's computer. Players can direct them in this virtual environment however they like, with objectives of their own choosing—to build and decorate houses, to create characters, to design hairstyles and outfits for the Sims, or to play the role of god in guiding the Sims' living situation and helping them to achieve their aspirations.

Unlike most games that only provide us with two possible endings—winning and losing—*The Sims 2* type of game with its fuzzier logic and scope beyond winners and losers can provide an environment that allows games to grow in scope and artistry (Frasca, 2003). In short, *TS2* ships without specific rules so that everybody can play the game differently. The appeal of playing *The Sims 2* is that the game is what you make it, since *TS2* is the game that provides players with a platform and then leaves them to define their own goals. On the other hand, the problems (conflicts) generated based on the goals players pick usually have more than one method of resolution which, on the other hand, can encourage players' imagination and creativity.

Players can create a virtual character (called a Sim) and assign each a personality, an astrological constellation, interests, and an aspiration. A Sims in *TS2* is a semi-autonomous character whose behavior, wants, and fears, based on players' previous choices and the inner game artificial intelligence (AI) system. The Sims grow and age, from being toddlers to elders. They have very different approaches to life at different stages; different kinds of successes and failures. The player can take snapshots or record video sequences for every important moment of Sims' everyday life. In addition, *The Sims 2* (*TS2*) allows players to add their own written thoughts and dialogue so that there is a context to the images throughout game play. The players then can share the stories and movies online with other community members (audience).

3 Reflection and Learning

Different from the early research on learning, "dominated by behaviorism and cognitive psychology, limited itself to measurable, observable behavioral outcomes" (Brockbank, McGill, & Beech, 2002, p. 6), most modern theories promote the concept of reflection as essential for deep and significant learning. According to Dewey (1933), reflection is the process by which one makes meaning from experiences that involve more than simply attending to events, but also the interactions with other individuals, the environments, and the world. Similar to Dewey's idea of reflection as a response to a situation of uncertainty or a problem, Boud, Keogh, and Walker (1985) delineated reflection, in the context of learning, as "a generic term for those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations" (p. 19). Thus we

[3] Data from IGN.com

[4] By May 2006, *The Sims 2's* expansion packs include *Universality, Nightlife,* and *Open for Business.* Its new expansion, *Pets* was released in October 2006.

can see that reflection is a self-directed process of meaning making that occurs when an individual is aware of a problem, analyzes a problem, associates new information with existing knowledge or experiences, finds relationships among information, and solves a problem with new understanding and changed conceptual perspectives.

Moreover Donald Schön (1983) proposed two types of relevant reflection: "reflection-in-action" is a simultaneous reflection through which the individual is consciously monitoring the problem-solving process and modifying next actions instantaneously, while "reflection-on-action" is the reflection that occurs after an event and leads to changes in the future course of actions. More recently, in terms of the relation between reflection and learning, Jennifer Moon (2004) believed that reflective learning occurs when the learner is upgrading stages of learning from lower stages, like making sense, to higher stages, such as making meaning, working with meaning, and transformating learning. Subsequently, Brockbank, McGill, and Beech (2002) also stressed the importance of presenting and actively engaging with others in a social context to improve and transform his/her learning through reflection. They defined reflective learning at three different levels: improvement, transformation, and learning about learning.

As Moon (1999) and Brockbank et al. (2002) argued, reflection is not a solitary pursuit but is a collaborative activity in a social context. Therefore, conversation with others can be seen as a significant way to encourage reflective learning. Reflective dialogue or reflection-with-others is distinguished from internal dialogue, where reflection is limited to the insights of the individual. Through reflective dialogue with others, individualistic assumptions, beliefs, and perceptions may be challenged and may also lead to a reconsideration of how things are being done, and how things can be improved (Brockbank & McGill, 1998; McDrury & Alterio, 2003). Reflective dialogue, at the same time, can facilitate learning from a passive level to a deeper level of reflective learning—what Brockbank et al. called "learn about learning itself" (p. 10).

On many occasions, dialogue is employed as a means of facilitating reflective learning. Storytelling also is addressed in a large body of studies, as an apparatus for inducing reflective learning. Researchers, such as McDrury and Alterio (2003), link the art of storytelling with reflective learning processes to propose storytelling as a theory of learning within a socio-cultural framework. They describe the process of storytelling as "*a way to knowing*" and outline five stages[5] of learning through storytelling—story finding, story telling, story expanding, story processing, and story reconstructing—that move learners from the surface to a deeper approach to learning.

Moreover, in recognizing that "stories are [a] product of reflection,"[6] McDonnell, Lloyd, and Valkenburg (2004) stressed that the act of storytelling requires more than just passively reviewing an experience. It also requires reflective articulation of an experience—reflection on that experience, reconstructing it from a particular perspective and conveying that to an audience in a way that engages them. When we tell our own practice stories and listen to those of others, all of us work "together to process them deeply and critically, we connect in ways which enrich self, relationship and practice," and also in this manner, "we construct new knowledge and advance our understanding of the relationships we construct and are constructed by" (McDrury & Alterio, 2003, p. 175).

---

[5] This is *reflective Learning through Storytelling* Model.

[6] The argument originated with Schön in 1988.

4 Research Method

The purpose of this study was to examine whether players' experiences with narrative play in the digital game *The Sims 2* facilitate players' reflection, and learning. I used case study methods to understand a particular situation—play of the digital game *The Sims 2*, its impacts on players' experiences in relation to reflection and learning. The Internet data collection strategy included game players' online logs, which provided useful data by being a complete record of their events and play (e.g., uploaded creations, activities, and discussion). These logs are digitally archived and can be re-accessed time after time. For example, on the *TS2* site, each player has a personal Web space, called a *MySim* page, through which players share their basic information, creations, play diaries, and messages on his/her guest book. With time stamps, all information and messages posted are contextually archived and accessible to all *TS2* members. This rich textual material database offers users the opportunity to read this information, or to search by keywords, player's ID or country, story themes, or discussion topics. The results of the search may be shown in the order of the users' preference, or may be saved and printed. Researchers can analyze sequences of events, observing how events early in a sequence influence those occurring later through this complete database. As a result, time-based research can be carried out through access to this digital archive, even after the events themselves are finished (Wood et al., 2004).

Documents collected and analyzed for this study included *TS2* game reviews, the design team's work diaries, game developers' interviews, and game players' interviews. These document data were used in the analysis to glean basic understandings of the nature of the digital game *The Sims 2* and its online community. These documents also helped to corroborate evidence gathered from other sources in this case study. Archival records collected and analyzed included *TS2* online survey data, online discussion forum records, live chat transcripts, participants' game diaries, and participants' artifacts (stories, movies, houses, characters, and objects design). All archival data were collected from the *TS2* official site by the researcher to ensure the consistent origin and accuracy of the records. These records provided important data concerning each player's experiences with *TS2*. To gain a detailed understanding of each individual player's experience with *TS2*, a semi-structured interview was proposed as the primary data collection strategy in this research.

With regard to the focus on the activities in *TS2* that render the experience meaningful and cause deeper reflection during the gameplay, I concentrated on two main activities. They were: the experiences of narrative play and interactive story creation and sharing—interpreted through the perspective of *reflection through storytelling* (Bruner, 2002; McDrury & Alterio, 2003; Schön, 1988), which maintains that stories are products of reflection, and storytelling is an effective way to evoke reflection; the participation in online dialogue—explained by the approach of *reflection with others (dialogue)* (Brockbank et al., 2002; Kolb, 1984; Schön, 1983) and *reflection-on-action*v (Schön, 1983), which stresses that dialogue is a significant way to encourage reflection leading to a reconsideration of how things are being done, and how things can be improved.

5 Research Finding

In being a god and controlling their Sims, players gain a chance to try out different behaviors and personalities in order to explore and challenge their perception of their lived experiences, the world, and even themselves. By imposing their values and desires onto their gameplay, the players could construct aspirational worlds for their escape and satisfaction. The game-worlds they created, at the same time, reveal not only their values, desires, and fears, but also disclose what they think are the most important and most threatening aspects of life, as well as elements of their inner selves and their identities.

At the surface level, through an iterative process of trying out solutions, revising assumptions, and getting feedback to regenerate new solutions, the players receive opportunities to make meaning of their experiences, to learn through reflection on the meaning of those experiences, and then to create strategies for overcoming obstacles in order to approach their goal of playing *TS2*. Yet, more than that, *TS2* also promotes deeper reflection that takes place through gameplay, as players review their narrative play experiences and their identity construction during *TS2* gameplay, and connect it their real life.

With its realistic designs for character behaviors and compelling narrative scenarios, *TS2* invites players to become emotionally engaged in the game as they immerse themselves in this simulation system and the Sims. Such engagement and immersion could lead the players to see themselves as Sims, leading them to reflect not only on the Sims' behaviors and responsiveness, but also on themselves and their own lives.

Moreover, by playing a god in the game, the players are permitted to experiment with different viewpoints in particular scenarios both as god and Sims—taking a Sim view to explore the consequences of acting within the game, or taking a god viewpoint to direct observe, and interpret all actions and consequences. By shifting between observers and participants in the game-world, the players achieve a critical distance from their gameplay and actions/consequences that allow them to view them more objectively, which is a reflective learning process.

Furthermore, as game play is completed in *TS2*, the players' narrative experiences become linear stories in retrospect. While sharing these play experiences with others, the players engage in a process of storytelling that requires them not only to passively rethink their experiences, but also to locate the significance of the experiences, reconstructing them from a particular perspective and then to articulate those experiences to other community members. This storytelling process, according to McDrury and Alterio (2003), encompasses "ways of knowing" that may help the players to reflect, to explain, to express, to analyze or to understand their experiences, themselves, others, and the world (p. 35).

Through reflection via sharing discussion on their narrative gameplay in *TS2*, the player are provided opportunities to recapture their play experiences, to think about the ways they played—the game-world they created, and the things they wanted their Sims to do—and later to evaluate their play experiences in relation to their real life and themselves. This reflection enables the players to make meaning and generate new understanding of their experiences. According to many theorists, this all points to the process of learning from experience. Therefore, the process of sharing and

discussing their narrative play experiences might help the players to develop self-awareness and create new understanding of their gameplay, their desire and fears in relation to their real life, and dimensions of themselves.

6 Conclusion

The digital game *TS2* provides an interactive narrative interface (INI) through which players may navigate, explore, express themselves, and intensify their experience narratively and artistically. The narrative play experiences with INI in *TS2*, at the same time, serve to initiate and powerfully facilitate players' identity construction, evoking reflection about their gameplay, multi-identities, the world and themselves. Narrative play furthers learning by recapturing experiences and reflections of narrative play, giving the play new meaning.

References

1. Alman, R.E.: Video games: Interaction vs. observation as sources of social learning. Michigan State University, East Lansing (1992)
2. Asgari, M., Kaufman, D.: Virtual environments: Identity and learning. In: The 3rd International Conference on Imagination and Education, Vancouver, Canada (2005)
3. Boud, D., Keough, R., Walker, D.: Reflection: Turning experience into learning. Kogan Page, London (1985)
4. Brockbank, A., McGill, I., Beech, N.: The nature and context of learning. In: Brockbank, A., McGill, I., Beech, N. (eds.) Reflective learning in practice, pp. 5–17. Aldershot, England (2002)
5. Bruner, J.: Making stories: Law, literature, life, 1st edn. Farrar Straus and Giroux, New York (2002)
6. Dewey, J.: How we think: A restatement of the relation of reflective thinking to the educative process. D. C. Heath and Company, New York (1933)
7. Frasca, G.: Simulation versus narrative: Introduction to ludology. In: Wolf, M.J.P., Perron, B. (eds.) The video game theory reader, pp. 221–236. Routledge, New York (2003)
8. Garris, R., Ahlers, R., Driskell, J.: Games, motivation, and learning: A research and practice model. Simulation & Gaming 33(4), 441 (2002)
9. Gee, J.P.: What video games have to teach us about learning and literacy. Palgrave Macmillan, New York (2003)
10. Gee, J.P.: Video games, mind, and learning. The Interactive Digital Media & Arts Association Journal 2(1), 37–42 (2005)
11. Greenfield, P.: The effects of television, computers and video games. Fontana, London (1984)
12. Jenkins, H.: Game design as narrative architecture. In: Wardrip-Fruin, N., Harrigan, P. (eds.) First person: new media as story, performance, and game, pp. 124–131. MIT Press, Cambridge (2004)
13. Kolb, D.: Experiential learning: experience as the source of learning and development. Prentice-Hall, Englewood Cliffs (1984)
14. McDonnell, J., Lloyd, P.A., Valkenburg, R.: Development of design expertise through the construction of video stories. Design Studies 25, 509–525 (2004)

15. McDrury, J., Alterio, M.: Learning through storytelling in higher education: using reflection & experience to improve learning. Kogan Page, Sterling (2003)
16. Millians, D.: Simulations and young people: Developmental issues and game development. Simulation & Gaming 30(2), 199–226 (1999)
17. Moon, J.: Learning journals: A handbook for academics, students and professional development. Kogan Page, Sterling (1999)
18. Newman, J.: Videogames. Routledge, New York (2004)
19. Prensky, M.: Digital game-based learning. McGraw-Hill, New York (2001)
20. Prensky, M.: Digital game-based learning. ACM Computers in Entertainment 1(1), 1–4 (2003)
21. Prensky, M.: Computer games and learning: digital game-based learning. In: Raessens, J., Goldstein, J. (eds.) Handbook of computer game studies, pp. 97–122. MIT Press, Cambridge (2005)
22. Salies, T.G.: Promoting strategic competence: what simulations can do for you. Simulation & Gaming 33(3), 280–283 (2002)
23. Schön, D.: The reflective practitioner: how professionals think in action. Basic Books, New York (1983)
24. Schön, D.: Coaching reflective teaching. In: Grimmett, P., Erickson, G. (eds.) Reflection in teacher education, pp. 19–29. Teachers College Press, New York (1988)
25. Ulicsak, M.: Time out? exploring the role of reflection in the design of games for learning. In: The DiGRA 2005 Conference: Changing Views – Worlds in Play, Burnaby, Canada (2005)
26. Vaupel, C.A.: The effects of video game playing on academic task performance and brain wave activity. The University of Tennessee, Knoxville (2002)
27. Wallace, M.: The game is virtual. The profit is real (2005), `http://www.iht.com/articles/2005/05/29/business/games.php` (retrieved May 30, 2005)
28. Water, D.: Games industry is failing women. BBC news Website (2006), `http://news.bbc.co.uk/2/hi/technology/5271852.stm` (retrieved October 21, 2006)
29. Wood, R., Griffiths, M., Eatough, V.: Online data collection from video game players: methodological issues. Cyberpsychology & Behavior 7(5), 511–518 (2004)
30. Squire, K.: Replaying history: learning world history through playing Civilization III. Indiana University, Bloomington (2004)
31. Squire, K., Jenkins, H.: Harnessing the power of games in education (2003), `http://distlearn.man.ac.uk/dldev/download/PowerOfGames.doc` (retrieved March 1, 2004)

A Story Authoring System for Children

Danli Wang[1], Tingting Yin[1], Fang Peng[1], Jinquan Xiong[2], Hongan Wang[1], and Guozhong Dai[1]

[1] Institute of Software, Chinese Academy of Sciences, Beijing 100090, China
[2] Jiangxi Institution of Education, Nanchang 330029, China
danli@ios.cn

Abstract. Storytelling is a practical and powerful tool for children to develop their language expression and creativity. Many researchers have studied and built storytelling systems for children. Based on the analysis on the existing work, we designed and developed a 3D story authoring system for children by using pen/speech-based multimodal interaction technology. The system allows children to create roles, design roles' actions, make and share their own stories. The aim of this system is to cultivate the imagination and creativity of children, and to improve their language expression.

Keywords: Story authoring system, Children, Multimodal interaction.

1 Introduction

Storytelling has been going on for centuries, and it is a wonderful way to educate and entertain children. Stories are not direct or personal, but they convey a message that can be interpreted by other world views and perspectives. During the process of learning language, storytelling is essential for children to develop their language expression, logic thinking, imagination and creativity [1]. By telling stories during their growth, children learn to understand the world and culture surrounding them, and learn to recognize and blend themselves into the social and cultural context [2].

The traditional way to tell a story is rather simple and is not flexible, because it is usually done by book or by description, as a result, the children cannot participate in story creating freely. With the remarkable progress in computer, researchers are now using computers to help, and finding new storytelling patterns to make the children more free and active. Mush research has been conducted to provide more convenient tools for children to create their story freely and some research has got good results, like SAGE[3], KidPad[4], StoryRoom[5] and Dolltalk[6]. Besides, there are also some systems to let children create stories freely, such as JiVE[7]. These systems give children a totally new experience during storytelling and cultivate their interest in creating and playing. However, though the aforementioned systems provide tools for creation and storytelling, the operational props and content are not abundant enough, which restrains children's creativity. Some of them require certain programming skills, which may cause difficulty for pre-school and primary school children. In this paper, a story authoring system which allows children to create their stories more freely is discussed. Children can use the role creation, action creation and story creation toolkits to create roles, actions and interactive story. Story listening function of

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 228–238, 2009.

the system allows children to enjoy their own or system's stories. Using the system can advance children's creativity and language ability.

To design application software suitable for children, the interaction method needs to be considered. Due to limitation of literacy for pre-school and lower-grade school children, speech input is the most effective way to tell stories [8]. But the recognition rate of speech input at this level has been less than satisfactory. However, because children are quite distractible, which can be even worsen by low recognition of speech, this approach is not quite practicable. Multimodal interaction systems permit a more natural human computer interaction, where users can apply more than one modality to express their needs. Therefore, the multimodal interaction pattern combining speech input and pen input is used to facilitate storytelling for children on the computer as a comparatively practical and realizable method. In UI design, the cognitive level of children should be considered. The UI should be simple and clear, so that children can learn the software quickly and create their own stories. So we designed a storytelling system using pen and speech-based input multimodal interaction technology to support children's creating stories with the help of computers.

Based on our storytelling system [9], we added the two functions and enable the roles and actions designed for creating stories. We have invited six children to use the system. Responses from the users were quite positive. The organization of this paper is as follows: Section 2 discusses the related works. Section 3 presents the multimodal 3D storytelling system. Section 4 describes a usage scenario and the informal evaluation. Finally the conclusion and future work are provided in Section 5.

2 Related Work

2.1 Storytelling System for Children

During recent years, many researches on the model and software of children storytelling have been carried out. SAGE was developed by the MIT media lab, and it provides a storytelling tool to let children develop the interactive stories, and make them express their feelings in the game environment. SAGE can help children develop their own story from the stories they have heard before. SAGE supports children in designing and programming their own meaningful storytellers [3]. KidPad, developed by Hourcade, is a coordination creation tool designed for children. It provides the drawing tool in a large two-dimensional zoomable space [4]. Children can develop a story and display it in the space using various drawing elements. The story described by language can be hyperlinked with the objects in the space. KidPad provides advanced interactive technology under a cooperative environment. StoryRoom was developed by the HCI Lab of the University of Maryland. Its size is the same as the room, and it provides the immersed environment for telling stories [5]. Doll Talk captures children's gesture and speech information. Then, it simulates and feeds back the speech content to children by modulating the voice, and make children improve their recount [6]. Sam, an embodied conversational storyteller who tells stories interactively with children, encourages children to use a toy castle and castle props to tell a story in a physical world [10,11]. Alice is a 3D graphic programming environment, designed for the high school students who have no 3D graphic modeling experience and/or programming experience, especially for the

female students who do not like programming. It is oriented to end users directly, allowing the users to construct their stories using an easier user language and create a 3D virtual world [12]. FearNot is a virtual learning environment consisting of artificial actors, aiming at teaching the children in 8-12 how to react when facing menace. And it achieves the aim through storytelling [13,14]. JiVE [7] is a 3D story creation tool. By offering children the tool to create their own roles and stories, it can develop their initiative and the ability to analyze and solve problems.

The aforementioned systems provide rather good technologies and ideas, supporting children to tell stories and learn knowledge from multiple aspects. Children can gain great experiences from these systems, while problems do exist in them. However, some of them restrain the space for creation, and then children have to create their stories with limited tools. Some of them use fixed roles, which virtually bounds the content of stories. Some of them allow users to create their stories by programming, but it is difficult for pre-school and lower-grade pupils.

Nowadays children spend considerable amount of their time using computers, so they are very familiar with the normal operations and digital virtual environment. Therefore, based on aforementioned analysis, we developed a multimodal story authoring system to provide a 3D storytelling environment. The system provides a space for children to allow them to create roles and roles' actions, tell their own stories. It gives them greater creation space. Moreover, creation through this system and training by story listening and storytelling can advance their language and thinking abilities.

2.2 Multimodal Interaction

Multimodal user interfaces allow users to interact with computers via various different sensory channels compared to traditional interfaces [15]. Multimodal interaction systems permit a more natural human computer interaction, where users can apply more than one modality to express their needs. A central part of these systems is the modality fusion entity that takes care of combining and integrating the mono-modal interpretations of multiple modalities into a single semantic representation of the intended meaning [15]. Basically, there are two major architectural approaches to the analysis part of multimodal systems: (a) early fusion — fusing modes already at signal or recognition level and (b) late fusion — multimodal semantic processing [16]. The speech and pen-gesture multimodal system could support mutual disambiguation of errors and lead to more robust performance [17]. In this system, in order to achieve the mutual disambiguation benefits, semantic constraints between the user's voice commands and a set of pen gestures was imposed on what constitutes a "legal" multimodal command. Much of the current multimodal research is based on the premise that each individual mode does not have recognition errors, thus no treatment is given to address such errors [18, 19].

All the multimodal technologies have their own application value in their relevant fields. While considering the cost of equipments and the features of storytelling, we think pen-based interaction combined with speech input is a more practical interaction mode, based on which we designed the children story authoring system. By story telling function children can set the scene, locate position of actors and control behaviors of actors by pen while recording their speech of the storytelling. This interaction mode is kind of similar to the ordinary storytelling, and do not increase children's cognitive load.

3 The Children Story Authoring System

Based on pen and speech interaction technology, we have developed the multimodal story authoring system to provide a 3D storytelling environment, where children can make their roles and actions freely and combined their works to story creation. The aim of this system is to cultivate the imagination and creativity of children, and to improve their language expression.

3.1 Architecture of the System

The Architecture is shown in Fig. 1. There are three layers in this system: interaction layer, information processing layer, and database layer. In the interaction layer, we use pen and speech as inputs. At most time, we use pen-based interface, although we use speech simultaneously at story creation. In the information processing layer, we analyze the inputs and classify them into different modules and produce feedback as outputs by rendering different scenes. In the database layer, we process inputs referring to the libraries in database and store outputs into database. There are four libraries in the database: template library, knowledge library, material library and works library.

3.2 System Function

As shown Fig.2, the main function module of the system includes role creation, action creation, story telling and story listening, which provides the functions to make roles, make actions, create stories and then enjoy the stored stories. The functions are described as following.

Role creation
Users can create roles freely or by templates. After choosing the creation model, user can create a new entity or an adjust existing entity by pen. The entities of a role can be spheres, cuboids, cylinders and circular cones. The sizes, colors and positions of the entity are all changeable. If one makes roles freely, one should offer the correlations between the entities. The roles can be stored in works library and then be used in story creation.

Action creation
Users can create basic actions and composite actions in this module. The system classifies familiar actions to three different types (actions for two-leg roles, actions for four-leg roles and actions for fly roles). In basic actions design, according to the type of the role, users can adjust actions' range, angle and speed. In composite actions design, users can combine basic actions which are provided by the system or by creating to composite actions. The actions happening simultaneously are called parallel actions (PA), while the actions happening one by one are called sequential actions (SA). The composite action is a mixture with parallel actions and sequential actions. We can also change the sequence of composite actions. After the composite actions done, they can be stored in works library and be used in story creation.

Story telling
The module for creating the story includes setting scene, telling story and saving story. At the stage of laying out scene, users can select the natural sceneries (such as trees, flowers, houses, and rivers etc.) and the ground and sky texture in the 3D space by pen, and place them. Users can also select 3D special effects. For example, if the

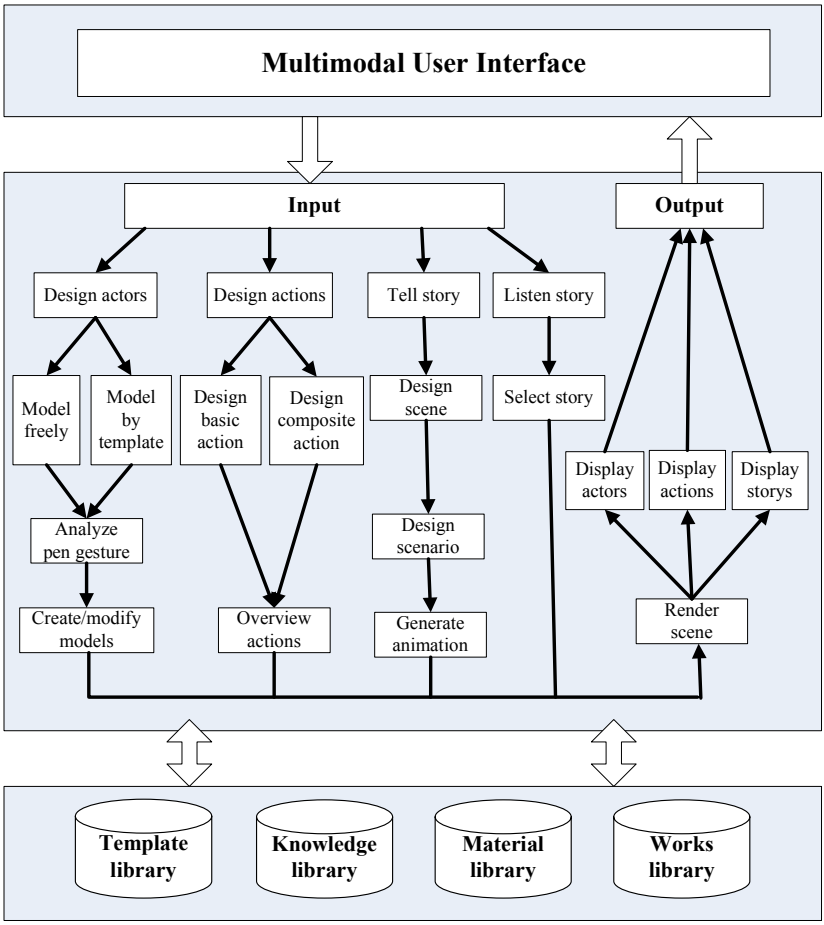


Fig. 1. Architecture of the story authoring system

story occurs in a rainy day, he or she can click raining special effect to simulate the rain falling. The system will search these resources in the resource library respectively and render them in real time, and users can observe them from different viewpoints. At the stage of the telling story, users can selects some 3D roles from works library. The user can create his/her plot by adding different actions from works library to roles and describes the story by speech simultaneously. According to inputs of pen and speech, the system will generate 3D animation tasks, record the action sequences of user design, and dynamically update the state of the existing models of the story (the roles' type, position and size parameters etc.). Therefore, it is convenient to generate the corresponding animation effect in the generation module of animation. At the story saving stage, users can select background music for the story and name it.

Story listening

The module for story listening includes the functionality of the story selection, play, control and deletion. The module of story play shows users the existing stories from a

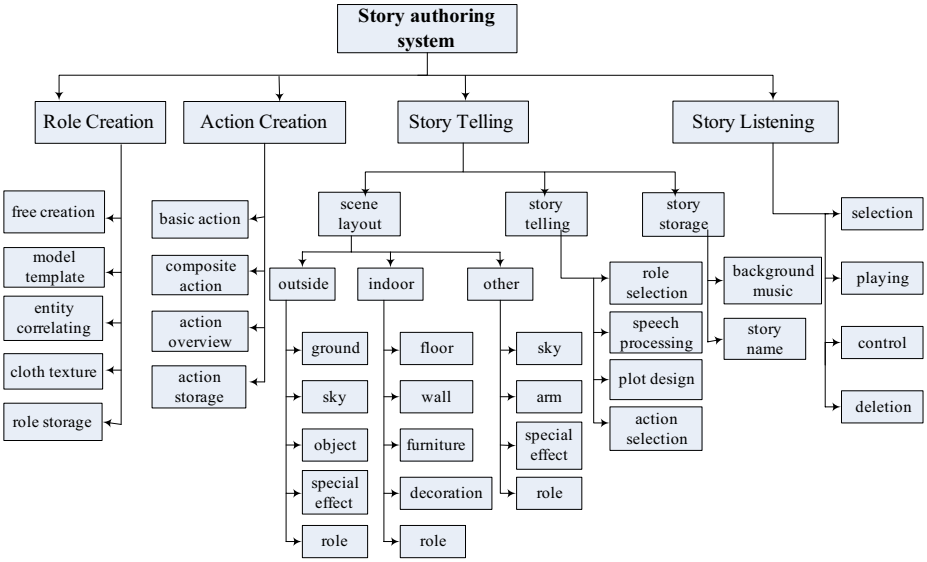


Fig. 2. Function of the story authoring system

list. Once the user selects the story to play, the scenario and story plot will be shown on the screen in parallel and the recorded speech is played at the same time.

3.3 Multimodal Interaction

In order to make the interaction natural and convenient, we use pen-based interface as the main input pattern in role creation, action creation and story telling. While in story creation, we use multimodal interfaces based on pen and speech. In story creation, the speech will describe what happened in the story, and pen-pointing is to point the information of object, position and path in the interface. We proposed a context-based approach for multimodal semantic fusion, which incorporates the semantic meaning of the two modals together as per the constraint of fusion time, based on the recognition and understanding of the input from pen and speech modal, supported by the context knowledge and fusion rules. The fusion modal is shown in figure 3.

The specific process of multimodal fusion is as follows: first, the information from two modals will be recognized and understood, then the system judges whether the semantics from the two sides are coincided. If it does, it can obtain the fusion semantics directly. If it does not, the semantics will be fused according to the context and the system's existing knowledge. After that, the output task will be planned according to the fusion result, and be exported to the user in the appropriate form. The user can provide the information of correctness for any fusion error.

3.4 Realization of the System

Based on the above fusion algorithm of multimodal pattern, the story authoring system for children was developed. It was implemented on a PC running Microsoft

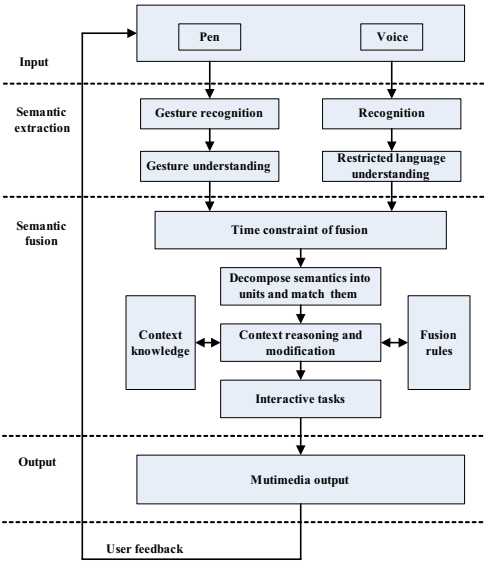


Fig. 3. Multimodal fusion model

(a) role creation (b) action creation

(c) Story telling (d) Story listening

Fig. 4. Interfaces of the system

Visual C++2008, and supports children to interact with computer using two channels: speech and pen. Among them, the speech channel adopts the Microsoft Speech SDK5.1 (SAPI) engine, and transforms the speech data to the corresponding semantics. The pen-channel provides users to sketch freely using a tablet. Children can create the stories by natural language or sketching, and the system uses 3D cartoon as the feedback to the scenarios described by users. The realization of 3D rendering is done with the OpenGL graphics library. Fig.4 is the layout for the main interfaces of the software and its explanation.

4 Usage Scenario and Informal Evaluation

4.1 Usage Scenario

We use an example to show how a story is created in our system. Step 1, we design the model of a bear as in Figure 5. We choose the right color and draw the outline of a bear (head, body, arms, legs, eyes, ears, nose and mouth). Make sure that the relationship of each entity is correct, for example, the connective relationship of head, body, arms and legs, and the symmetrical of its eyes as well as ears. After the modeling step, we can save it into works library for the future use.

(a) Drawing entity **(b) Showing entity** **(c) Creation model**

Fig. 5. Process of the role creation

Step 2, as in Figure 6, we can design the bear's action, for example, swing its arms and jump, a composite action. First we design the swing of its right arm, and choose the swing extent and speed. The process will display in the Area 1. And then we design the action of its left arm in the same way. Note that the left arm and right arm will swing simultaneously, so we put the actions of left arm in Area 1 too. Secondly we design the jumping actions by setting the height and speed when jumping, and put the action in Area 2 because it's a sequential action after swing. After that we can preview the whole composite action and save it.

Finally, we can create a story, A Panda and A Bear, as in Figure 7. In the user interface shown in Figure 4(c), click button "New" in the section 1 (function section) first and then click “Lay out” button in the same section. Then in section 2 (Layout options), choose the ground, sky, sceneries and roles (the panda and the bear) to be

(a) Choose basic action (b) Add PA (c) Add SA

Fig. 6. Process of the action creation

used. Then after clicking "Tell" button, we can use speech to describe the story, and use speech or pen commands to control the action of a role. The actors in the story will travel around along the tracks specified by the user. The composite actions display on the right of the user interface as in 7(c). We can choose any composite actions when telling the story. For example, by clicking the panda and then clicking the action "swing its arms and jump" designed in step 2, we can let the panda performs correspondingly. More actors and special effect can be added during story telling. The lens view is also adjustable. Also, the story can be saved once the story telling is finished.

(a) Set sceen (b) Add actors (c) Tell story

Fig. 7. Process of the story telling

The story listening function is rather simple, and thus we will not describe it any more.

4.2 Informal Evaluation

We have invited six children to use the system. Responses from the users were quite positive. They all thought that it was very easy for them to learn how to use the system and the using process was very natural, efficient, and reliable. When they used the system to create their story, all of them felt it interesting and satisfactory. Most of them would like to use it in the future.

5 Conclusion and Future Works

The story authoring system that provides an interactive creative environment for children is given in the paper. By using computers to let children create their own roles

and actions, tell stories by both pen and speech and finally create 3D cartoons as feedback, the system can inspire the interest of the children creating stories, make it funny during the creation, and improve their language ability.

We have several considerations for our future work. New interaction patterns should be added in order to make children create stories more freely. More entities and/or templates to create roles and action Classification of users according to the knowledge level at different ages, and the corresponding design tool of story actors and action will be provided. In addition, a large amount of story materials, including background, scenery, etc. should be added. In addition, we will evaluate the story authoring system in a large scale and improve it continuously. Hence we will be able to create better and larger learning and entertainment space for the children.

Acknowledgments. The research is supported by National Key Project of Scientific and Technical Supporting Programs (Grant No. 2008BAI50B02), the National Natural Science Foundation of China (Grant No. 60373056), National Facilities and Information Infrastructure Foundation for Science and Technology (Grant No. 2005DKA46300-05-32) and the CAS Pilot Project of the National Knowledge Innovation Program (KIP) (Grant No. KGCX2—YW—606).

References

1. Wright, A.: Creating stories with children. Oxford University Press, England (1995)
2. Qu, M.: Intelligent Equations for Chinese Children. China Women Publishing House, China (1998)
3. Bers, M., Cassell, J.: Interactive Storytelling Systems for Children: Using Technology to Explore Language and Identity. Journal of Interactive Learning Research 9(2), 183–215 (1998)
4. Hourcade, J.P., Bederson, B.B., Druin, A., Taxen, G.: KidPad: Collaborative Storytelling for Children. In: Extended Abstracts of Human Factors in Computing Systems, CHI 2002 (2002)
5. Montemayor, J., Druin, A., Chipman, G., Farber, A., Guha, M.L.: Tools for children to create physical interactive StoryRooms. Computers in Entertainment: Educating children through entertainment Part II (2004)
6. Vaucelle, C., Jehan, T.: Dolltalk: a computational toy to enhance children's creativity. In: CHI 2002 (2002)
7. Hintze, J., Masuch, M.: Designing a 3D Authoring Tool for Children. In: Proceedings of the Second International Conference on Creating, Connecting and Collaborating Through Computing, pp. 78–85 (2004)
8. Nicol, A., Casey, C., MacFarlane, S.: Children are Ready for Speech Technology - but is the Technology Ready for Them? Interaction Design and Children, Eindhoven, The Netherlands (2002)
9. Danli, W., Jie, Z., Jie, L., Guozhong, D., Qiang, L.: A Multimodal 3D Storytelling System for Chinese Children. In: Hui, K.-c., Pan, Z., Chung, R.C.-k., Wang, C.C.L., Jin, X., Göbel, S., Li, E.C.-L. (eds.) EDUTAINMENT 2007. LNCS, vol. 4469, pp. 511–526. Springer, Heidelberg (2007)
10. Colleen, K.: Out of the Lab and into the World: Bringing Story Listening Systems to the Classroom. Poster Presented at AERA (2004)

11. Kimiko, R., Catherine, V., Justine, C.: Literacy Learning by Storytelling with a Virtual Peer. In: Proceedings of Computer Support for Collaborative Learning (2002)
12. Caitlin, K., Randy, P., Sara, K.: Storytelling Alice Motivates Middle School Girls to Learn Computer Programming. In: CHI 2007 Proceedings (2007)
13. Aylett, R.S., Louchart, S., Dias, J., Paiva, A., Vala, M.: FearNot! - an experiment in emergent narrative. In: Panayiotopoulos, T., Gratch, J., Aylett, R.S., Ballin, D., Olivier, P., Rist, T. (eds.) IVA 2005. LNCS (LNAI), vol. 3661, pp. 305–316. Springer, Heidelberg (2005)
14. Hall, L., Vala, M., Hall, M., Webster, M., Woods, S., Gordon, A., Aylett, R.: FearNot's appearance: Reflecting Children's Expectations and Perspectives. In: Gratch, J., Young, M., Aylett, R., Ballin, D., Olivier, P. (eds.) IVA 2006. LNCS (LNAI), vol. 4133, pp. 407–419. Springer, Heidelberg (2006)
15. Oviatt, S.L.: Multimodal Interfaces. In: Jacko, J., Sears, A. (eds.) Handbook of Human-Computer Interface. Lawrence Erlbaum, New Jersey (2002)
16. Pfleger, N.: Context Based Multimodal Fusion. In: Proceedings of ICMI 2004, USA, pp. 265–272 (2004)
17. Oviatt, S.L.: Mutual disambiguation of recognition errors in a multimodal Architecture. In: Proc. CHI 1999 Human Factors in Computing Systems Conf., Pittsburgh, PA, pp. 576–583 (1999)
18. Neal, J.G., Thielman, C.Y., Dobes, A., Haller, S.M., Shapiro, S.C.: Natural language with integrated deictic and graphic gestures. In: Maybury, M.T., Wahlster, W. (eds.) Readings In Intelligent User Interfaces, pp. 38–51. Morgan Kaufmann Publishers, San Francisco (1991)
19. Campana, E., Baldridge, J., Dowding, J., Hockey, B.A., Remington, R.W., Stone, L.S.: Using eye movements to determine referents in a spoken dialogue system. In: Process of workshop on perceptive user interface, Orland, Florida (2001)

Simplified Creation and Presentation of Non-linear Adaptive Content

Oliver Schneider[1,2,3], Udo Bleimann[1,2], Andrew D. Phippen[3], and Bettina Harriehausen-Mühlbauer[2]

[1] Centre for Advanced Learning, Media and Simulation (igdv), Schöfferstraße 1, 64295 Darmstadt, Germany
Oli.Schneider@mac.com,
http://www.igdv.h-da.de

[2] Institute for Applied Informatics Darmstadt (aiDa), Birkenweg 7, 64295 Darmstadt, Germany
http://www.aida.h-da.de

[3] Information Security and Network Research Group, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, United Kingdom
http://www.plymouth.ac.uk

Abstract. A interactive storytelling based service has been developed for the learning project Atlantis University. It provides methods for presenting user adaptive non-linear coherent content in the context of Extended Blended Learning. Like other non-linear projects, it has the problem that huge amount of content is needed.

First the Atlantis University Project including the most significant methods used are presented briefly. Then an approach to overcome the problem by merging learner-types, a storytelling based coherence service and a content contribution system is presented.

1 Introduction

As the successor of Blended Learning, Extended Blended Learning overcomes the pure eLearning obstacles by integrating eLearning with face-to-face learning and project-based learning [1]. The first project realising this approach is Atlantis University [2]. Within the scope of this project a storytelling based system has been developed that provides methods for presenting user adaptive non-linear coherent content [3].

A problem of these systems is the huge amount of content that is needed for real user adaptation. Normally one person cannot create it by his own. Even more difficult is the adaption itself. To present content from different point of views, lots of discussions are needed to ensure that the content is understandable by the addressed learners.

To solve this problem, many authors may create the content as each of them would understand it best by themselves. However, this raises the difficulty of interconnecting the content sections in a way that adaptive coherent non-linearity arises.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 239–250, 2009.

This paper sketches a possibility to overcome this problem by merging the approaches of learner-types, a storytelling based coherence service and a content contribution system.

2 Atlantis University Project

The interdisciplinary project Atlantis University started in 2002. Ten universities and companies from England, Ireland, Poland, Hungary, Germany and United States of America collaborate in research and implementation of new pedagogical concepts. It is focused on an innovative combination of different knowledge-transfer forms called Extended Blended Learning.

Extended Blended Learning (EBL) sets the teaching on three pillars, as shown in Figure 1. The first pillar consists of classical face-to-face learning. For example, the learning topic's high-level dependencies and basics are communicated as well as questions and problems are clarified. The second pillar consists of the eLearning component used by learners to dynamically deepen knowledge and contribute with own information. This information can be interpreted generating knowledge and compiled results in, for instance, a Wiki system. In theoretical and practical terms great importance is assigned to project-based learning since it improves "communicating skills" – a major objective in education [4,5,6]. Not any other learning form is suited this well for the requirements of professional life [7, p 13], because within the scope of a project the project members gather not only the necessary knowledge, but also strengthen their team ability, communication and project management experience [2, p 4].

Atlantis University integrates all three columns of Extended Blended Learning into a virtual university. The respective pillar's part is measured depending on the teaching contents as well as the learner's previous experience and the learner's general situation [1]: A full-time student needs another mix than an employed person who needs specific skills.

The internationalisation of Atlantis does not end with its international project-partners: Of course, students may take modules at the partner universities. But there are also international modules like International Project Based Learning. In this way, the courses, modules and even lessons of the partner universities have been already merged. This enables the partners (and the lecturers) to focus on their own strengths. The students gain internationally accredited and recognised qualifications by international cooperative, collaborative and interdisciplinary learning.

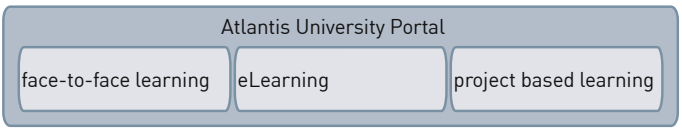


Fig. 1. Three pillars of Extended Blended Learning [2]

Because Atlantis University will bring together the contents of many existing universities, large amounts of learning content will be available. Especially students of small universities or departments would profit from this, because they could still select from a big offer. Although that is an immense advantage, the factor agony of choice also has to be taken into consideration: In today's universities the students know their lecturers from earlier lectures. Hence, usually they can estimate who provides the best content for them. However, in Atlantis University much more modules and lecturers as well as languages and individual student preferences have to be taken into consideration. Software has to be able to offer a suitable preselection.

3 Learner Types

For further improvement going beyond the Extended Blended Learning concept, individual learning characteristics of learners and teachers have been taken into consideration. The model developed by Franz Josef Röll merges seven preference determination models out of 70 existing models [8]. It defines six different learner types [9]. A person does not correspond to only one learner-type, but his strong and weak developed learning preferences are averaged through all six preferences, see Figure 2. Typically two preferences are strong, two are medium and two are weak developed.

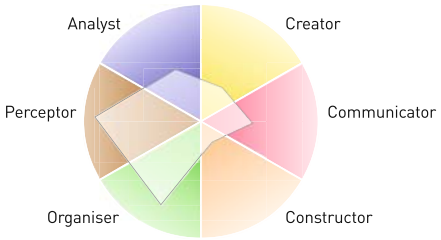


Fig. 2. Example for the six learner-types

The illustration shows exemplarily strengths in the domains of perceptor and organiser. A person of this learner type learns especially well and with pleasure if he is led step-by-step through clearly structured learning content [10]. In addition, the amplitude in the perceptor field shows that the learner should get these content audio-visually presented to achieve the optimum learning success. Hence, the learning material prepared for this learner type should stimulate his senses. These can be charts, animations or videos, but also kinetic stimulation like touch, or auditive for example talks and discussions. However, constructors prefer experimentation and are generally very pragmatically assessed. Engineers often represent this type. Communicators need the group work, while analysts use a rather analytical approach and achieve the best learning results only using

books. Creators learn best if they deal with something completely new. They lose often the interest if standard operations are involved in this process.

Atlantis University is not bound to the use of this special learner type theory. Hence, the discussion about the right learner characterisation is not scope within this paper. The learner type model can be replaced easily at any time.

4 Supporting the Learning Process via Technological Concepts

The basis of the Atlantis University learning environment consists of the following well-known components: Moodle is used as the Learning Management System. It provides all the needed basic functionality and is used to create modules, enrol the students to the courses, and provides basic information.

Wiki is used intensively as a collaboration tool. Students fulfil their tasks and describe their work in the Wiki system. Some modules use the Wiki as documentation system – each semester the students describe some parts of a certain topic. In contrast to books the Wiki-content is always up to date.

Moodle is optimised in handling learning content, but it is not intended to be used as Document Management System (DMS). Hence, for handling and versioning large amounts of revised documents a DMS has been integrated into Atlantis University. It is used for document based project work and for submitting the outcomes of a work that has been done by students during the semester.

In addition to these and other well known components (for example calendar, video conference system) some special learning-tools have been developed by the Atlantis University team.

4.1 Adjusting Content: Coherence

Dan Norman states [11]: "For teaching to be effective, cognition and emotion must work together." This statement gets confirmed by studies in neuronal sciences that stress the importance of emotional engagement for learning efforts and motivation [12]. The key for this can be found in stories: Stories foster emotional engagement, because of having content structured in a suspenseful way. Total immersion into the imaginary world can be caused for the recipient, because of not only reading or viewing but also experiencing a good story.

Stories and their structures provide essential functionalities for learning environments: Focussing the teacher's attention, provision of information and feedback about the learner's efforts [13]. Stories are not limited to a certain topic. With narrative structures complex dependencies can be explained in a human understandable way. Stories are fundamental to culture and human understanding. They have familiar structures which are recognisable and can easily be understood. In human tradition stories were means for information transmission and knowledge acquisition, e.g. within families and cultural communities. "Much true understanding is achieved through storytelling. Stories are how we communicate events and thought processes." [14]

Lectures are often processed in an uniform way like a lecture script and then used for years. As a result eLearning modules are mainly used like lecture notes. Comparable to usual lectures the students work step by step through the content, without making use of their individual strengths and without avoiding their weaknesses. In contrast to this, the Extended Blended Learning concept of Atlantis University supports learning using the individual strength of the students. Thus it is characterised by non-linearity in several dimensions. To be able to control these processes, a new software approach is needed.

Therefore the Coherence service has been developed. Its design is based on interactive digital storytelling methods, which present non-linear content in a coherent way and is user-adaptive and independent of any concrete content [15]. The StoryEngine that is based on Propp's story model [16] is most suitable for Extended Blended Learning [17]. Propp analysed Russian fairy tales and could verify a subset of a total of 31 action functions in every story [18]. These functions are arranged in a generally static order, but may be repeated individually or in groups [19, p 63]. Several variations (scenes) of a function can exist and all these functions are linked by dependencies [19, p 64].

The principle of the summarisation of scenes into functions and relations, to repeat and to apply conditions, can be transferred to the needs of Extended Blended Learning. However, Propp's functions do not fit directly to the Extended Blended Learning scenario.

Because of the mixture between the three pillars, the execution of various Extended Blended Learning modules differ. Thus, one single model with firmly prescribed functions is not adaptable enough to describe those variations. The StoryEngine has been advanced in this respect so that it can process different models and that each of these models is able to define its own functions.

The Propp-model is originated in the fairy-tale world and therefore did not consider interaction [19, p 70]. The functions are not polymorphic; all variations always return the same result. Grasbon has extended the Propp-model by splitting some functions into two part-functions, so that interaction becomes possible. Within the scope of Extended Blended Learning all functions are polymorphic, so that they can influence the action. With the StoryEngine the course through the story is determined by predefined contexts, that may change to one of the following states: *not-set*, *demanded*, *set*, and *on-stage*. Because this is too inflexible in the domain of Atlantis University, contexts can be defined freely, may be grouped, and they stretch value ranges instead of only supporting the four stages mentioned above.

With this extensions to Braun's concept, this service is able to provide coherence, so that module content-sections are not lined up pointlessly or contradictory. The performance of the learners and their personal learning types [8] decisively influence the path through the learning-module by using interactive content.

The eLearning environment works completely regardless of any concrete content. This signifies that it is not only independent from the media type, whether the content is a video or a set of slides, but the system is usable for any kind of learning content and learning styles.

Therefore it divides content into three levels: The highest level is the coherence-model that describes the content-types and their relationship to each other. The medium level is an abstract content-description. It defines the content-sections, their relationship to each other and to which content-type they belong to. The lowest level includes the content itself and the interactions. These descriptions are processed by Coherence and a Content Service (Figure 3), for example the Learning Design engine CopperCore [20].

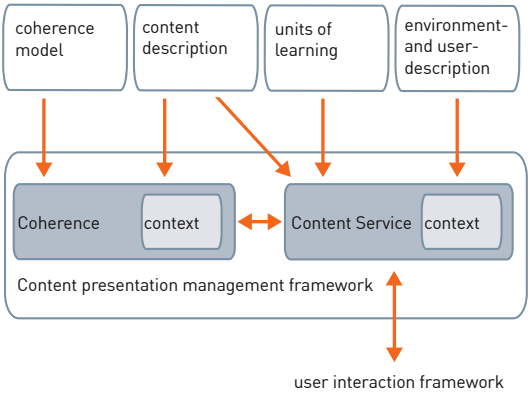


Fig. 3. System's overall architecture

The model has a timeline that provides a flexible duration. At this timeline the content-types are ordered. This order is not strict – it is more comparable to a proposal. It can be influenced by weights, contexts and loops. Each content type may typify several content-sections that refer to portions of concrete content. Figure 4 shows a very simple example for content-types typifying content-sections.

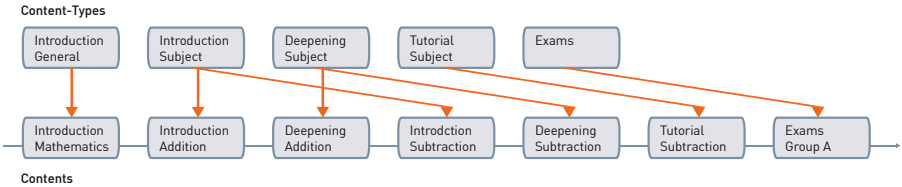


Fig. 4. Mathematics module composed of content-types

During runtime, the following content-section is selected depending on the history and the current context. Contexts provide coherence and dependencies between the content-sections. They serve as variables for the communication between content-sections, module-contents and systems. In contrast to usual computer languages every context has two values stretching a value range. For example, the context `acceptedAge` could be set with the minimum value 18 and

the maximum value 30. The content-sections needing these contexts likewise define a value range that is compared to the set range. The comparison delivers a standardised return value between 0 and 1 that is multiplied by a weighting value that is likewise defined in the context query. This value's range is defined between -1 and 1 and serves to evaluate the result of the corresponding query. The effect reaches fluently from *must not* (-1) through *should not* and *should* until *must* (1). Hence, the limit values -1 and 1 signify compelling requirements.

The concept provides two different query-modes, illustrated in Figure 5. The first mode is overlapping. In this mode the system investigates how much the set context and the needed area overlap. Using overlapping the result is more than 0 as soon as the set context overlaps with the needed one. 1 is returned only if both value ranges are identical. using the second query mode, the nearness between the set and the requested values is checked. 1 is returned if the values touch. With increasing distance the value becomes smaller and smaller and approaches 0.

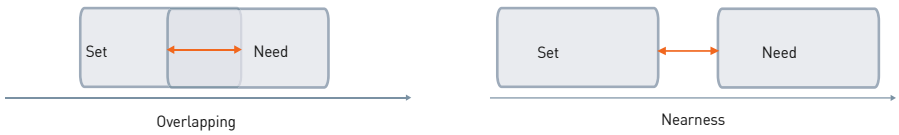


Fig. 5. Context comparison modes

Currently the context `duration` and the context group `learnerType` are mandatory. With the help of these contexts it is guaranteed, that a specific content is presented in a best fitting way to a learner type within a specific duration. Further contexts can be used to help to localise the content, for example the preferred (and provided) language, the needed locations, like lecture-room, laboratory, at home or maybe a specific university. Because of its flexibility this service is able to merge learning-modules of different lecturers to provide the optimal learning path for a specific learner-type. This includes modules of different universities.

This flexible approach has a huge demand of content that has to be kept up-to-date. The storytelling-based approach provides a user-friendly approach for non-linear interactive content creation. Nevertheless, currently Atlantis University lacks of an integrated authoring environment [21]. But a first step in this direction has been done with the development of CoCoMa.

4.2 Learning by Contribution: CoCoMa

When traditional teaching forms are used, the backward channel to the lecturer is limited and learners have little influence on the learning content, since knowledge in sciences as computer science loses it's relevance rapidly. In conditions of fast changing information a new approach to impart knowledge is necessary. This approach will involve students more actively and increase their direct influence on the learning content.

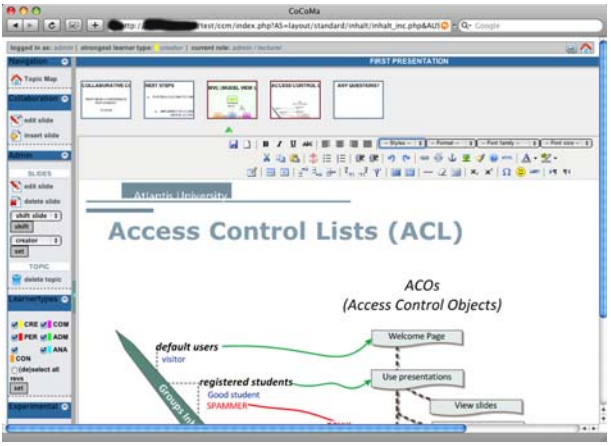


Fig. 6. CoCoMa screenshot

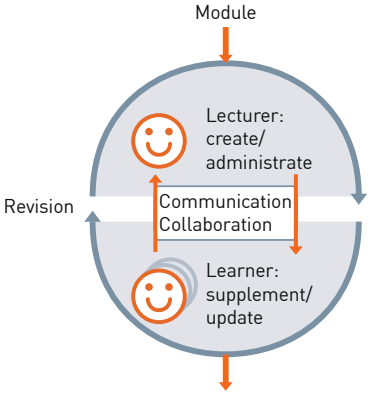


Fig. 7. CoCoMa content updating circle

The Atlantis University concept does this by allowing students to generate learning content with WIKI-systems and semantic networks. In addition, within the scope of the project a system called Cooperative Content Manipulation (CoCoMa) has been developed. With CoCoMa students can update directly the learning content that has been initially provided by a lecturer. Lecturers don't lose the control of their content [22]. In contrast to normal versioning tools as used in WIKI systems, the initial author must actively accept amendments to replace the original version. By this way the content is always up-to-date without too much effort (see Figure 7).

CoCoMa gives great advantages to both, learners and lecturers. Learners may influence the learning content to their need. Hence, they identify themselves more with the content that consists of parts of their own work. This results in better learning abilities and results. This approach has been named "Learning by Contribution".

On the other hand, for many lecturers CoCoMa is the enabler for eLearning like on-line content presentation. They do not loose control, while students are encouraged to cooperate. This decreases the shy and being anxious about putting content online in an editable manner. CoCoMa will have a positive impact on students and lecturers work with other eLearning components like Wiki.

5 Merging Content

The coherence service provides the ability to merge content created by different persons during runtime. The key to that is the context belonging to each content-section.

The coherence service creates coherent content out of many content-sections that are annotated by context. The context may be added explicitly, but most of the mandatory context can be set on the fly. For example, the author's learner-type is a context that must be set. But as it is known to the system because of preceding learner-type tests, no action is needed by the authors.

Provided that lecturers teaching the same module agree upon the same coherence-model, they fill it with content that fits best to their own type. Regarding to Röll's theory students learn best, if the content has been created by a lecturer whose learner type is close to theirs [10]. Therefore the coherence service compares the content's learner-type (that is in fact the content creator's learner-type) with the learner-type of the actual content consumer and chooses the best fitting content-section.

Following example demonstrates this. In Figure 8 the student's learner type is split into its fragments and lined up individually.

Figure 9 illustrates the learner type of one content section created by three different authors (framed). The student's learner type (non-framed) is compared with them and the most akin (the third) is chosen.

This concept also enables the coherence service to explain the same topic with different point of views by looping the content-type. Doing this, it will not repeat the same content-section but presents the same topic that has been created by another lecturer. This encourages the likeliness that the student will understand the topic he has to learn.

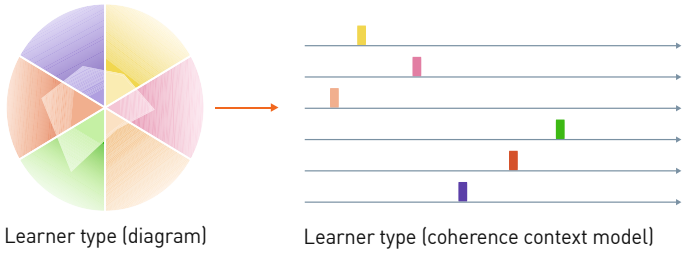


Fig. 8. Splitting up the learner-type

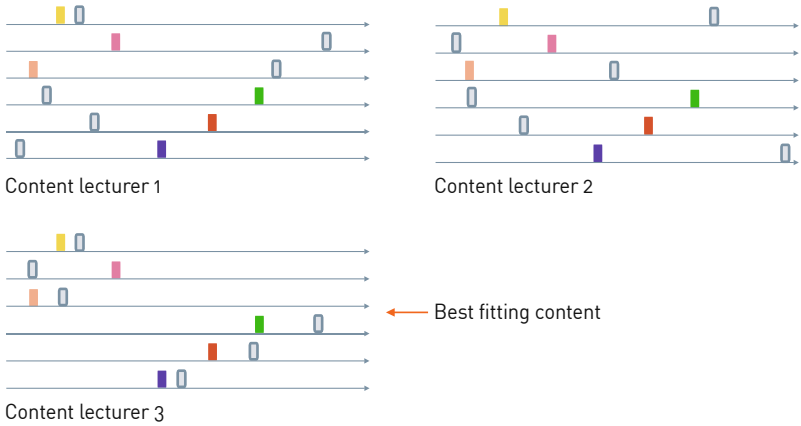


Fig. 9. Evaluation of the best fitting content

Of course, the coherence service does not only compare the learner types, but it also compares the other contexts as well as it factors in the content's dependencies. Hence, a content network is build up and adjusted during runtime.

6 Conclusion and Outlook

This paper presents a method that may overcome the difficulties of presenting adaptive non-linear content that has been created cooperativly in a learning context. Therefore the Atlantis University Project including the most significant methods used – Extended Blended Learning and learner types – are presented briefly. Two tools that have been developed in this context are explained: The storytelling based coherence service that ensures coherence of interactive presented content and CoCoMa that enables author guided contribution of students for content revision. These tools and approaches have been merged to gain support in creating and presenting the content. The concept is still under evaluation and needs refinement. But first results are very promising.

Further developments include expanding CoCoMa with an *Alternative*-button that graduates students from correctors to coauthors. Instead of accepting the revised version and dismissing all other revisions (including the original), the revised version becomes an alternative content. Typically this will not be a different content but a different view onto the topic. Hence, the *content update circle* would become a *content enrichment circle*.

References

1. Bleimann, U., Röll, F.J.: Extended Blended Learning – Innovative Lernszenarien für die Hochschule. In: Querschnitt (Beiträge aus Forschung und Entwicklung der FH Darmstadt, Darmstadt, Germany, vol. 01/06 (2006)

2. Bleimann, U.: Atlantis University – A New Pedagogical Approach beyond E-Learning. Campus-Wide Information Systems 21(5), 191–195 (2004)
3. Schneider, O., Bleimann, U., Phippen, A.D., Harriehausen-Mühlbauer, B.: Inside Coherence: Concept for a Non-Linear eLearning Solution. In: Proceedings of the Seventh International Network Conference (INC 2008), Plymouth, UK, Network Research Group, University of Plymouth (July 2008)
4. Bruffee, K.A.: Collaborative Learning: Higher Education, Interdependence, and the Authority of Knowledge. Johns Hopkins University Press, Baltimore (1999)
5. Batatia, H., Ayache, A., Markkanen, H.: Netpro: An Innovative Approach to Network Project Based Learning. In: Proceedings of the International Conference on Computers in Education (ICCE 2002), Auckland, New Zealand, College of Business, Massey University, pp. 382–386. IEEE Computer Society, Los Alamitos (2002)
6. Neo, M.: Web-Enhanced Learning: Engaging Students in Constructivist Learning. Campus-Wide Information Systems 22(1), 4–14 (2005)
7. Mills, J.E., Treagust, D.F.: Engineering Education – is Problem-Based or Project-Based Learning the Answer? In: Scott, N., Hadgraft, R., Ilic, V.V. (eds.) Australasian Journal of Engineering Education, The Australasian Association for Engineering Education Inc. (2003) ISSN 1324-5821, http://www.aaee.com.au/journal/2003/mills_treagust03.pdf (accessed 23rd January 2009)
8. Brückner, S.: Structure Patterns Depending on Various Learner Types in an e-learning Context. Diploma thesis, Fachhochschule Darmstadt (2005)
9. Röll, F.J.: Computermedien, Bildungsmedien. Vom pädagogischen Nadelöhr zur selbstbestimmten Bildung. In: Schindler, W. (ed.) MaC*_Reloaded: Perspektiven aus der Skepsis für *Menschen am Computer. RabenStück Verlag für Kinder- und Jugendhilfe, Chemnitz, Germany, pp. 37–58 (2005) ISBN 3-935607-22-9
10. Röll, F.J.: Entdecken Sie Ihren persönlichen Lernstil (April 2006), http://comas.offeneslernen.de/lerno/MPX_rubrik.php?rubrik_id=289 (accessed January 30, 2009)
11. Currin, L.: Feelin' Groovy (2004), http://www.elearnmag.org/subpage.cfm?section=articles\&article=10-1 (accessed February 6, 2009)
12. Spitzer, M.: Lernen. Gehirn-Forschung und die Schule des Lebens. Elsevier, Spektrum, Akademischer Verlag, München (2002)
13. Gagné, R.M., Briggs, L.J., Wager, W.W.: Principles of Instructional Design. Harcourt Brace Jovanovich College, Fort Worth (1992)
14. Schell, J.: Understanding Entertainment: Story And Gameplay Are One. In: Jacko, J.A., Sears, A. (eds.) The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications. Lawrence Erlbaum Associates, Florence (2002)
15. Schneider, O., Bleimann, U., Harriehausen-Mühlbauer, B., Phippen, A.D.: Non-Linear Extended Blended Learning. In: Proceedings of the Sixth International Network Conference (INC 2006), Plymouth, UK, Network Research Group, University of Plymouth, July 2006, pp. 377–384 (2006)
16. Braun, N.: Nonlinear Storytelling: Programmierter, interaktiver Narrationsansatz für kontinuierliche Medien. Phd-thesis, Technische Universität, Darmstadt (December 2003)

17. Schneider, O., Bleimann, U., Phippen, A.D., Harriehausen-Mühlbauer, B.: Learn Your Own Way: Decision Way Through Narrative Approaches, Methods and Paradigms for Learning Purposes. In: Proceedings of the Third Collaborative Research Symposium on Security, E-learning, Internet and Networking (SEIN 2007), Plymouth, UK, Network Research Group, University of Plymouth, June 2007, pp. 99–114 (2007) ISBN O978-1-8410-2173-7
18. Propp, W.J.: Morphology of the Folktale. International Journal of American Linguistics 24 (1958)
19. Grasbon, D.: Konzeption und prototypische Implementation einer Storyengine: Dynamisch-reaktives System zum Erzählen nichtlinear-interaktiver Geschichten bei größtmöglicher Spannung, gedanklicher Immersion, Identifikation und Motivation des Spielers. diploma thesis, Technische Universität, Darmstadt (2001)
20. Martens, H., Vogten, H.: A Reference Implementation of a Learning Design Engine. In: Koper, R., Tattersall, C. (eds.) Learning Design, pp. 91–108. Springer, Heidelberg (2005)
21. Schneider, O., Braun, N., Habinger, G.: Storylining Suspense: An Authoring Environment for Structuring Non-linear Interactive Narratives. Journal of the WSCG, Plzeň, Česká republika (2003)
22. Pieke, M., Russell, C., Bleimann, U.: Collaborative content manipulation – an e-learning approach. In: Internet Research, Bradford, England, Hochschule Darmstadt, vol. 17, pp. 49–60. Emerald Group Publishing Limited (2007)

Exploration of Affect Sensing from Speech and Metaphorical Text

Li Zhang

School of Computing
University of Teesside, UK
l.zhang@tees.ac.uk

Abstract. We report new developments on affect detection from textual metaphorical affective expression and affect sensing from speech. The textual affect detection component has been embedded in an intelligent conversational AI agent interacting with human users under loose scenarios. The detected affective states from text also play an important role in producing emotional animation for users' avatars. Evaluation of the affect detection from speech and text is provided. Our work contributes to the conference themes on engagement and emotion, virtual AI agents, narrative storytelling in education and evaluation of affective social interaction.

Keywords: Affect sensing/detection, affective speech processing, and metaphor.

1 Introduction

We intend to provide anti-bullying functionalities for online interaction via affect detection in speech and text and incorporate such functionalities with an automated intelligent conversational agent, engaged in a virtual storytelling environment with human users. In order to achieve this research goal, first of all, we have developed a textual affect detection component, EMMA (emotion, metaphor and affect) on detecting simple and complex emotions, meta-emotions, value judgments etc [1]. The work presented here reports further developments on textual affect detection for one particular metaphorical expression with affect implication, affects as physical objects metaphor ("anger ran through me", "fear attacks me") and a new development on affect sensing from informal conversational speech.

The textual affect detection component has been embedded in an intelligent conversational AI agent, engaged in a drama improvisation with human users under loose scenarios (school bullying and skin cancer). In both scenarios, the AI agent plays a minor role in drama improvisation. It plays a close friend of the bullied victim (the leading role) in school bullying scenario, who tries to stop the bullying and a close friend of the sick leading character in Skin Cancer scenario who tries to give support to his friend with the decision on his life-changing operation. The animation engine adopts the detected affect implied in users' text input to produce emotional gesture animation for the users' avatars. The conversational AI agent also provides appropriate responses based on the detected affect from users' input in order to stimulate the

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 251–262, 2009.

improvisation. The newly developed component on affect sensing from speech has not been integrated with the AI agent yet. Thus we report the initial evaluation of this component separately.

We have also analyzed textual affect detection performance based on the collected transcripts from a new round of user testing by calculating agreements via Cohen's Kappa between two human judges, human judge A/the AI agent and human judge B/the AI agent respectively.

The content is arranged in the following way. We report relevant work in section 2. In section 3, we present the further developments on textual affect and intensity detection especially for the processing of affect metaphor, and the new development of emotion recognition from speech. Brief discussion on the overall system framework and how the detected affects from user's text input contribute to the emotional animation is provided in section 4. Newly produced evaluation results of affect detection from speech and text are reported in section 5. Finally we summarize our work and point out future directions for further developments in section 6.

2 Relevant Work

Automatic affect interpretation from open-ended text and speech could be a very challenging task. Affect expression in verbal communication generally differs from culture to culture, from female to male and from one age group to another, especially for metaphorical expression of affect and emotional expression in speech. In this section, we briefly review relevant well-known research work in this research area.

Textual affect sensing is a rising research branch for natural language processing. ConceptNet [2] is a toolkit to provide practical textual reasoning for affect sensing for six basic emotions, text summarization and topic extraction. Shaikh et al. [3] provided sentence-level textual affect sensing to recognize evaluations (positive and negative). They adopted a rule-based domain-independent approach, but they haven't made attempts to recognize different affective states from open-ended text input.

Although Façade [4] included shallow natural language processing for characters' open-ended utterances, the detection of major emotions, rudeness and value judgements is not mentioned. Zhe and Boucouvalas [5] demonstrated an emotion extraction module embedded in an Internet chatting environment (see also Boucouvalas [6]). It used a part-of-speech tagger and a syntactic chunker to detect the emotional words and to analyze emotion intensity for the first person (e.g. 'I' or 'we'). Unfortunately the emotion detection focused only on emotional adjectives, and did not address deep issues such as figurative expression of emotion (discussed below). Also, the concentration purely on first-person emotions is narrow. There has been relevant work on general linguistic clues that could be used in practice for affect detection (e.g. Craggs and Wood [7]).

There is also well-known research work on the development of emotional conversational agents. Egges et al. [8] have provided virtual characters with conversational emotional responsiveness. Elliott et al. [9] demonstrated tutoring systems that reason about users' emotions. They believe that motivation and emotion play very important roles in learning. Virtual tutors have been created in a way that not only having their own emotion appraisal and responsiveness, but also understanding users' emotional

states according to their learning progress. Aylett et al. [10] also focused on the development of affective behaviour planning for the synthetic characters. Cavazza et al. [11] reported a conversational agent embodied in a wireless robot to provide suggestions for users on a healthy living life-style. Hierarchical Task Networks (HTN) planner and semantic interpretation have been used in this work. The cognitive planner plays an important role in assisting with dialogue management, e.g. giving suggestions to the dialogue manager on what relevant questions should be raised to the user according to the healthy living plan currently generated. The user's response has also been adopted by the cognitive planner to influence the change of the current plan. The limitation of such planning systems is that they normally work reasonably well within the pre-defined domain knowledge, but they will strike when open-ended user input going beyond the planner's knowledge has been used intensively during interaction. The system we present here intends to deal with such challenge.

Moreover, there is also much work in the area of emotion recognition in speech. Murray & Arnott [12] have suggested five vocal effects associated with several basic emotions such as 'pitch average', 'speech rate' and 'intensity' etc from their study. Nogueiras et al. [13] have also used Hidden Markov Models to recognise emotion from speech. Their study proved that the structure of HMM was useful to capture the temporal behaviour of speech. In their work, low level features such as pitch, energy, articulation and spectral shape were employed to recognize emotion. Grimm et al. [14] have used articulatory features from speech signal and mapped them to an emotion state in a multi-dimensional, continuous-valued emotion space to recognize driver's emotional state while driving. Amir and Cohen [15] have also attempted to characterise emotion in the soundtrack of an animated film. Cichosz and Ślot [16] reported a symbol-based learning approach to classify emotion in speech. They used a binary decision tree based classifier. Emotions have been used as the nodes of the tree which were assessed by feature triplets. They have evaluated their approach using two databases of emotional speech on German and Polish. Oudeyer [17] made attempts to detect emotion from speech using genetic algorithm with a set of optimal features. Although he also made attempts in using several different machine learning approaches (such as neural networks, support vector machines etc) to perform the task, naïve bayes classifier hasn't been mentioned at all.

Our work is distinctive in the following aspects: (1) affect detection in textual metaphorical expression; (2) real-time affect sensing for basic and complex affects, meta-emotions, value judgments etc (including 25 affective states) in improvisational role-play situations from open-ended textual user input; (3) affect recognition from speech using naïve Bayes classifier; (4) and real-time simple facial and gesture emotional animation activated by the detected affective states from users' text input.

3 Affect Sensing from Text and Speech

3.1 Affect Recognition from Textual Metaphorical Expression

Affect terms have been used intensively during online interaction. Besides they have been used literally to convey users' emotional states (e.g. "I am angry", "I get bored"), affect terms have been mentioned in affective metaphorical language. One

category of such metaphorical expression is 'Ideas/Emotions as Physical Objects" [18, 19], e.g. "joy ran through me", "my anger returns in a rush", "fear is killing me" etc. In these examples, emotions and feelings have been regarded as external entities. The external entities are often, or usually, physical objects or events. Therefore, affects could be treated as physical objects outside the agent in such examples, which could be active in other ways [18]. Implementation has been carried out to provide the affect detection component the ability to deal with such affect metaphor.

WordNet-affect domain (part of WordNet-domain 3.2) [20] has been used in our application. It provides an additional hierarchy of 'affective domain labels', with which the synsets representing affective concepts are further annotated. Rasp has been used to detect statements with a structure of 'a singular common noun subject + present-tense lexical verb phrase' or 'a singular common noun subject + present-tense copular form + -ing form of lexical verb phrase'. Various user inputs could possess such syntactic forms, e.g. "the girl is crying", "the big bully runs through the grass" etc. We use WordNet-affect to refine the user inputs in order to obtain metaphorical affective expression. The singular common noun subject is sent to WordNet-affect in order to obtain the hierarchical affect information. If the subject is an affective term such as 'panic', then the hierarchical affect information obtained from WordNet-affect is 'negative-fear -> negative-emotion -> emotion -> affective-state -> mental-state'. The system realizes that a mental state has been used as a subject which carries out an activity indicated by the verb phrase(s). Thus the system regards such expression as affective metaphor belonging to the category of 'affects as entities'. A further processing based on the hierarchical affect result leads to the exact affective state conveyed in user's input – fear (negative emotion). If such input has a first-person object, 'me' (such as "panic is dragging me down"), then it indicates the user currently experiences fear. Otherwise if such input has a third-person object, 'him/her' (such as "panic is sweeping over and over him"), it implies that it's not the user who currently experiences 'fear', but another character. The step-by-step analysis is listed in the following for the user input "panic is dragging me down":

1. Rasp recognizes the input with a structure of 'a singular common noun subject (panic) + present-tense copular form (is) + -ing form of lexical verb phrase (dragging) + object (me)';
2. The subject noun term, 'panic', has been sent to WordNet-affect;
3. The obtained hierarchical affect information from WordNet-affect indicates the input is interpreted as a semantic syntactic structure of 'a mental state + an activity + object (me)';
4. The user input is regarded as affect metaphor belonging to the category of 'affects as entities';
5. The detected affective state ('fear') is recovered from the hierarchical affect information;
6. Since the object is 'me', then the system concludes that the user is experiencing 'fear' implied in his/her input.

If the subject of the user input is not an affect term (e.g. "the girl is crying", "the boy sweeps the floor"), other suitable processing methods (e.g. checking syntactic

information and affect indicators etc) are adopted to extract affect. On the whole, such processing is indeed at a very initial stage. However, it provides a useful way to recognize both affect from textual user input and affect metaphor in which emotions are used as external entities.

3.2 Affect Recognition from Speech

Because of the online chat nature of our application, first of all, we have constructed our own specialized speech database. In our application, we mainly intend to recognize 6 basic emotions from speech: neutral, happiness, sadness, fear, anger and surprise. At the initial stage, we have adopted 10 neutral and 10 emotional informal conversational short sentences for each emotional category (some are taken from previous user testing transcripts while the others are created by the authors) for the purpose of emotional speech recording. In order to justify the articulatory features discovered for different emotional speech, we have made neutral sentences not only recorded in a neutral way, but also recorded in the other five emotional ways. Similarly, we have also recorded all affective example sentences in a neutral way so that such speech samples could assist us to remove some of the recovered features from emotional speech data mainly caused by the syllables or phonemes used in some particular speech context. Thus we have recorded 1600 utterances as training data from 10 speakers age 18 – 27 with northeast British accent using standard sound studio. Each speaker contributes 100 emotional utterances – 20 for each category (including 10 neutral sentences spoken in that particular emotional way) and 60 neutral utterances – 10 for each category. We have also recorded 120 utterances as test data set by one chosen female speaker and one male speaker (60 from each speaker).

A speech processing tool, Praat [21], has been used to analyze the speech data. First of all, for each speech sample, Praat provides an automatic summarized voice report containing detailed information on articulatory features such as pitch (median pitch, mean pitch etc), pulses, voicing, jitter, shimmer, harmonicity of the voiced parts (mean noise-to-harmonics ratio etc). After a careful study of the voice reports and other articulatory features of the emotional and non-emotional speech samples from all the speakers, we have chosen 9 articulatory features (mean pitch, median pitch, standard pitch deviation, minimum and maximum pitch, pulses per second, mean intensity, minimum and maximum intensity) to carry out further analysis for both male and female groups. A further analysis and comparison between the generated voice reports of all the speech samples from each category, we further extend the 9 articulatory features to 69 features for male speakers and 52 features for female speakers. Table 1 contains some example features recovered for mean intensity for each emotional category for the male group.

In our application, naïve Bayes classifier has been used to recognize emotion from speech. Equation 1 has been used to calculate the probabilities of different emotional states for any given test speech sample. The emotional state with the highest probability is regarded as the most probable affective state implied in that instance.

$$V_{max} = \text{argmax}_{vj \text{ in } V}\, P(v_j) * P(a_1|v_j) * P(a_2|v_j) * \ldots * P(a_n|v_j) \quad (1)$$

Table 1. Mean intensity value ranges for the male group

Range	Emotion	Feature
] … , 56]	Happy Fear	Ihf
]56 , 58]	Fear Sad	Ifs
]58 , 65]	Fear Sad Angry	Ifsa
]70 , 76]	Angry Happy Surprise	Iahsu
]76 , …]	Happy Surprise	Ihsu

In equation 1, a_1, a_2, … and a_n represent the articulatory features recovered for each speech training data, such as features for mean pitch, median pitch, mean intensity etc. We assume that these 9 general features are all independent. Each training speech sample is represented by the set of 9 articulatory features with different values. M-estimate has been adopted to produce the probability of an attribute value given any emotional or neutral classification. A Java application has been implemented based on the above discussion to recognize emotion from speech. The training input data file contains distinctive 477 utterances with average 82 from each emotional category and 45 neutral utterances. The 120 test speech samples have also been represented in a similar format, but with totally different sets of values of the 9 articulatory features. We report the evaluation of this affect sensing component in section 4.

4 System Architecture and Emotional Animation

In this section, we report the framework of our application and how to employ the detected affect from text to activate emotional animation for users' avatars.

Our system adopts client/server architecture for implementation. The conversation AI agent and other human-controlled characters consist of clients. The server broadcasts messages sent by one client to all the other clients. Thus user's text input from normal user client is sent to the AI agent client via the server. Then the AI agent, who plays a minor role in the improvisation with other human-controlled characters, analyzes the user's text input and derives the affective implication out of the text. Then the AI agent also searches its knowledge base to provide a suitable response to the human players using the detected affective states. We have particularly created the AI agent's responses in a way which could stimulate the improvisation by generating sensitive topics of the storyline. Then an XML stream composed of the detected affective state from one user input and the AI agent's response is dynamically created and broadcasted to all other clients by the server. The users' clients parse the XML stream to obtain the information of the previous "speaker's" emotional state and the current AI character's response. An animation engine has embedded in each user client which updates the user avatars' emotional facial and gesture animation on each user's terminal. Therefore, if the previous human-controlled character expresses

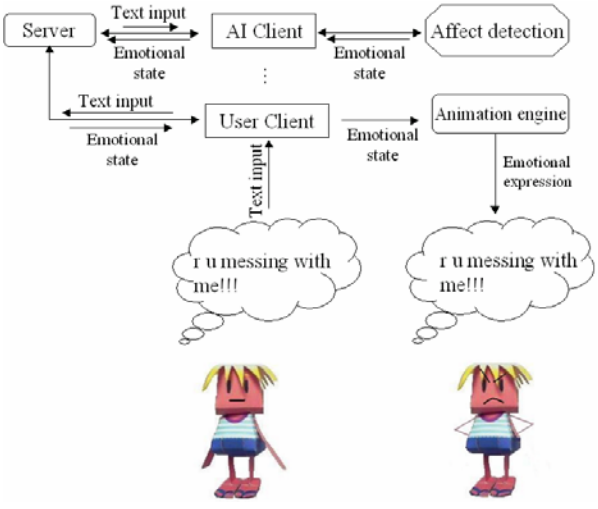


Fig. 1. An example of real-time interaction

'anger' affective state by saying "r u messing with me!!!", the animation engine in each user client updates emotional animation of that character on each terminal using cross behavior via simple facial and gesture animation (see Fig. 1). In each session, up to four characters are engaged in. Fig. 2 displays the architecture of the overall framework.

We have adopted an approach of generating simple facial and gesture animation dynamically. We have assigned different lip shapes, eye brow shapes and arm positions dynamically to different emotional expression. Expressive animation has been considered for eight emotional states including 'neutral', five of Ekman's basic

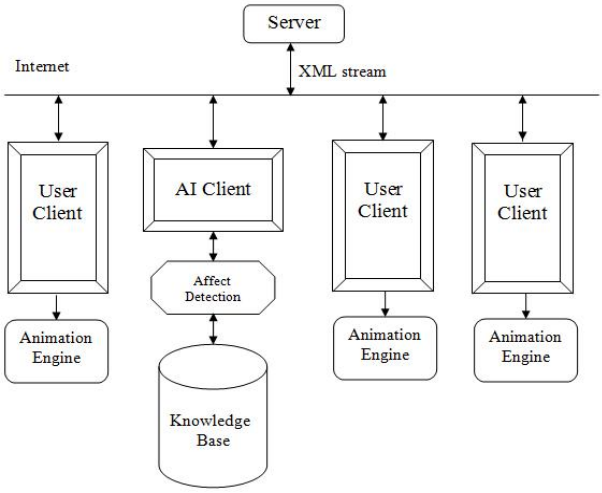


Fig. 2. The system architecture

emotions – 'happy', 'sad', 'fear', 'angry', 'surprise' – and another two complex emotions, 'threatening', 'caring', and an non-emotional state 'greeting'. If the AI character derives an emotional state from a human-controlled character's text input, emotional animation engine in each client updates the emotional expression of that user' avatar on each client terminal. The overall system could provide the effects that the users' avatars move in a way which is consistent with their emotional states implied in their text input in a real-time application. Although user avatars' emotional animation is truly basic and simple, we obtained very positive feedback from the testing subjects based on the analysis of the post questionnaires and the discussion in the debriefing session for a new round of testing (see section 5).

Relationships between characters play an important role in how characters respond to one another. We have implemented a simple emotion appraisal model for the AI character. In the bullying scenario, there are four characters: the bully, the victim, and two close friends of the victim who try to stop the bullying. The AI agent plays a minor role – one male close friend of the bullied victim. If the AI character realizes that the bully seems being aggressive ('rude', 'angry' or 'threatening') implied in his text input, the AI character becomes 'angry' due to the fact that they have a negative relationship. Similarly, the AI character would become 'caring', if the bullied victim indicates 'sad' or 'fear' in the text input during the interaction. It also indicates that the AI character and the bullied victim have a positive relationship. In the meantime, the AI character's responses also reflect its current emotional states.

5 Evaluation

Since the component of affect sensing from speech hasn't been embedded into the AI agent yet, we have evaluated its performance individually based on the testing of 120 utterances from one male and one female speaker (60 from each speaker). The emotion recognition results are in the following. For the male speaker, utterances with emotional state surprise (100%), neutral (90%), anger (60%), and fear (50%), have been recognized well. It needs improvements on the emotion recognition of utterances with sadness (10%) and happiness (20%) implication. For the female speaker, the affect sensing component performs well for the utterances with emotional state neutral (90%), sadness (60%) and happiness (60%). For the utterances with emotional state surprise (40%), fear (10%) and anger (20%), the recognition performance became worse. A further detailed analysis indicated that for both male and female speakers, an emotional sentence labeled with one negative affective state tends to be recognized to contain another negative affect implication because of the resemblance of the articulatory features in these two emotional categories. E.g. speech samples with 'sadness' implication have been mis-interpreted to contain the affective state, 'fear'. Similarly, speech data with 'happiness' implication have been mis-regarded to contain 'surprise' taste, because they have also showed much similarity as those with 'good surprise' indication. These results indicate that our affect sensing component may have extracted some underlying generalization in the recognition of the general positive and negative affective states from the training data, but further improvement is needed in order to effectively distinguish one positive/negative affective state from another. We also aim to extend the evaluation by using more speech samples from several other speakers.

Moreover, we have also conducted a new round of user testing with 40 school children age from 11 to 15 to test the overall system with the textual affect detection and the AI agent under the improvisation of school bullying (SB) and skin cancer (SC) scenarios. We have classified the testing subjects based on their age into three groups. Group 1 has the children age 11 – 13, group 2 composed of children age 13 – 14 and group 3 with school children age 14 – 15. Generally, our statistical results based on the collected questionnaires indicate that the involvement of the AI character has not made any statistically significant difference to users' engagement and enjoyment with the emphasis of users' notice of the AI character's contribution throughout.

In the following, we especially report some results on the performances of the AI character and textual affect sensing from the testing. In general, we have compared the performance of the AI minor character in SB with that of the human-controlled minor character in the same scenario. Fig. 3 & 4 respectively show to what extent the AI and human-controlled minor characters have said strange things and to what extent the AI and human-controlled minor characters have contributed to the improvisation usefully based on the analysis of the questionnaires filled up by the three groups of young people respectively. The AI agent seemed haven't impressed the first group users with the scores for 'useful contribution' AI vs Human, 57% - 63% and the scores for 'saying strange things' AI vs Human, 51% - 47%. For the other two groups of users, the AI character has scored slightly better than the human-controlled minor character with the scores for 'useful contribution' AI vs Human respectively, 56% - 47% (Group 2) and 60% - 53% (Group 3) and the scores for 'saying strange things' AI vs Human respectively, 42% - 60% (Group 2) and 53% - 67% (Group 3). Some pupils from Group 3 expressed they felt more relaxed when doing improvisation online than in real-life situations. The group 1 users stated that they felt the scenarios (especially, the skin cancer scenario) were too heavy for them. They indicated that they preferred a light-hearted scenario embedded with entertainment.

Moreover, we have provided *Cohen's Kappa* in order to evaluate the efficiency of the textual affect detection processing for the detection of 25 affective states, although simple emotional facial and gesture animation could only deal with 8 particular emotional states. Two human judges (not involved in any development stage) have been employed to annotate part of the recorded transcripts of the SB scenario (72

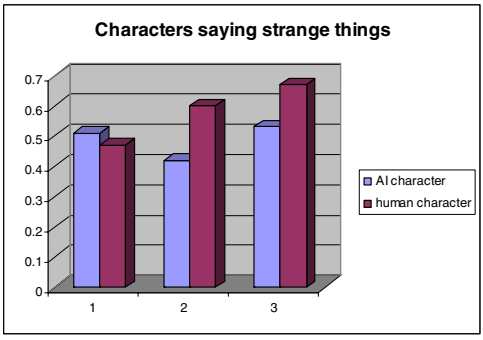


Fig. 3. The comparison of characters saying strange things during the improvisation between the AI and the human-controlled minor characters for the 3 groups

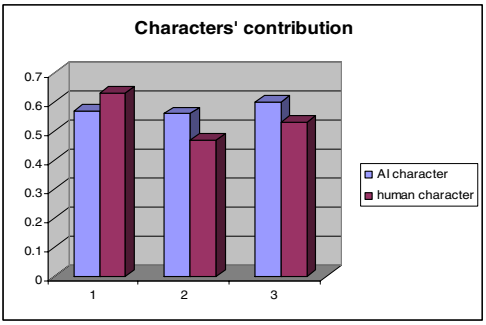


Fig. 4. The comparison of useful contribution to the improvisation between the AI and the human-controlled minor characters for the 3 groups

turn-taking user input) filed from the testing. The inter agreement between human judge A and B is 0.896. The agreements for human judge A/the AI agent and human judge B/the AI agent are respectively 0.662 and 0.729. Although improvement is needed, the AI agent's affect detection performance is acceptable and could achieve satisfactory level in good cases. Analysis results also indicate improvement is needed for negative affect detection (e.g. using context information). In some cases, when the two human judges both believed that user inputs carried negative affective states (such as angry, threatening, disapproval etc), the AI agent regarded them as neutral. The most obvious reason is that the context information used by the human judges to interpret emotions has been discarded by the AI agent due to the fact that our current processing is only based on the input of individual turn taking level rather than context level. However, an individual user input, regarded as neutral by itself in most cases by all human judges, could be interpreted as emotional with the consideration of the context profiles. Thus we aim to improve the detection performance by adopting context profile as one direction for future development for textual affect sensing.

6 Conclusions

First of all, we have made a step towards automatic affect sensing from textual metaphorical figurative language. However, there is still a long way to go in order to successfully process the rich diverse variations of metaphorical language and other figurative expressions, such as humor, lies, irony etc. Also, context information sometimes is very crucial for textual affect detection. These indicate in which our strength needs to lie in the future development.

We have also implemented a prototype system for affect sensing from speech using naïve bayes classifier. Although there is room for further improvements, the current performance of the affect sensing component is acceptable and promising. We intend to integrate this component with another intelligent conversational agent who interacts with human users during online speech based interaction so that the intelligent agent would be capable of detecting bullying or other emotional situations automatically from users' speech via the affect sensing component reported here.

Overall, our work provides automatic improvisational agents for virtual drama improvisation situations. It makes a contribution to the issue of what types of automation should be included in human-agent interaction, and as part of that the issue of what types of affect in speech and text should be detected and how. It also provides an opportunity for the developers to explore how emotional issues embedded in the scenarios, characters and dialogue can be represented visually without detracting users from the learning situation. Finally, the automated conversational AI agent and the emotional animation may contribute to improving the perceived quality of social interaction.

References

1. Zhang, L., Barnden, J.A., Hendley, R.J., Lee, M.G., Wallington, A.M., Wen, Z.: Affect Detection and Metaphor in E-drama. Int. J. Continuing Engineering Education and Life-Long Learning 18(2), 234–252 (2008)
2. Liu, H., Singh, P.: ConceptNet: A practical commonsense reasoning toolkit. BT Technology Journal 22 (2004)
3. Shaikh, M.A.M., Prendinger, H., Mitsuru, I.: Assessing sentiment of text by semantic dependency and contextual valence analysis. In: Paiva, A.C.R., Prada, R., Picard, R.W. (eds.) ACII 2007. LNCS, vol. 4738, pp. 191–202. Springer, Heidelberg (2007)
4. Mateas, M.: Ph.D. Thesis. Interactive Drama, Art and Artificial Intelligence. School of Computer Science, Carnegie Mellon University (2002)
5. Zhe, X., Boucouvalas, A.C.: Text-to-Emotion Engine for Real Time Internet Communication. In: Proceedings of International Symposium on Communication Systems, Networks and DSPs, Staffordshire University, UK, pp. 164–168 (2002)
6. Boucouvalas, A.C.: Real Time Text-to-Emotion Engine for Expressive Internet Communications. In: Riva, G., Davide, F., IJsselsteijn, W. (eds.) Being There: Concepts, Effects and Measurement of User Presence in Synthetic Environments, pp. 305–318 (2002)
7. Craggs, R., Wood, M.: A Two Dimensional Annotation Scheme for Emotion in Dialogue. In: Proceedings of AAAI Spring Symposium: Exploring Attitude and Affect in Text (2004)
8. Egges, A., Kshirsagar, S., Magnenat-Thalmann, N.: A Model for Personality and Emotion Simulation. In: Proceedings of Knowledge-Based Intelligent Information & Engineering Systems (KES 2003). LNCS (LNAI), pp. 453–461. Springer, Heidelberg (2003)
9. Elliott, C., Rickel, J., Lester, J.: Integrating Affective Computing into Animated Tutoring Agents. In: Proceedings of IJCAI 1997 Workshop on Intelligent Interface Agents, pp. 113–121 (1997)
10. Aylett, R., Louchart, S., Dias, J., Paiva, A., Vala, M., Woods, S., Hall, L.E.: Unscripted Narrative for Affectively Driven Characters. IEEE Computer Graphics and Applications 26(3), 42–52 (2006)
11. Cavazza, M., Smith, C., Charlton, D., Zhang, L., Turunen, M., Hakulinen, J.: A 'Companion' ECA with Planning and Activity Modelling. In: Proceedings of the 7th International Conference on Autonomous Agents and Multi-Agent Systems, Portugal, pp. 1281–1284 (2008)
12. Murray, I.R., Arnott, J.L.: Implementation and testing of a system for producing emotion-by-rule in synthetic speech. Speech Communication (16), 369–390 (1995)
13. Nogueiras, A., Moreno, A., Bonafante, A., Maririo, J.: Speech Emotion Recognition Using Hidden Markov Models. In: Eurospeech 2001, pp. 2679–2682 (2001)

14. Grimm, M., Kroschel, K., Harris, H., Nass, C., Schuller, B., Rigoll, G., Moosmayr, T.: On the Necessity and Feasibility of Detecting a Driver's Emotional State While Driving. In: Paiva, A.C.R., Prada, R., Picard, R.W. (eds.) ACII 2007. LNCS, vol. 4738, pp. 126–138. Springer, Heidelberg (2007)
15. Amir, N., Cohen, R.: Characterizing Emotion in the Soundtrack of an Animated Film: Credible or Incredible? In: Paiva, A.C.R., Prada, R., Picard, R.W. (eds.) ACII 2007. LNCS, vol. 4738, pp. 148–158. Springer, Heidelberg (2007)
16. Cichosz, J., Slot, K.: Emotion recognition in speech signal using emotion-extracting binary decision trees. In: Doctoral Consortium. ACII 2007, Lisbon. ACM, Springer (2007)
17. Oudeyer, P.Y.: The production and recognition of emotions in speech: features and algorithms. International Journal in Human-Computer Studies 59(1-2), 157–183 (2003); Special Issue on Affective Computing
18. ATT-Meta Project Databank: Examples of Usage of Metaphors of Mind (2008), `http://www.cs.bham.ac.uk/~jab/ATT-Meta/Databank/`
19. Kövecses, Z.: Are There Any Emotion-Specific Metaphors? In: Athanasiadou, A., Tabakowska, E. (eds.) Speaking of Emotions: Conceptualization and Expression, pp. 127–151. Mouton de Gruyter, Berlin (1998)
20. Strapparava, C., Valitutti, A.: WordNet-Affect: An Affective Extension of WordNet. In: Proceedings of the 4th International Conference on Language Resources and Evaluation (LREC 2004), Lisbon, Portugal, pp. 1083–1086 (2004)
21. Praat, a speech processing tool (2008), `http://www.personal.rdg.ac.uk/~llsroach/phon2/freespeech.htm`

QuizMASter - A Multi-Agent Game-Style Learning Activity

Mark Dutchuk[1], Khalid Aziz Muhammadi[2], and Fuhua Lin[3]

[1] Vancouver Island University, Canada
Mark.Dutchuk@viu.ca
[2] Department of Energy, Government of Alberta, Canada
khalidaziz@gmail.com
[3] School of Computing and Information Systems, Athabasca University, Canada
oscarl@athabascau.ca
http://io.acad.athabascau.ca/~oscar/

Abstract. This paper describes a research project in progress of developing a Multi-Agent System-based educational game QuizMASter for e-learning that would help students learn their course material through friendly competition. We explore the use of perceptive pedagogical agents that would be able to determine the learner's attitudes; to assess learners' emotional states through examining learner's standing, response timing, and history, and banter; and to provide appropriate feedback to students in order to motivate them.

Keywords: Agents, edutainment, virtual game-show, game-based learning, e-learning, virtual learning environment, pedagogy.

1 Introduction

We are working on a research project of developing a Multi-Agent System-based educational game QuizMASter that would help students learn their course material through friendly competition. We explore the use of software agents in educational applications – specifically the use intelligent software agents to provide appropriate feedback to students in order to motivate them.

Conceptually, QuizMASter is designed similar to a TV game show, where a small group of contestants compete by answering questions presented by the game show host. Contestants score points by correctly answering questions before their opponents do. Questions are drawn from a Learning Management System database and presented to players one question at a time. The answer given, along with the length of time taken to respond, is transmitted back to a central agent. Scores will be tallied, and the feedback on a player's standing will be provided to motivate the player.

In QuizMASter, students naturally take the place of game contestants, however the game-show host has been replaced with an intelligent software agent. By studying the reaction of students to the game, and by altering the feedback provided by the game show host, we hope to determine the degree of success the agent has at motivating the player.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 263–272, 2009.

2 Related Work

Games are a popular way of enhancing learning, and many researchers have found educational games to be beneficial learning tools [1][2]. Paper [3] provides an excellent overview of game-based learning.

While some argue over the benefits to educational games, Crawford (1982) asserts that games are the *natural* way to learn, and that what we would normally consider "conventional" methods are, in fact, recent unproven teaching methods [4].

Early research by Malone (1981) [5] identified three important characteristics of games that motivate people to play them: Fantasy, challenge, and curiosity. However, later work by Okonkwo and Vassileva (2001) [6] showed that while educational games can be successful at motivating students to play them, their effect on actual learning might be small. Nevertheless, many researchers have used Malone's work as the basis for educational game design.

Kirriemuiret al. (2004) note that, among other reasons, educational games often fail because theyare too *simplistic*when compared with commercial video games, too repetitive, and the tasks do not support progressive understanding [7]. Some researchers have attempted to address these issues through the use of intelligent software agents [8]. Intelligent agents are capable of behaviors that can be used to add an element of unpredictability and complexity to game-play. Agents, especially those that present an anthropomorphic persona, have been shown to be highly effective in engaging the student [8].

One well-known study of agents in a learning environment was Herman The Bug / Design-A-Plant [9]. 'Herman' was a virtual insect character capable of 30 behaviors and more than 150 audio responses, who would guide students in the design of a plant suited to an extra-terrestrial environments. Herman was capable of giving advice using both verbal and animated behaviors. It was found that the use of this animated agent had significant benefits to both motivation *and* performance.

MCOE (MultiagentCo-operative Environment) is an educational game that simulates a lake environment [10]. As human players play the game, they learn the effects of pollution and try to control it. MCOE includes purely reactive agents such as fish and plants, and cognitive agents including a tutoring agent and a virtual 'ecologist'. Here, the term '*cognitive'* refers to the ability of the agent to perceive its environment whereupon it may be able to change its behavior accordingly.

Other examples of agent-based educational games include TALENT [11], REAL [12], and Ask&Answer [13]. TALENTis a multi-player game designed to teach programming to University students. A pedagogical agent assumes the role of Mentor to supply guidance, hints, and motivation to students as they work through various programming problems. TALENT's agent forms a model of the learner based on the learner's progress and achievement, and is able to adapt its behavior accordingly [11]. REAL (Reflective Agent Learning Environment)[12] is an agent-based learning environment provides a framework for simulation game scenarios. REAL provides an Expert agent that contains the knowledge about the system being simulated, and a Reflective agent to model what the learner 'knows' about his or her environment. A Pedagogical agent compares the Reflective agent's knowledge with that of the Expert agent's and adjusts it teaching strategy. Finally, a communication agent is used to handle actual human-computer interaction. In Ask&Answer [13], teams of students

are presented with questions that they must answer. In doing so, they interact with an agent named CNPC (Capricious Non-Player Character) that knows the answers to the questions and is willing to hand out important clues that would help a particular team win. However, the agent must be emotionally 'stroked' in order to maintain loyalty to a team. If a particular team fails to satisfy the agent, it will change its loyalties giving advantage to the other team. Given this behaviour, an important component of an overall winning strategy is to maintain a strong social bond with CNCP. As such, Ask&Answer provides researchers with data on how students form and maintain social relations with an artificial entity.

3 Our Approach

Our approach is based on the framework for building classrooms and online learning environments proposed by Bransfordet al. (2000), which suggests that learning environments should be knowledge, student, assessment, and community centered [14] (Bransford, et al., 2000), and that game-based learning environments should be enjoyable. There are three primary design decisions in our approach:

1. TV Game Show Format

Few would deny that TV Game shows are popular. Since their first appearance in the 40's and 50's, TV game shows have attracted a large and steady audience. Examples such as 'The Price is Right' have endured for over 35 years [15].

While there are many educational games available, many are targeted to a younger learner. We believe the TV Game Show format will appeal to an older student, where intellectual stimulation generally holds a higher priority than flashy graphics and/or 'shoot-em-up' action. By putting the emphasis on mental challenge, we hope to avoid the simplicity problems noted by Kirriemuir& McFarlane (2004) [7], while still providing the motivational elements of fantasy,challenge, and curiosity identified by Malone (1980) [2].

2. The Use Of Pedagogical Agents To Provide Feedback and Motivation

By using pedagogical agents we hoped to avoid the simplicity problems mentioned above. Central to this idea is the agent designed for the role of game-show host.In QuizMASter, as in real life, one of the primary roles of the game show host is to keep to game interesting.

Conati&Klawe (2002) assert that, with respect to pedagogical agents in an educational game scenario, it is fundamental that the educational interventions be delivered within the spirit of the game, by characters that (i) are an integral part of the game plot; (ii) are capable of detecting students' lack of engagement, in addition to lack of learning; (iii) know how to effectively intervene to correct these negative emotional and cognitive states [16].

We addressed point (i) by casting our pedagogical agent as the host of a TV game show. Students will easily identify the role played by our host agent, and this should contribute to the fantasy element of the game. On point (ii) we looked for ways to assess the student's interest and engagement in a manner that was consistent with the game. Three opportunities presented themselves: One, is the standing of the student in the game; two, through the analysis of timing information related to a student's

response to questions; and three, by engaging the student in short conversations typical of what a game-show host does between rounds of game-play.On point (iii) we saw an opportunity to favorably *alter* the student's attitude through short conversations between the Host agent and the contestant.

3. The Use Of The Moodle LMS

The Moodle LMS (http://www.moodle.org) providestwo important functions for QuizMASter.First, we use Moodle's user management system to maintain user accounts and control access to learning resources. Second, we use Moodle's quiz module as the source for our game questions. Thus, QuizMASter could be integrated in any course where a Moodle quiz is available[1].

Assessing Contestant Emotional State

Within the QuizMASter game environment, we identified three opportunitiesto gain information on the contestant's emotional state:

- **Contestant Standing**: We assume that a contestant that is winning is sufficiently engaged, and that those in last place are somewhat unhappy with, or uninterested in their performance in the game. Based on such assumptions we use the contestant's current standing as a factor when calculating their attitude.
- **Response Timing and History**: QuizMASter records the contestant's response time to the questions. These can then be analyzed and compared with the other players. Responses that are consistently too fast, too slow, or contain too many wrong answers, might indicate a lack of engagement, or insufficient knowledge on the subject. Currently, QuizMASter only uses this information to display the order in which contestants correctly answered questions, based on their response time.
- **Banter**: Research by Ward &Tsukahara (2003) suggests it is possible to design agents that can infer a user's state from their conversations [17]. In QuizMASter, we will examine the interaction between the host and the player during what we will call 'banter' sessions.

Anyone who has watched TV game shows is probably familiar with the short discussions or 'banter' that the host carries out with each of the contestants. For example, the host may tease a contestant about their work, their family, etc. In the case of QuizMASter, banter provides an important source of information as to the contestant's emotional state and their attitude towards the game-play.

4 The Architectural Design

QuizMASter consists of a Host agent and two or more Player agents - one for each contestant or team of contestants playing the game. Agents are implemented in Java and the JADE (**J**ava **A**gent **DE**velopment framework) agent development platform

[1] Currently, only true/false, multiple choice, and fill-in-the-blank question types are supported.

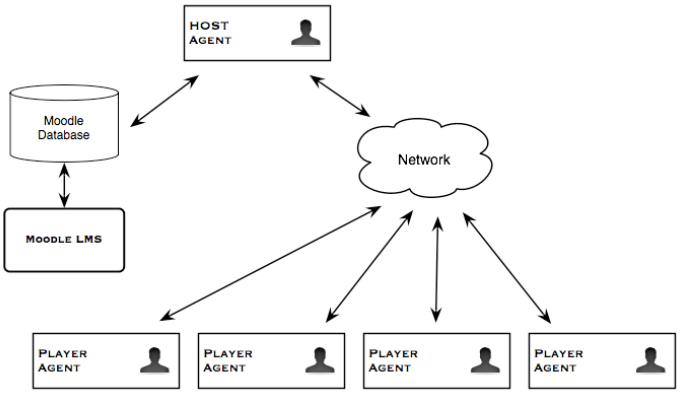


Fig. 1. The Software Architecture of QuizMASter

(http://jade.tilab.com/). JADE has become a de facto standard in the multi-agent system community.QuizMASter depends on Moodle's database structure for user management and quiz questions. (See Fig. 1).

4.1 Player Agent

It is the responsibility of the Player agent to:

- Assess and maintain the contestant's emotional state
- Receive and display questions
- Calculate response timing
- Send Response objects back to the Host agent

During game-play, the Player agent will display the new question, and begin a local timer[2]. To score points, the contestant must answer the question first, before other human players, and before the timer expires. When the human player answers the question, or the allotted time has expired, the Player agent will report the player's response and the timing data to the Hostagent.

The Player agent interface is responsible for displaying information sent from the Host agent (see Fig. 2).In addition to the questions and answers themselves, the contestant's current standing in the game and the number of questions left in the round are displayed. The Player agent also displays the face of the game show host, the conversational text produced by the host agent and the various players, and provides the means for each contestant to contribute to the conversation using an 'instant messaging' style text interaction.

[2] Although the timing appears as a single 'game time' for all contestants, the actual response timing is calculated at the Player agent. This eliminates the possibility that a contestant might be disadvantaged because of transmission delays in sending a response back through the network. Under normal network conditions any timing discrepancies between contestants should be indistinguishable.

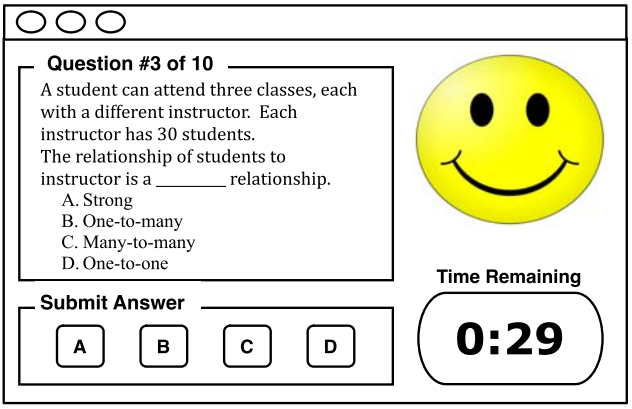


Fig. 2. Prototype Player agent interface presenting a question

4.2 The Host Agent

The QuizMASter Host agent assumes the role of a TV game show host. Consistent with that role, our Host agent provides the following functionality:

- Presentation of questions
- Feedback to the contestants
- Engage in banter sessions with contestants
- Attempt to 'bond' with the contestant, by displaying appropriate emotion.
- Maintain an high level of interest/excitement
- Scorekeeping

Banter Session
Periodically throughout the game (typically after every 2-3 questions) the Host agent will engage in 'banter' with a contestant. The contestant is chosen based on:

- The contestant with the lowest 'emotion' factor
- The winner after the current 'round' of play
- Random selection when no clear data is available

However, the software attempts to talk with all contestants. Once a contestant has participated in a banter session, they are removed from the pick list. Once all contestants have participated, the list is repopulated.

Bonding
Each Host agent attempts to bond with its contestant by celebrating their success, and 'sharing the pain' of an incorrect response. This is accomplished by presenting an appropriate face to the contestant. In an attempt to maintain a positive attitude, the Host agent will normally display a 'happy' face. However:

- Between the time that a new question has been presented and the time the contestant responds, the Host agent will present a 'thinking' face.

- If the contestant answers correctly the Host agent presents a ‘happy’ face.
- If the contestant answers incorrectly, or a timeout occurs, the Host agent will temporarily present a ‘sad’ face. This will return to a happy face after a short period of time.

The ‘Dramatic Pause’
Consistent with game-show formula, a ‘dramatic pause’ is introduced into the feedback system before revealing the correct answers to the questions. At the beginning of the game, this pause is minimal. As the game progresses, the pause is increased.

Scoring Subsystem
A scoring subsystem is responsible for processing Response objects, calculating scores and standings for current game. Response objects contain the answers contestants have supplied to a Question, along with timing and emotional state information. Currently, scores are not written back to the Moodle database. In fact, they do not persist beyond the active QuizMASter session.

TheHost agent user interface provides for choosing Moodle quiz activities as the source for game-play, inviting contestants, and displaying game status. Fig.3shows our prototype Host agent interface during game-play.

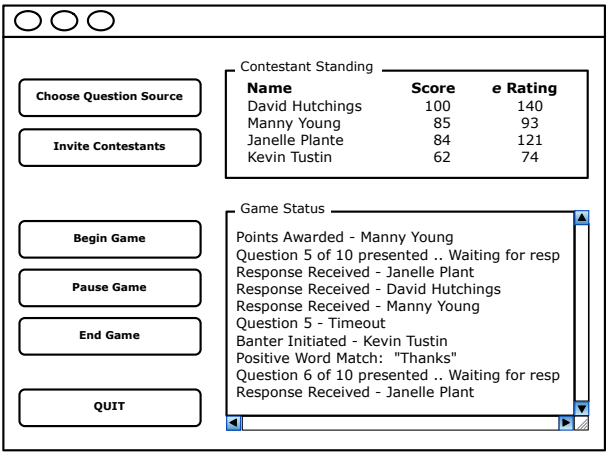


Fig. 3. Prototype Host agent interface during game-play

5 Implementation

The Player agent class implements the student model, and is the interface through which contestants interact with the system. An instance of the Player agent runs on the contestant’s hardware (typically a PC or laptop) and connects to the server-side components via a LAN or Internet connection. Up to four instances of the Player agents may be active at any one time.The Host agent interface provides the ability to select a course to draw the quiz activity from, and invite other players to join. The

instructor of a course creates quizzes and stores them in the Learning Management System ahead of time.

A standard Moodle installation provides the required database functionality needed by QuizMASter. Moodle's Question Bank subsystem allows one to add, edit, delete, and import questions to be used by Moodle's Quiz subsystem. Username and password are checked against the user table in the Moodle database, and access and permissions to resources are consistent Moodle's defined roles of 'Teacher', 'Course Creator', 'Administrator', and 'Student'.Java classes were implemented to retrieve appropriate fields from the User, Course, Quiz, Question, andAnswer tables of the Moodle database. MySQL was used as the database server, but any Moodle-supported database could be used with very minor alterations to the QuizMASter codebase.

We assessthe contestant'semotional state by considering their current standing in the game – first place, second-place, etc., and through the banter sessions. In a typical banter session, the host agent will choose a contestant to chat with, and initiate the chat using a set of pre-defined questions and/or statements. The response from the contestant is compared against two sets of keywords. A response containing words that match those in the 'positive' set of words is an indication of a positive attitude towards the game; a response containing words that match those in the 'negative set of words is an indication of a negative attitude.In our naïve initial implementation, these sets contain only a few words. As we study game-play over many sessions, additional words will be added to both lists.

Initially QuizMASter assumes that all contestants are equally interested in playing the game and assigns an initial value of $e = 100$ to each contestant. During game-play:

- A value of 10 is added for each 'positive' word matched during banter
- A value of 10 is subtracted for each 'negative' word matched during banter
- Contestants in first place, or tied for first place are assigned $e * 1.00$
- Contestants in second place, or tied for second place are assigned $e * 0.80$
- Contestants in third place, or tied for third place are assigned $e * 0.70$
- Contestants in last place are assigned $e * 0.60$

The host agent alters its behavior by preferring to engage in banter sessions with the contestant with the lowest value of e. Through this, we hope to positively affect the contestant's attitude toward the game.

6 Conclusions and Further Research

We have presented QuizMASter, an educational game based on a TV game-show format that usespedagogical agents to provide relevant and motivating feedback to participants in a game-based learning activity. The current version of QuizMASter provides basic perception and feedback systems to assess a player's attitude during game-play and provide appropriate responses. It has allowed us to identify and study several implementation issues. However, there is considerable room for improvement:

- Currently our prototype Host agent provides text-only interactions. FreeTTS[3] speech synthesis software and Sphinx-4[4] voice recognition software are being considered to provide natural language communications between contestants and the QuizMASter host. This would provide a less distracting interface for contestants, while permitting QuizMASter to identify keywords directly from the contestant's speech.
- QuizMASter could implement a considerably more sophisticated Banter subsystem by using the A.L.I.C.E.[5] chat bot or similar technology. Using A.L.I.C.E., one could provide context-specific game conversations by creating a custom set of AIML categories.
- Software is currently available that is able to detect emotions based on facial recognition. Software such as this could supplement the conversation-based perception subsystem used by the current version of QuizMASter.

Certainly the most significant improvement planned over the next year is to implement QuizMASter in Sun's Wonderland[6]3D virtual environment.The Wonderland environment willimprove our system substantially by adding graphics, animation, and sound elements. These features will go long way to satisfying the educational requirements identified by Malone (1981), Bransford et al. (2000), and Conati&Klawe (2002).Within the Wonderland environment, avatars will represent QuizMASter contestants, and the game show host will be implemented as an Animated Pedagogical Agent (APA). One can envision the ability to choose between a number of TV game show scenarios that would load alternate background graphics to simulate a particular game such as 'Price is Right'[15] or 'Who wants to be a Millionaire?'[7]. Choosing a particular scenario would alter the scoring system's rules and feedback system to be consistent with the particular game being simulated.

QuizMASter in an Immersive Environment

Since reporting on our initial work, we have focused our attention on implementing QuizMASter in a virtual 3D immersive environment using Sun's Project Wonderland Virtual World Toolkit (https://lg3d-wonderland.dev.java.net). The current version of Sun's toolkit has progressed to the point where, in addition to movement through the 3D environment, the avatar subsystem is able to convey simple gestures, and some rudimentary facial expressions. We intend to exploit these features to provide more natural and expressive interactions between QuizMASter's virtual game show host and the game's contestants. The 3D environment also provides the opportunity to create quiz questions and game interactions based on viewing and/or manipulating 3D objects in virtual space.We have elected to use a simple messaging system to bridge the gap between the 3D virtual environment, and the QuizMASter's JADE agent-based environment, and are currently developing the protocols necessary to support the various game scenarios such as question asking and answering, and emotional expression. We hope to have a working prototype running later this year.

---

[3] freetts.sourceforge.net
[4] http://cmusphinx.sourceforge.net
[5] http://www.alicebot.org/about.html
[6] https://lg3d-wonderland.dev.java.net/
[7] http://www.millionairetv.com/

References

1. Gee, J.P.: What video games have to teach us about learning and literacy. Computers in Entertainment 1(1), 20 (2003)
2. Malone, T.W.: What makes things fun to learn? Heuristics for designing instructional computer games. In: Proceedings of the 3rd ACM SIGSMALL Symposium and the First SIGPC Symposium on Small Systems, SIGSMALL 1980, pp. 162–169. ACM, New York (1980)
3. Mitchell, A., Savill-Smith, C.: The Use of Computer and Video Games for Learning. Learning and Skills Development Agency, London (2004)
4. Crawford, C.: The Art of Computer Game Design (1982), `http://www.vancouver.wsu.edu/fac/peabody/game-book/Coverpage.html`
5. Malone, T.W.: Toward a theory of intrinsically motivating instruction. Cognitive Science: A Multidisciplinary Journal 5(4), 333–369 (1981)
6. Vassileva, J., Okonkwo, C.: Affective Pedagogical Agents and User Persuasion. In: Proc. Universal Access in Human-Computer Interaction (UAHCI), New Orleans, USA, pp. 397–401 (2001)
7. Kirriemuir, J., McFarlane, A.: Games and learning. Graduate School of Education, University of Bristol (2004)
8. Baylor, A.: Beyond butlers: Intelligent agents as mentors. Journal of Educational Computing Research 22, 373–382 (2000)
9. Lester, J., Callaway, B., Stone, B.: Mixed initiative problem solving with animated pedagogical agents. In: Haller, S., McRoy, S. (eds.) Working Notes of AAAI 1997 Spring Symposium on Mixed-Initiative Interaction, Stanford, CA, pp. 98–104 (1997)
10. Giraffa, L.M.M., Viccari, R.M., Móra, M.C.: Modeling the MCOE Tutor Using a Computational Model. In: de Oliveira, F.M. (ed.) SBIA 1998. LNCS, vol. 1515, pp. 50–60. Springer, Heidelberg (1998a)
11. Maragos, K., Grigoriadou, M.: Designing an Educational Online Multiplayer Game for learning Programming. In: Proceedings of the Informatics Education Europe II Conference (2007)
12. Bai, X., Black, J.B.: REAL: an agent-based learning environment. Paper presented at the Agent-Based Systems for Human Learning Conference, Hakodate, Japan (2006)
13. Iurgel, I.A., Ziegler, M.: Ask & answer: an educational game where it pays to endear your capricious virtual companion. In: Panayiotopoulos, T., Gratch, J., Aylett, R., Ballin, D., Olivier, P., Rist, T. (eds.). LNCS, pp. 15–24. Springer, London (2005)
14. Bransford, J.D., Brown, A.L., Cocking, R.R. (eds.): How People Learn: Brain, Mind, Experience and School, Committee on Developments in the Science of Learning, NRC Commission on Behavioral and Social Sciences and Education, Washington, DC. National Academy Press (2000)
15. The Price is Right, `http://en.wikipedia.org/wiki/The_Price_is_Right`
16. Conati, C., Klawe, M.: Socially Intelligent Agents in Educational Games. In: Socially Intelligent Agents - Creating Relationships with Computers and Robots. Kluwer Academic Publishers, Dordrecht (2002)
17. Ward, N., Tsukahara, W.: A Study in Responsiveness in Spoken Dialog. International Journal of Human-Computer Studies 59, 603–630 (2003), `http://citeseer.ist.psu.edu/ward03study.html`

The Effects of Type of Interactivity in Experiential Game-Based Learning

Ming-Puu Chen and Li-Chun Wang

Graduate Institute of Information and Computer Education
National Taiwan Normal University
162, Ho-ping East Road, Sec. 1, Taipei, Taiwan 10610
mpchen@ntnu.edu.tw, cct101wang@gmail.com

Abstract. The purpose of this study was to examine the effects of type of interactivity, prior knowledge and gender on learners' performance in learning computer programming skills through an experiential game-based learning activity. One hundred and forty six junior high school students participated in the experimental activity. Participants' levels of prior-knowledge (high vs. low) were identified according to previous computer course performance. The interactions of type-of-interactivity-prior-knowledge and type-of-interactivity-gender were significant on participants' performance. The analysis revealed that (a) for the gender effect, the male group outperformed the female group while receiving the challenge-interactivity game-play activity, but while receiving the mixed-interactivity game-play activity, the male group and the female group performed equally; (b) similarly, for the prior-knowledge effect, the high prior-knowledge group outperformed the low prior-knowledge group while receiving the challenge-interactivity game-play activity, but while receiving the mixed-interactivity game-play activity, the high prior-knowledge group and the low prior-knowledge group performed equally. The mixed-interactivity game-play was found to compensate for females' gender disadvantage and insufficient prior-knowledge.

Keywords: E-learning, Interactivity, Instructional design, Game-based learning.

1 Introduction

Recently, the rapid growth of internet technology has changed the nature of interactions especially for the online learning environments. Consequently, there have been increasing concerns towards interaction issues in e-learning. Accordingly, the use of interactivity as a variable in empirical studies has dramatically increased with the emergence of new information and communication technologies such as the Internet. Nowadays, interactivity has become a synonym of quality learning. Engaging learners in the learning process is the pre-requisite for effective e-learning. However, making learning more engaging relies on considerate design of learning activities that allow learners to participate and involve in the learning process. Interactivity is not just necessary and fundamental in the knowledge acquisition process but also an intrinsic factor for successful and effective online learning [1, 2, 3]. Therefore, the instructional design of e-learning activities must incorporate

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 273–282, 2009.

adequate levels of interactivity into the learning processes to make learning become more engaging and effective.

Game-based learning is generally considered as an effective means to enable learners to construct knowledge by playing, maintain higher motivation and apply acquired knowledge to solve real-life problems. Therefore, game-based learning becomes a promising method for providing highly motivating learning situations to the e-learners. Through a combination of engaged playing, problem solving, situated learning and challenge, game-based learning can support learners to construct knowledge from ambiguity, trial and error [4, 5]. Kiili [6] also suggested that successful game-based learning was strongly correlated with higher degrees of flow experience. Pivec and Dziabenko [7] further indicated that pedagogy was one of the major components of successful game-based learning. The majority of researches of game-based learning, however, emphasized on the theoretical aspects of gaming and lacked empirical evidence to validate its educational meaningfulness. Therefore, the present study employed an experiential gaming model as the pedagogical framework to enhance learners to learn computer programming concepts and skills. Accordingly, the effects of type of interactivity, prior knowledge and gender on participants' project performance were examined.

2 Related Literature

2.1 Learning Interaction

Interaction is a two-way communication process. Norman suggested that the interactive process is a repeated looping of decision sequence of a learner's action and the environment's reaction [8]. Kiousis asserted that interactivity is the degree to which a communication technology can create a mediated environment in which participants participate in reciprocal message exchanges in the forms of one-to-one, one-to-many, and many-to-many communication and both synchronously and asynchronously [9]. Therefore, interactivity consists of three factors, including the technological structure of the media employed, the characteristics of communication settings, and individuals' perceptions [10]. Furthermore, based on the instructional quality of the interaction, Schwier and Misanchuk identified three levels of interaction, including reactive, proactive, and mutual interactions [11]. A reactive interaction is a response to a given question. Proactive interaction involves learner construction and generation activities during the learning process. In a mutual interactive environment, the learner and system are mutually adaptive in reactions with each other. The relationships among the three levels of interaction are hierarchical in terms of quality of interaction. That is to say, the quality of a mutual-level interaction is higher than that of a proactive-level interaction, and the quality of a proactive-level interaction is higher than that of a reactive-level interaction. Consequently, the higher levels of interaction provide a greater opportunity for mental engagements and learner involvements than the lower ones [11].

The quality of interaction is a function of the learner's response and the computer's feedback [12]. If the response matches a learner's needs, then it is meaningful to the learner. Therefore, interactive learning has to be more than pointing and clicking and be involving and personal to the learners. Therefore, there is an urgent need to

examine whether specific strategies will increase the levels of interaction in web-based learning environments and facilitate learners to become actively engaged.

2.2 Learning through Game-Play

Games-based learning can provide a rich learning context to help learners construct higher level knowledge through ambiguous and challenging trial and error opportunities [4]. Through the game-play processes, learners can develop reflection skills and metacognitive strategies and transform the learning experience into problem solving. The developed cognitive strategies help learner bridge prior knowledge with new knowledge and enhance meaningful learning [13]. Therefore, the higher level programming knowledge and skills can be acquired by the learners through gaming. Moreover, different types of game strategies can be utilized to fulfill specific learning objectives. Previous studies [14, 15] suggested that action or sports games were appropriate for declarative knowledge content, adventure games were appropriate for practicing procedural knowledge, and role-play games were suitable for conditional knowledge. Hence, the present study employed matching game and challenge game to provide various types of interactivity to engage learners and facilitate learning of computer concepts and skills through the joyful gaming processes.

2.3 Enhancing Learning through Experiential Learning

As shown in Figure 1, the experiential learning framework contended that meaningful learning experiences are developed by means of a cyclic process of concrete experience, reflective observation, abstract conceptualization and active experimentation [16]. Learners generate reflective observation from concrete experiences, use them as a basis to assimilate abstract conceptualization, and verify the acquired abstract knowledge through applying in specific situations. With the help of game-play, the critical links for transferring the learning experiences can be achieved [14]. The prospective components of games for education include game scenarios, matching games, challenge games and problem-solving games [5, 7, 14]. Game scenarios can produce a simplification of target abstract concepts and provide learners with opportunities to develop problem-solving skills. Matching and challenge games can maintain learners' motivation through engaging playing, construct knowledge by trial and error, and consolidate the constructed concepts by means of the given progressive challenges. It was also suggested that flow experience can take place as learners engaging in game-play. Flow experience is a situation of complete absorption or engagement in an activity. Learners can assimilate abstract concepts after flow and further apply those learned concepts in certain problem-solving situations. Eventually, the consequence of flow becomes a start for another learning cycle. Therefore, games can provide a rich learning context and play an important role in the development of skills, motivation and attitudes. As shown in Figure 1, employing game-play within the experiential learning process provides an ideal context for learners to construct concrete experiences, reflective observation, abstract conceptualization and active experimentation.

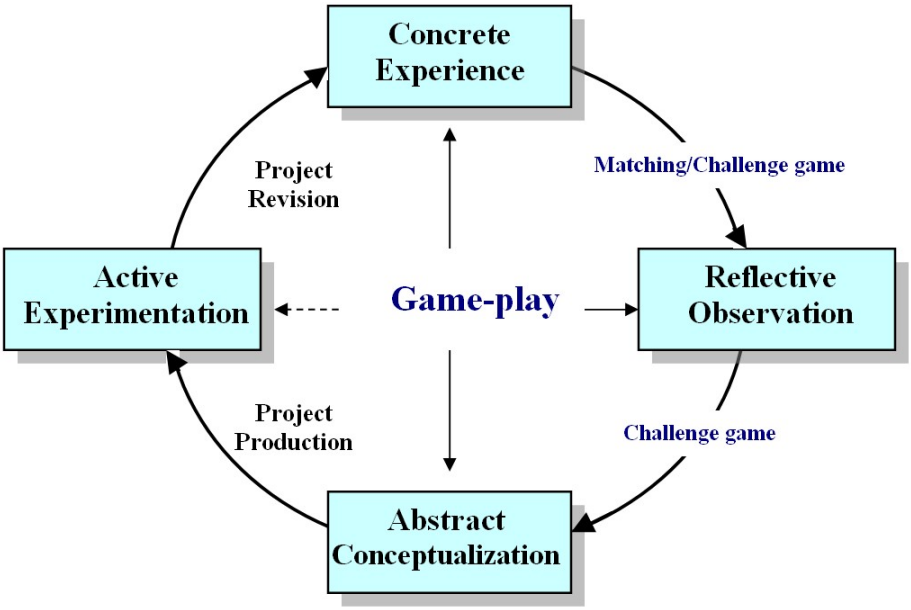


Fig. 1. Matching and challenge game-play activities were employed within the experiential learning framework to facilitate participants' formation of concrete experience, reflective observation, abstract conceptualization and active experimentation

2.4 Individual Differences

Learners' individual predispositions somehow conditioned their readiness to benefit from the learning environment. Giving a certain environment to learners, some benefited more, some less and some not at all. In the field of computer skills learning, computer prior knowledge was suggested to dominate learners' performance. Individual differences in background and prior experience were found to affect the performance and attitude of users of computers [17, 18]. Prior knowledge is either a necessary or at least a facilitating factor in the acquisition of new knowledge in the same content domain. Individuals who have greater knowledge will learn more quickly and more effectively. It was also suggested that domain-specific expertise is the most important difference between novices and experts in various knowledge domains, such as physics, algebra, geometry, and computers. Previous studies have shown that the most reliable predictions of computing attitude and achievement are based on the amount of prior computing knowledge [19, 20]. Therefore, it is important to examine learners' prior knowledge along with learners' performance while learning computer skills.

Previous computer science education studies have indicated a disproportionate low number of females in the computer science domain [21]. The U.S. Department of Education also found that there was no difference for male and female high school students in the enrolment of computer-related courses, but their preferences in types of courses showed significant different between groups [22]. Singh, Darlington, and

Allen [23] also indicated that the numbers of women in computer related majors have continued to decline in recent years. The phenomenon of gender differences and similarities has implications for education. Therefore, it is worthwhile to examine how girls and boys benefit from a specific type of computer-based learning activity, so that educators can deliver instruction and deploy instructional resources adapting to their needs.

3 Methods

3.1 Research Design

The present study employed a quasi-experimental design to examine the effects of type-of-interactivity, prior-knowledge and gender on learners' performance. The experiment was conducted in a 4-week session of learning basic programming concepts and control structure. As shown in Figure 1, a baseline model for learning was implemented and employed game scenarios, matching/challenge games, project production and project revision to fulfill the four stages of the experiential learning framework. Game scenarios provided learners with real-life problems and examples and served as contexts for reflective observation. Matching/challenge games were utilized to facilitate learners to conduct reflective observation and abstract conceptualization through interactive activities. After game-ply, learners needed to complete the given programming project individually. Due to the different interactivity natures of matching games and challenge games, two versions of game-play activities were implemented to provide learners with different types of interactivity including the challenge-interactivity and the mixed-interactivity. As shown in Figure 1, the mixed-interactivity game-ply activity employed matching games for the learning stage of reflective observation and challenge games for the abstract conceptualization stage. In contrast, the challenge-interactivity game-play activity only employed challenge games for both the learning stages of reflective observation and abstract conceptualization. The prior-knowledge was obtained from participants' grades of previous computer course. Analysis of Variance (ANOVA) was conducted on learners' performance with a significance level of .05 for the present study.

3.2 Participants

One hundred and forty six junior high school students participated in the experiment. All participants were novices to programming languages. Participants were randomly assigned to either the *challenge-interactivity* group or the *mixed-interactivity* group. Participants' levels of prior-knowledge (high vs. low) were identified according to their grades on previous computer course. A programming project was employed to facilitate participants to apply acquired knowledge to solve real-life problems after learning from the game-play activities. Project performance was assessed for further analysis. The numbers of participants for each group are shown in Table 1.

Table 1. The numbers of participants for each group

	Aspect	Total
Type of Interactivity	Challenge-interactivity	75
	Mixed-interactivity	71
Gender	Male	82
	Female	64
Prior-knowledge	High Prior-knowledge	81
	Low Prior-knowledge	65
Total		146

4 Findings

The group means of participants' performance are shown in Table 2. The overall mean score for all participants was 14.27 as measured on a 20-point scale. For type-of-interactivity, participants seemed to perform better while receiving the *mixed-interactivity* game-play activity (mean=15.36) than receiving the *challenge-interactivity* activity (mean=12.92). The mean score of males was 14.83 and was slightly higher than the mean score of females (mean=13.56). For the prior knowledge groups, the high prior-knowledge group (mean=14.31) was slightly higher than the low prior-knowledge group (mean=13.10). As for the interactivity-gender groups, the low-interactivity female group scored the lowest among four groups.

Three-way ANOVA was conducted in the study to examine the effects of type of interactivity, prior knowledge and gender on participants' performance. First, Levene's test of equality was not significant ($F_{(7, 138)} = .704$, $p = .553$). The null hypothesis that the error variance of the dependent variable is equal across groups was

Table 2. Summary of group means on project performance

		Interactivity	Mean	SD	N
Gender	Male	Challenge-interactivity	**14.13**	3.00	30
		Mixed-interactivity	15.23	4.42	52
		Total	14.83	3.70	82
	Female	Challenge-interactivity	**11.89**	3.04	35
		Mixed-interactivity	15.59	4.22	29
		Total	13.56	3.64	64
Prior-knowledge	High Prior-knowledge	Challenge-interactivity	**13.60**	3.70	45
		Mixed-interactivity	15.54	3.04	26
		Total	14.31	4.22	71
	Low Prior-knowledge	Challenge-interactivity	**11.40**	3.70	20
		Mixed-interactivity	15.27	3.04	55
		Total	13.10	4.22	75
Total		Challenge-interactivity	12.92	4.48	75
		Mixed-interactivity	15.36	3.04	71
		Total	14.27	3.13	146

Table 3. ANOVA Summary of prior-knowledge, interactivity and gender on performance

Source	SS	df	MS	F	Sig	Partial Eta Squared
Prior-knowledge	51.673	1	51.673	7.016	.009	.048
Interactivity	250.677	1	250.677	34.036	.000	.196
Gender	34.959	1	34.959	4.747	.031	.033
Interactivity-PK	33.465	1	33.465	4.544	.035	.031
Interactivity-Gender	63.139	1	63.139	8.573	.004	.058
Error	1031.117	140	7.365			

sustained. The ANOVA summary is shown in Table 3, the effects of the interactivity-gender interaction and the interactivity-prior-knowledge interaction were significant on project performance (Interactivity-Gender: $F_{(1,140)}$=8.573, p=.004; Interactivity-PK: $F_{(1,140)}$=4.544, p=.035). Therefore, simple main effects needed to be further examined to explore the nature of the interactions.

4.1 The Simple Main Effect Analysis for the Mixed-Interactivity Group

For the *mixed-interactivity* group, one-way ANOVAs were conducted in the study to examine the simple main effects of gender and prior-knowledge on project performance, respectively. As shown in Table 4 and Table 5, for the *mixed-interactivity* group, the simple main effects of gender and prior knowledge on project performance were not significant (gender: $F_{(1,79)}$=2.205, p=.142; prior knowledge: $F_{(1,79)}$=1.154, p=.286). The results indicated that the male group (mean=15.18) and the female group (mean=15.60) and the high prior-knowledge group and the low prior-knowledge group performed equally when learning from the *mixed-interactivity* game-play activity. In other words, gender and prior knowledge did not affect learners' performance while learning from the *mixed-interactivity* game-play activity which employing matching games for reflective observation and challenge games for abstract conceptualization.

Table 4. The simple main effect of gender on project performance for the mixed-interactivity group

Source	SS	df	MS	F	Sig
Gender	2.352	1	2.352	2.205	.142
Error	85.371	79	1.067		

Table 5. The simple main effect of prior-knowledge on project performance for the mixed-interactivity group

Source	SS	df	MS	F	Sig
Prior-knowledge	1.247	1	1.247	1.154	.286
Error	84.265	79	1.067		

4.2 The Simple Main Effect Analysis for the Challenge-Interactivity Group

Similarly, one-way ANOVAs were conducted in the study to examine the simple main effects of gender and prior knowledge on participants' project performance for

the *challenge-interactivity* group. As shown in Table 6, the ANOVA summary revealed that the simple main effect of gender was significant ($F_{(1,63)}$=4.069, p=.048). For learning from the *challenge-interactivity* game-play activity, the male group (mean=14.13) outperformed the female group (mean=11.89). The result seemed to indicate that without the support of matching game in clarifying concepts during reflective observation, female learners couldn't achieve as well as males.

Table 6. The simple main effect of gender on project performance for the challenge-interactivity group

Source	SS	df	MS	F	Sig
Gender	67.015	1	67.015	4.069	.048
Error	1037.600	63	16.470		

Similarly, as shown in Table 7, the ANOVA summary revealed that the simple main effect of prior knowledge was significant ($F_{(1,63)}$=5.026, p=.029). For learning from the *challenge-interactivity* game-play activity, the high prior-knowledge group (mean=13.60) outperformed the low prior-knowledge group (mean=11.40). That is to say, without the support of matching game in clarifying concepts, the low prior-knowledge group couldn't perform as well as the high prior-knowledge group.

Table 7. The simple main effect of prior-knowledge on project performance for the challenge-interactivity group

Source	SS	df	MS	F	Sig
Prior-knowledge	81.606	1	81.606	5.026	.029
Error	1023.010	63	16.238		

5 Conclusions

Interactivity is the key to successful e-learning. With the help of high levels of interactivity, learners will be able to acquire learning content based on individual needs, correct misconceptions, and develop into independent learners more efficiently. In the present study, matching and challenge game types were employed in an experiential learning activity to provide different types of learner-content interaction for the learners to learn computer programming skills. The results suggested that employing a mixed-interactivity of matching and challenge game-play brought forth better performance in the learners with comparison to employing challenge game-play alone. In other words, the matching-challenge game-play process enhanced the learners to identify the key attributes from the scenarios, clarify misconceptions, formulate solid mental models of computers and achieve better learning performance. Therefore, the compensation effect of the matching-challenge game-play activity was found on gender and prior knowledge. Employing a matching-challenge game-play strategy for e-learning can compensate for learners' insufficient prior knowledge and overcome females' gender disadvantage. This also suggested that the development of e-learning should increase the diversity of learning interactivity to provide opportunities for

learners to bypass disadvantages in gender characteristics and compensate for insufficient prior knowledge and, therefore, bring forth better learning effectiveness.

Although, higher degree of interactivity brings forth better learning quality, Reichert and Hartmann [24] indicated that only few computer-based learning environments satisfy the demand for a high degree of interactivity. Therefore, educational software needs to correspond to the modern multimedia technologies to attract and motivate the learners. Furthermore, the scope of interactivity examined in the present study was limited to a specific type of human-content interaction delivered by matching and challenge game-play, how other types of game strategies, such as role-play, adventure, action, and other combinations will affect learning and performance need to be further examined.

Acknowledgement

This study was supported by the National Science Council of Taiwan under Grant NSC 97-2511-S-003-008-MY2.

References

1. Sim, R.: Interactivity: A Forgotten Art. Computers in Human Behavior 13(2), 157–180 (1997)
2. Sims, R.: An Interactive Conundrum: Constructs of Interactivity and Learning Theory. Australian Journal of Educational Technology 16(1), 45–57 (2000)
3. Song, H.D., Yonkers, V.: The Development and Evaluation of Multi-level Assessment Framework for Analyzing Online Interaction (ERIC Document Reproduction Service No. ED442873) (2004)
4. Van Eck, R.: Six Ideas in Search of a Discipline. In: Shelton, B.E., Wiley, D.A. (eds.) The Design and Use of Simulation Computer Games in Education. Sense Publishing, The Netherlands (2007)
5. Adcock, A.: Making Digital Game-based Learning Working: An Instructional Designer's Perspective. Library Media Connection, 56–57 (2008)
6. Kiili, K.: Content Creation Challenges and Flow Experience in Educational Games: The IT-Emperor Case. Internet and Higher Education 8, 183–198 (2005)
7. Pivec, M., Dziabenko, O.: Game-based Learning in Universities and Lifelong Learning: "UniGame: Social Skills and Knowledge Training" Game Concept. Journal of Universal Computer Science 10(1), 14–26 (2004)
8. Norman, D.: The Psychology of Everyday Things. Basic Books, New York (1988)
9. Kiousis, S.: Interactivity: A Concept Explication. New Media & Society 4(3), 355–383 (2002)
10. Chaffee, S.H.: Communication Concepts 1: Explication. Sage, Newbury Park (1991)
11. Schwier, R., Misanchuk, E.: Interactive Multimedia Instruction. Educational Technology Publications, Englewood Cliffs (1993)
12. Jonassen, D.: Instructional Designs for Microcomputer Courseware. Lawrence Erlbaum, Hillsdale (1988)
13. Weinstein, C.E.: Learning and Study Strategies Inventory: User's Manual, 2nd edn. H&H, Clearwater (2002)

14. Gros, B.: Digital Games in Education: The Design of Game-based Learning Environment. Journal of Research on Technology in Education 40(1), 23–38 (2007)
15. Prensky, M.: Digital Game-based Learning. McGraw-Hill, New York (2001)
16. Kolb, D.A.: Experimental Learning. Prentice-Hall, Englewood Cliffs (1984)
17. Kieras, D.E., Polson, P.G.: An Approach to the Formal Analysis of User Complexity. International Journal of Man-Machine Studies 22, 365–395 (1985)
18. Vicente, K.J., Hayes, B.C., Williges, R.C.: Assaying and Isolating Individual Differences in Searching a Hierarchical File System. Human Factors 29(3), 349–359 (1987)
19. Clark, R.E.: Facilitating Domain-general Problem Solving: Computers, Cognitive processes and Instruction. In: Corte, E.D., Lin, M.C., Mandl, H., Verschaffel, L. (eds.) Learning Environment & Problem Solving, pp. 265–285. Springer, New York (1992)
20. Carlson, R., Wright, D.: Computer Anxiety and Communication Apprehension: Relationship and Introductory College Course Effects. Journal of Educational Computing Research 9(3), 329–338 (1993)
21. Davies, V., Camp, T.: Where Have Women Gone and Will They Be Returning. The CPSR Newsletter (2000)
22. US Department of Education: The 1994 High School Transcript Study Tabulation: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates. Project Officer, Steven Gorman. Washington, DC (1998)
23. Singh, K., Darlington, L., Allen, K.R.: Evidence-based Strategies and Interventions: Increasing Diversity in Computer Science. Paper presented at the Mid Atlantic Conference on the Scholarship of Diversity, Roanoke, VA (2005)
24. Reichert, R., Hartmann, W.: On the Learning in E-Learning. In: Proceedings of EDMEDIA 2004 – World Conference on Education Multimedia, Hypermedia and Telecommunications, Lugano, Switzerland, pp. 1590–1595 (2004)

Virtual Sport System for Optimum Exercising Based on a User Model

Kazumoto Tanaka, Takayuki Kataoka, and Makoto Hasegawa

Department of Information and Systems Engineering,
School of Engineering, Kinki University,
1 Umenobe, Takaya, Higashi-hiroshima, Hiroshima, 739-2116, Japan

Abstract. It is said that improving movement habits is effective to solve the problem of obesity. In this paper, we describe a physically interactive computer game system that can control a game mode to let a user maintain an appropriate exercise load based on an estimation of the user's heart rate state. We propose a Bayesian network model that can estimate heart rate states. The model calculates probability distribution of a heart rate state using user's motion features. We also describe an experimental validation of the system.

Keywords: Physically interactive computer game, Exercise load, Heart rate state estimation, User model, Bayesian network.

1 Introduction

It is said that improving movement habits is effective to solve the problem of obesity. However, there are many people who are unable to form a habit of exercising for reasons, such as "feeling troublesome to go to the gym" and "getting sick of exercise at home due to the monotony." Research has therefore been conducted into prompting continuation of exercise by performing exercise by physically interactive games in a virtual space (hereafter, virtual sports system) [1][2][3][4].

Previous research has proposed a system that provides visual entertainment by exploring a virtual reality space using an exercise bike [1], and a system for enjoying interactive virtual boxing using a motion capture camera [2]. However, one problem with previous research was that it did not consider user's heart rate state, and did not necessarily provide effective exercise. In general, the exercise that is thought to be effective for maintaining health is the one that maintains a suitably high heart rate range (hereafter, target heart rate range).

There has also been research on virtual sports systems that measure user's heart rate and control the exercise load [3][4]. In these systems, a sensor that measures heart rate is used to give feedback of the measured heart rate to the system. However, because of the need to attach an expensive sensor to the body, these are not generally suitable for home use, and problems are also expected regarding the trouble of wearing the measurement equipment.

In general, a causal relationship can be observed between motion features and heart rate state, for example "a person's footwork tends to become disorderly as her/his heart rate increases and becomes harder." In this research, our virtual sport system

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 283–290, 2009.

therefore measures the motion features of a user through non-contact means by applying a motion capture camera, which is an element of the virtual sport system, and estimates the heart rate state based on the measurement result. In this paper, a model representing the causal relationship between motion features and heart rate state is proposed using Bayesian networking [5]. This model is a model for estimating the heart rate state from motion features. This study also describes a virtual sport system with a function for maintaining the target heart rate range by changing the exercise load based on heart rate state estimation results, and the results of evaluating the virtual sport system.

2 Virtual Sport System Structure

Figure 1 shows the structure of our virtual sport system. In this research, a tennis rally was chosen as the virtual sport. This game is played by a computer graphics (CG) opponent displayed on a screen who hits a CG tennis ball and a user who responds by performing footwork to chase the ball and hitting the ball back with a virtual racket. The users play by holding an accelerometer sensor device in their hand as the virtual racket. This device can sequentially transmit accelerometer data wirelessly.

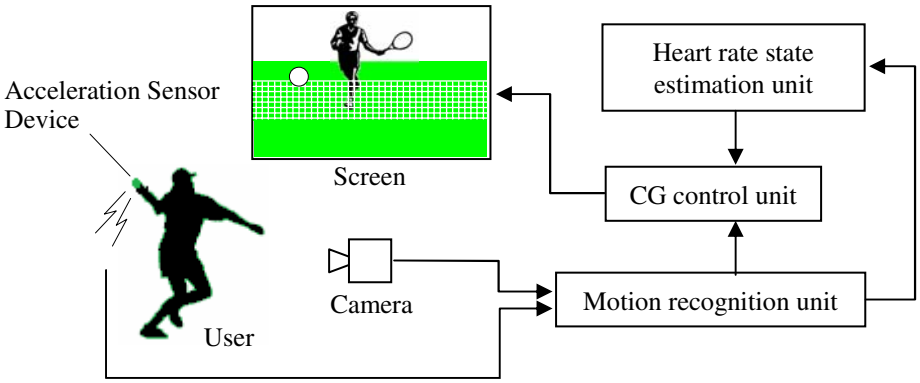


Fig. 1. System structure diagram

The motion recognition unit receives accelerometer data, identifies swings, and sends swing information to the CG control unit. The motion recognition unit also extracts features of the user's footwork by analyzing images input from a camera, and passes the footwork information to the CG control unit. The footwork analysis is performed by tracking the lower part of the human body extracted by the background substitution.

The CG control unit generates CG of a tennis rally based on the swing and the footwork information and displays this on the screen. The motion recognition unit sends the information to the heart rate state estimation unit. The heart rate state estimation unit has a heart rate state estimation model that estimates user's heart rate state by inputting the motion features to the model. The results of the estimation are sent to

the CG control unit, which controls the speed of the returning ball based on the heart rate state estimation result.

Speed control is performed in two steps corresponding to the two modes: a mode for increasing the heart rate until going over the upper limit of the target heart rate range (*up mode*), and a mode for reducing the heart rate until being less than the lower limit of the target heart rate range (*down mode*). The speed of the ball is determined appropriately to achieve the heart rate up/down effect and also so that the entertainment value of the game is not lost. Figure 2 shows the state transition diagram of the game modes. The form of the virtual tennis is shown in Figure 3.

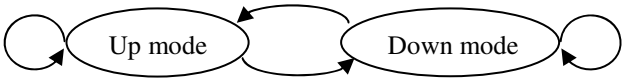


Fig. 2. Game state transition diagram

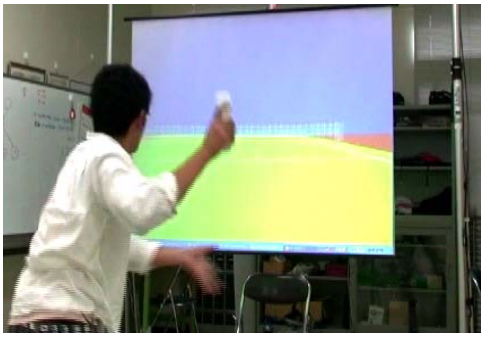


Fig. 3. Virtual tennis

3 Heart Rate State Estimation Model Using a Bayesian Network

Research into user model using Bayesian networks includes research into e-learning systems that provide learning that adapts to suit the characteristics of the learner [6], and research into estimating the driving intention of drivers [7]. Furthermore, examples also exist for practical applications of user model by Bayesian networks, including the assistance for beginners by an avatar (dolphin, etc.) in Microsoft Office. Up to the present moment, however, there has been no research on modeling for estimating the heart rate state of the user.

The following empirical knowledge is used in the construction of the heart rate state estimation model.

(1) The condition of the load on the human body as represented by the heart rate state affects the motion features during exercise. In this study, motion features refer to the quickness, accuracy, and so on of movement during exercise.
(2) While exercising, there is a causal relationship between the heart rate state during one segment of time and the heart rate state during the previous segment of time.

The motion features are calculated from the movement data measured within a segment of time. From the empirical knowledge, the heart rate state estimation model is taken to be a model where "the heart rate state during a period of measuring motion features has a causal relationship with the motion features in the same period and the heart rate state in the surrounding periods." The proposed model is shown in Figure 4. The heart rate state nodes are random variables that represent heart rate state. The motion feature node MF_*i* is a random variable that represents the motion feature *i*. The types of motion features are described in Section 4. Actually, a partial model (see Figure 4) composed of one heart rate state node and motion feature nodes (MF_1 to MF_N) is repeatedly used for the Bayesian network calculation.

The causal relationships are quantitatively represented by the probability of a result occurring for a cause, i.e., the conditional probability of a result. These probability distributions are determined experimentally, and two models are constructed, one for the up mode of the game and one for the down mode, because the exercise load differs between the two modes.

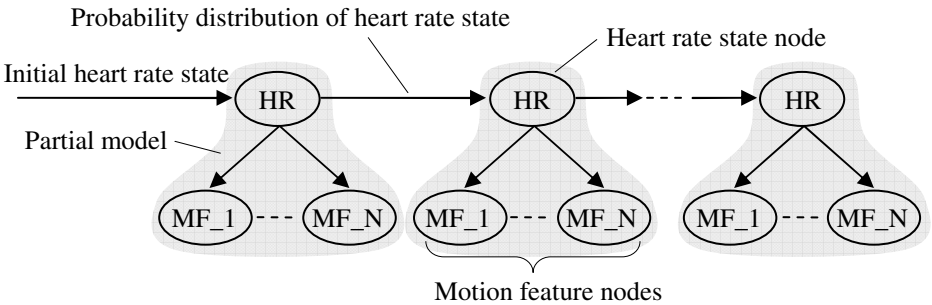


Fig. 4. Structure of the heart rate state estimation model

4 Model Construction

In this section, a heart rate state estimation model is constructed by selecting the motion features and determining the random variables of the motion feature nodes and heart rate state nodes. The feature selection is performed by measuring the candidate motion features and heart rate experimentally and evaluating candidate models using the Akaike information criterion (AIC). For the problem of how best to quantize the quantity values of the motion features into several levels, the optimum quantization is also determined by AIC.

4.1 Motion Features

The motion features in tennis can be divided into swing and footwork. However, due to preliminary experimental results that indicated that almost of the features related to the swing exhibit small changes as time passes, only "miss shots" was taken as a feature candidate of the swing. As for the footwork, the features that can be measured by the motion capture camera were taken as the candidates. All the candidates are

shown in Table 1. The feature "changing direction" in the table means that user's position is corrected until the position where the ball is hit back is determined. The feature "stopping footwork" represents standing still that occurs while moving to the position where the ball is hit back. These measurements are performed in each segment of time described in the next section.

Table 1. Motion feature candidates

Swing	Miss shot	The number of miss shots
		Difference in the number from last time
Footwork	Reaction time (ms)	Average time
		Difference in the average time from last time
	Changing direction	The number of direction changes
		Difference in the number from last time
	Stopping footwork	The number of footwork stops
		Difference in the number from last time

4.2 Heart Rate State

An appropriate heart rate state needs to be maintained in order to exercise effectively. In general, approximately 20 minutes are needed before fat begins to burn. In this experiment, the exercise time for one game was taken to be 25 minutes, and this was divided into 10 segments to give 2.5 minutes of motion feature measurement time. This is also the experimentally determined time for the time needed to measure the features shown in Table 1. As a result, the partial model was repeatedly used for each of the 2.5 minutes segments.

When the target heart rate range is taken to be above H1 bpm and below H2 bpm, the random variable of the heart rate state node is taken to have the three levels of L: low, H: high, and O: outside range. Because of the difference between the up mode and down mode heart rates, the random variable in each mode is taken to be the range of values shown in Table 2. The Karvonen equation is used, which is a well-known rule for calculating target heart rate range.

Table 2. Heart rate state

	Up mode	Down mode
L	below H1bpm	H1–H2 bpm
H	H1–H2 bpm	above H2 bpm
O	above H2 bpm	below H1 bpm

4.3 Motion Feature Selection and Number of Feature Value Levels

Experiments were performed to select the motion features to use in the motion feature nodes from among the eight candidate motion features shown in Table 1. The experiments were performed by two male university students of age 22 years (A and B) who were treated as virtually physically equivalent, and the motion features were selected to construct each of the heart rate state estimation models. First, a 2.5-minute virtual tennis game was performed for the two initial heart rate states (L/H) for up and down

modes, and the eight motion features and heart rate were measured. These experiments were each repeated 20 times. The target heart rate range was calculated to be H1 = 115 bpm and H2 = 143 bpm from the Karvonen equation by assuming a 22-year-old with a stationary heart rate of 60 and exercise load of 40 to 60%.

Next, the AIC was evaluated for each combination of the motion feature candidates and was also evaluated while increasing the number of quantization levels of the discrete random variables for the motion features from 2 in order to determine the optimal number of quantization levels. The model that minimized AIC was selected finally.

As a result, the motion features of the models for up and down modes for the two subjects were determined as shown in Table 3. The optimal number of levels was 2 in all cases.

Table 3. Motion features of the heart rate state estimation models

A	Up mode	Difference in the number of miss shots from last time
		Difference in the number of direction changes from last time
		Average reaction time
	Down mode	Difference in the number of miss shots from last time
		Average reaction time
B	Up mode	Difference in the number of miss shots from last time
		Average reaction time
		Difference in the average reaction time from last time
	Down mode	Average reaction time
		Difference in the average reaction time from last time

5 Experiments

Experiments were performed to evaluate the game mode control for maintaining the target heart rate range (115–143 bpm). The subjects of this experiment were the same subjects in the model construction (A and B), and the heart rate state estimation model corresponding to the subject was used for the experiments.

The experimental subjects played virtual tennis 10 times each for 25 minutes, and a time series of both the game mode and estimated heart rate state was recorded each 2.5 minute. The subjects wore a sensor for measuring heart rate (RS800CX mfd. by Polar), and measurement results were also recorded each 2.5 minute. Figure 5 shows an example of the results (subject A). The horizontal axis of the graph in the figure represents elapsed time (minutes), and the vertical axis represents the measured heart rate (bpm).

The validity of the mode control was evaluated from two points of view. The first was evaluation with the ratio of the number of correct mode controls to the number of mode controls performed during one game (10 times per game × 10 games). The correctness was determined by comparing the estimated heart rate state with the measured heart rate. The second was the ratio of the number of the case that the average of measured heart rate during one game (except initial heart rate) was included within the target heart rate range (115–143 bpm) to 10 games. The results are shown in Table 4.

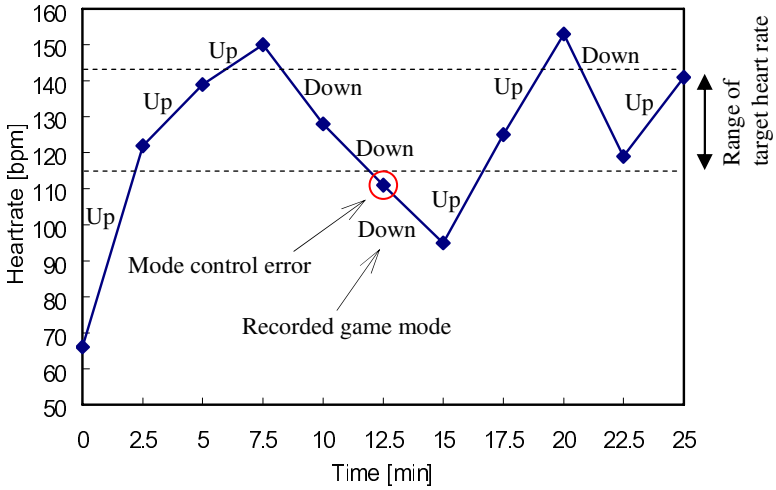


Fig. 5. Example of heart rate trends during play

Table 4. Experimental results

Subject	A	B
Percentage of correct control	92	94
Percentage of the case of appropriate heart rate average	100	100

6 Discussion

The percentage of correct control shows that there were some control errors, and it was found that these errors occurred in the vicinity of the boundary of the range of the target heart rate. It is possible to reduce the errors if the training data in the vicinity of the boundary are appropriately and sufficiently chosen for building the heart rate state estimation model.

From the percentage of the case of appropriate heart rate average, it is clear that the game mode was controlled to maintain the target heart rate range on the whole. It can be said that the model constructed from the Bayesian network is therefore thought to have functioned as planned.

However, it was clear that the motion feature nodes of the model were different even for test subjects treated as being virtually physically equivalent. Furthermore, even for the same user, there is a chance of the causal relationship between a heart rate state and motion feature changing as heart function improves. As a result, in order to maintain accurate game control when performing virtual tennis continuously, the model needs to be constructed and then updated for each user. Thus, for this system to become practical, the loads on the model construction and the update need to be reduced, e.g., by automating the modeling procedure.

7 Summary

A virtual tennis game was proposed that controls the game mode using a heart rate state estimation model that uses a Bayesian network to make the most suitable exercise possible. Furthermore, it was demonstrated experimentally that appropriate exercise can be provided to the user.

One problem for the future is reducing the loads on the model construction and the update by automating the modeling procedure.

Acknowledgement

This work was supported by Grant-in-Aid for Scientific Research 20500856.

References

1. Mokka, S., Väätänen, A., Heinilä, J., et al.: Fitness Computer Game with A Bodily User Interface. In: 2nd International Conference on Entertainment Computing, pp. 1–3 (2003)
2. Höysniemi, J., Aula, A., Auvinen, P., et al.: Shadow Boxer - A Physically Interactive Fitness Game. In: 3rd Nordic Conference on Human-computer Interaction, pp. 389–392 (2004)
3. Soh, M., Junichi, H.: An Exercise Game Reflecting Heart Rate. The Journal of The Society for Art and Science 6(3), 136–144 (2007)
4. Nenonen, V., Lindblad, A., Häkkinen, V., et al.: Using Heart Rate to Control An Interactive Game. In: SIGCHI Conference on Human Factors in Computing Systems, pp. 853–856 (2007)
5. Bayesian network from Wikipedia, http://en.wikipedia.org/wiki/Bayesian_network
6. Kai-min, C., Joseph, B., Jack, M., Albert, C.: A Bayes Net Toolkit for Student Modeling in Intelligent Tutoring Systems. In: Ikeda, M., Ashley, K.D., Chan, T.-W. (eds.) ITS 2006. LNCS, vol. 4053, pp. 104–113. Springer, Heidelberg (2006)
7. Van Dan, N., Kameyama, M.: Bayesian-Networks-Based Motion Estimation for a Highly-Safe Intelligent Vehicle. In: SICE-ICASE International Joint Conference, pp. 6023–6026 (2006)

Engaging Kids with the Concept of Sustainability Using a Commercial Videogame-A Case Study

Panagiotis Tragazikis[1] and Michael Meimaris[2]

[1] Msc in Models of Educational Planning and Development, Department of Sciences of Pre-school Education & Educational Design, University of Aegean, Metsovou 26. 17563, Athens, Greece
ptragaz@sch.gr
[2] Professor, Director of the New Technologies Laboratory in Communication, Education and the Mass Media, Faculty of Communication and Media Studies, University of Athens

Keywords: COTS (Commercial off-the-shelf games for learning), DGBL (Digital Games Based Learning), Sustainability (Education for Sustainable Development).

Extended Summary

This paper focus on the use of a commercial game, [COTS (Commercial off-the-shelf games for learning)], as a main motivating and educating tool, to do aware kids of 11 years old about the relation, between every day actions and activities with emissions. It also intents to prove that, with the use of the game achieved a satisfied level of modified behaviour towards the concept of sustainability by changing attitudes and taking actions. Furthermore, intents to introduce a method, who is related to the efficient implementation of COTS, in primary's school educational projects. It approaches the topic from theoretical point of view examine two critical dimensions: A. Commercial games use and their implementation in educational projects. B. COTS and their relation with concept of sustainability. Evaluating the education for sustainability, we introduce a model that describes the human being interactions between aspects of the real environment and the COTS digital environment. It also approaches the topic by the use of the commercial game "THE SIMS". That means that with the use of a simulation game, the pupils should create a simple model of life and manage it, realize their behaviour within the management of avatars life, comprehend the energy model of growth and its relation with their model of life and finally modify behaviours. The evaluation of the project has been done using a multi-dimensional research tools such as semi-structured questionnaire, focus groups and Likert-type questionnaire for attitudes measurement. The conclusions were very encouraging generally and they divided in three categories. Conclusions related to the game, related to the lesson plan and related to the attitudes. In a few words we can say that the project worked efficiently in attitudes change and in a considerable amount of cases in taking the willing actions.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 291, 2009.

Entertaining Education – Using Games-Based and Service-Oriented Learning to Improve STEM Education

Jon Preston and Briana Morrison

Southern Polytechnic State University, 1100 S Marietta Parkway
Marietta, GA 30060 USA
{jpreston,bmorriso}@spsu.edu

Abstract. This paper addresses the development of a computer game design and development curriculum at the authors' institution. The basis for curriculum decisions, as well as comparison to the other institutions' curricula is covered. In situating the curriculum within the current degree programs, games-based versions of existing courses are also being offered. The experience of the authors with the initial offering of a games-based introductory programming course is also explained, along with the initial assessment of results from the experience. Our experience of using games-based learning in an introductory laboratory is presented. Finally, we demonstrate how games-based learning can be extended beyond the classroom as we work to promote science, technology, engineering, and mathematics (STEM) with local elementary schools; our current project develops an ocean ecosystem exploration game that teaches oceanography and ecological sustainability.

Keywords: curriculum, games-based, learning, programming, motivation, STEM, K12, development, sustainability.

Summary

This paper presents our encompassing vision of incorporating gaming at our institution. Games-based learning offers an opportunity to motivate students in existing disciplines as well as expand the educational opportunities within universities. It has been exciting to see how motivated students at our university have been with the addition of gaming education at our institution. The degree program has received very favorable reviews from students and has generated interest from perspective students. The gaming based versions of the software development courses have proven so popular that additional sections have had to be added to the course schedule. The community that our play and development group of students has developed is also impressive, and it is inspiring to see our university students making connections with and motivating the elementary students. In an era where student interest in STEM education seems to be waning, we hope that we have had a long-term impact on students to see that science, mathematics, and computer science are all interesting fields where creativity and imagination are key elements of success.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 292, 2009.

Learning English through Serious Games – Reflections on Teacher and Learner Performance

Bente Meyer

Associate Professor, Department of Curriculum Research, Danish School of Education, University of Aarhus,
(+45) 8888 9509
bm@dpu.dk

In this paper I am exploring the challenges of designing game-based material for language learning as a specific field of competence. The empirical context of the paper is a project on *Serious Games on a Global Market Place* (2007-10) in which academics work with companies to explore, build and implement game prototypes. One aspect of this research consists in analysing and developing a design for learning English through serious games (www.mingoville.com) as well as exploring how this design is used and implemented in classroom teaching and learning. We studied the use of the platform in two classes with children aged 10-11.

As the study described aimed to understand the performance and role of the teacher and learners in the classroom during game-based teaching and learning, we had suggested to teachers that they use the platform in the ways that they found most relevant for their teaching. This approach allowed us to see how teachers managed, negotiated, and conceptualised gaming in the classroom as an aspect of teaching English as a foreign language.

The activities of the children in the classrooms studied showed that children were generally attracted to the most game- and play-like activities in the platform and that whenever possible, they would often choose these activities instead of activities that were more recognizable as traditional learning activities, for instance spelling exercises. In the 5th form class the exploratory approach to the platform chosen by the teacher inspired children to identify the platform with gaming activities and to explore challenges and playful activities rather than persevering for the sake of learning content. In the 4th form class pupils would also chose gaming activities if allowed, however, pupils were generally directed by teacher guidance and intervention to complete tasks and persevere in order to learn. These differences in platform use and performance suggest not only that pupils prefer to be players rather than learners if these roles are not integrated in serious game design, but also that the ontological perspectives on games often discussed in game theory are not sufficient to understand how games work in education [10]. Rather than asking "what is a game?" we should therefore explore the performative and social aspects of gaming in and out of classrooms. Exploratory and directed approaches to using games in the classroom are in this sense not outside perspectives added to the core of the game itself, but integrated aspects of the game understood as an actor in teaching and learning English in a formal learning context in Denmark.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 293, 2009.

ELEIN: E-Learning with 3D Interactive Emotional Agents

Amalia Ortiz, David Oyarzun, and María del Puy Carretero

VICOMTech Research Centre. Paseo Mikeletegi 57, E-20011 Donostia
aortiz@vicomtech.es

Abstract. The ELEIN system reached two important issues for e-Learning: the presence of virtual tutors and the importance of emotions in the learning process. In this research we deal with the presence by means of using an expressive 3D animated avatar. Regarding the emotions in the learning process, we differentiate between static and dynamic generation of emotions. In the paper, we specially detailed the development of the dynamic generation, which is achieved by means of the implementation of a computational emotional model based on the cognitive perspective.

Keywords: Affective computing, appraisal theory of emotion, virtual characters, facial animation.

1 Introduction

Emotions affect in many aspects of our live and many researchers have been studying trying to understand the fundamental aspects of them. They affect in the evaluative judgement, in the memory, in the creative thinking and in the decision making process, where some authors as Picard [1] estimated the computers would improve their decisions if they had emotions or emotional mechanisms which work with the computer rule systems. The emotions also affect in the communication and social interactions. This was studied by Mehrabian [2], who shows in his research, the 93% of our message goes through non-verbal language (55%), mainly based on facial and corporal motions, and the use of the voice (38%).

If the emotion affects in the memory, creative thinking or communication, this aspect cannot be exclude in the learning process. According to Hernandez et. al [3] the affective state has been recognized as an important component in learning.

In this work we propose to include emotional interaction in the learning process by means of using ELEIN (E-learning with 3D interactive emotional agents), a 3D virtual tutor which is capable of interacting with the student having into account the emotional state of the student. The aim of the ELEIN system is to achieve emotional multimodal interaction and communication in e-Learning environments, which allows educational contents to be expressed in a new communication language on the website. The main interaction element between the

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 294–305, 2009.

student and the environment consists in a Three Dimensional Educational Agent, with voice synthesis capacity in real time, fully integrated in the contents of the courses.

The paper is organized as follows. In section 2, we explain the importance of researching in both, the emotions in the learning process and the presence of the virtual tutor. Regarding to the emotions (section 3), we differentiate between the generation of the emotions when the virtual tutor is explaining the contents of the e-Learning course (section 3.1), and the generation of the emotions when the virtual tutor is assessing the student knowledge (section 3.2). We deal with the presence, by means of using an animated virtual tutor which is explained in section 4. The personification of the emotional educational agent implies to define how emotions should be expressed (section 4.1) and which are the animation techniques in order to execute the facial animation (section 4.2). At the end of this paper we explain the conclusion and future work produced by this work.

2 Using a 3D Emotional Agent in the Learning Process

The ELEIN system reached two important issues for e-Learning: the presence of the virtual tutor and the importance of the emotions in the learning process. In this work, we deal with the presence by means of the personification of the educational agent. We use an expressive 3D Avatar with voice synthesis capacity in real time, fully integrated in the contents of the courses. Integrating avatars in interactive applications has been a highly researched field in recent years. Several authors have performed evaluation involving real users to define the main advantages of interaction through avatars. Due to the following researches, we use a User Conversational Interface, in the form of a Three Dimensional Educational Agent, as main interaction element between the student and the environment:

- **It facilitates social interaction with the machine.** In 1994, Nass et al. [4] performed five experiments that revealed that the individual interactions of computer users are fundamentally social. Recently, Prendinger et al. in [5] also included that the user hopes to obtain the same type of social behaviour. Therefore, they proposed to give the interface with personality aspects and voice synthesis to improve the human machine interaction.
- **The student then considers the system to be more reliable and credible.** A user needs to believe in an agent's reliability in order to have the confidence to delegate certain tasks to it. There are evaluations that demonstrate that confidence and credibility increase with the personification of the agent, in other words, by giving it a face, eyes, body or voice. If the aspect of the character is also realistic, the agent is seen to be more intelligent and friendly [6].
- **The commitment of the student increases.** Personifying the agents increases the user's commitment to the application. In learning environments,

for example, personifying the virtual tutor has a positive impact on the perception of the students, particularly, if there are also emotional responses [7].

- **It catches the attention of the student.** Hongpaisanwiwat et al. [8] concluded that the avatar is capable of catching the user's attention and that this increases if the avatar is credible, as it generates the illusion of life in the system.
- **It focuses the student's attention.** An avatar can be used to focus the user's attention to points of interest, which is of great importance for learning environments [5].

Animated pedagogical agents have particular competence. As a real teacher they can show how to manipulate objects, they can demonstrate tasks and they can employ gesture to focus attention [9]. Following these researches, we decided to use an animated 3D avatar as virtual tutor.

However, there is another important issue: the importance of the emotions in learning. Learning process implies cognitive aspects as well as socio-emotional aspects: in real world, teaching also implies to observe the students affective behavior in order to detect affective responses which can express interest, excitation, confusion, etc. and suggest a review of the actual interaction flow [10]. The use of these animated pedagogical agents with emotional capabilities in an interactive learning environment has been found to have a positive impact on learners [11].

3 Generation of Emotions in the Learning Process

The main advantage of using virtual tutors within interfaces is to allow the student to interact intuitively with the system by giving him the illusion of communicating with a real tutor. This illusion is obtained by mimicking human communication, i.e. giving the avatar the ability of expressing emotions through facial and body gestures.

However, the way of giving the avatar the ability of expressing emotions can be different depend on the learning process phase. In the learning process, there are, at least, two differentiated phases: the phase in which the tutor is explaining the course content and the phase in which the student is assessed by the tutor. In a computational system, the generation of the emotions is different in both phase.

- **Explanation Phase** (Fig.1 a.). In this phase, the explanation of the virtual tutor had been pre-defined by the application designer (the real tutor) so the virtual tutor receives and executes pre-recorded emotions.
- **Assess Phase** (Fig. 1 b.). Dynamic generation of emotions: In this case, there is no pre-recorded emotion, but rather all the emotional responses are generated as the result of a process to evaluate the interaction events produced in the system.

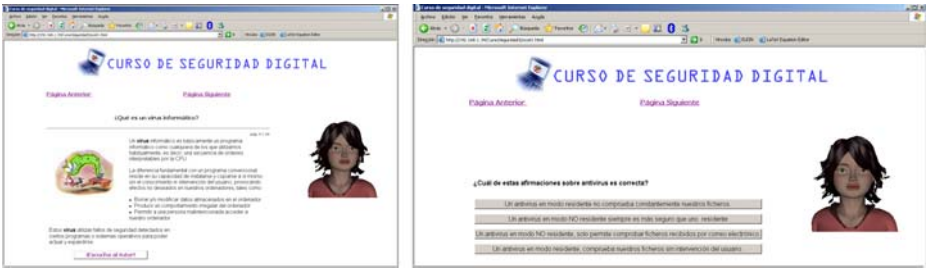


Fig. 1. Screenshot from e-Learning course of ELEIN system. a) Explanation Phase. b) Assess phase.

3.1 Explanation Phase: Static Generation of Emotions

During the explanation phase (Fig.1 a.) the student goes across web pages which have the course content. This content is shown with text and images, in HTML format, as traditional e-Learning courses. However, the content is also explained by an emotional 3D virtual tutor. The virtual tutor enhance the main concepts of the course. This explanations should be previously defined by the content designer (the real tutor who is creating the e-Learning course). The facial expressions and emotions are also pre-defined by the content designer, that means, they are generated statically.

Static emotional interaction is generated as a pre-defined reaction in the system. The fact of having to predefine the emotional behaviour implies that the system has tools to define this behaviour. This need has been researched by other authors who concluded that one of the most efficient ways of providing the system with static emotional qualities is by labelling, in other words, labels that will define the facial gestures, emotions or intensities (in the case of the avatar) that will have to be reproduced at a specific moment, in addition to the text that the system has to reproduce. The need to label the behaviour led to an analysis of the main existing languages that was published in [12]. We based our comparative study on the main features required by our animation engine (explained in section 4): facial animation, corporal animation, text-to-speech production and emotional representation. As can be seen in the analysis published in [12], the most comprehensive markup languages were VHML [13] and RRL [14], as they include all the parameters relating to emotion, body and facial animation, and the dialogue labelling. Finally, in this work, VHML has been chosen as it is a standard that allows all aspects of static emotional interaction to be defined.

In order to make easer the process of pre-defining the emotional behavior of the avatar while it is explaining the course contents, we have developed a highly innovative tool based on VHML that allows any non-specialized user (in this case, the real tutor) to define and automatically execute a complete avatar animation with high level of expressiveness.

3.2 Evaluation Phase: Dynamic Generation of Emotions

In the evaluation phase (Fig. 1 b.), the emotions can not be pre-defined, since the emotions has to appear dynamically depending on the user feedback and emotional state. In this case, the emotions will be the result of a cognitive process that evaluates the student events. There are principally four different perspectives on emotion: the Darwinian, the Jamesian, the social constructivist, and the cognitive. For the implementation of emotional computers, the most followed perspective is the fourth one. In this case, emotions are considered as responses to the meaning of events with regard to the individual's goals and motivations. There are a lot of emotional models which follows this perspective. We tried to find which one is the emotional model that better fits with an interface depending on the application requirements.

In general, the *appraisal theories* indicate that the result of an emotional reply comes from a dynamic assessment process of the needs, beliefs, objectives, worries or environmental demands. Each emotional model use different appraisals. Therefore, for choosing an emotional model that fits with the application in which it is going to be integrated, it is very important to know what kind of information about the user and system we have; which are the application requirements, how the user will interact and communicate with the system and what will be the avatar role. For this work we have the following requirements about the system: The avatar is an emotional interaction element in the interface and we do not have any previous information about the user, just the ones that are generating during the interaction and are implicit in the application (such as pass an exam). At this point we tried to find the emotional model that better fits for a system with this characteristics.

There are several emotional models on which this cognitive perspective have been based, such as those developed by Aaron Sloman [15], Lazarus [16], Ortony, Clore y Colins [17] or Roseman [18]. Within this set, the Ortony, Clore and Colins (OCC) and the Roseman models were explicitly designed to be integrated in computers and offer a rule-based mechanism to generate cognitive emotions. In fact, many authors have developed computational systems based on emotional models. For example, the Roseman model was implemented by Velasquez in Cathexis [19]. The OCC model has been extensively implemented. Special mention should be made of the models developed by Elliot [20] and by Bates [21]. As limitations were found in both models, other authors have combined them, such as El-Nars [22] o Buy [23]. In his thesis [24], Bartneck states that the reason why the majority of projects in this area choose the OCC model is that is the only one that offers a structure of variables that influence the intensity of the emotion. In a comparison between both models, significant differences have been found that make the use of each of them mainly depends on the level of interaction that is desired to obtain in the system. For example, it was concluded that the OCC model takes into account the standard models and preferences of the user in its evaluation process, while Roseman only evaluates according to objectives and this means that some emotions relating to attitudes or standards (taste/distaste or anger) cannot be specifically defined. However, in eLearning not always the

system has the student attitudes or standars, in this case the system only has the objective of the student and the information occurred during the learning process. Therefore, the Roseman implementation may be more appropriates for this case. In general, in this paper, we have opted for the Roseman model for the following reasons. On the one hand, this model considers surprise emotion within its 17 emotions and this emotion is very important as Ekman [25] considers it as one of the six universal basic emotions, and our facial animation engine is based on Ekman studies. However, the OCC model does not contemplate it. On the other hand, as Barneck concluded [24], a log function needs to be stored which will help to assess the probability, fulfilment and effort of each event to categorize the emotions, an element that is not contemplated in the OCC model.

3.3 A Computational Roseman's Model

We implement Roseman's model by means of a rule-based system based on the table shown in Fig.2. In this table are presented the six cognitive appraisals which determine whether an emotion arises and which one it is; 1)if the event is self-caused, other-caused or circumstance caused, 2)if the event is unexpected, 3)if the event is a motive consistent or motive inconsistent, 4) if the person can control of the situation (in case the event is motive inconsistent), 5) if the event is certain or uncertain and 6) if the event is noticed as negative because it blocks a goal or because it is negative in its nature.

The implemented model has been integrated in a prototype with the required requirements in order to prove it in a real application. This application consists in an e-Learning course in which the avatar gives to the user emotional feedback related with its results. The interface of the course (Fig. 1 b.) is composed by an emotional avatar, which expresses the emotions given the Roseman's model and by a questions zone, which are taken from a XML file. When the test exam begins the emotional module starts to assess the event following the Roseman's appraisals described above.

The first appraisal is the agency, this means whereas the event is self-caused, other-caused or circumstance caused. An event is circumstance-caused

<table>
<tr><th colspan="2"></th><th colspan="2">Positive emotions
Motive-Consistent
Appetitive | Aversive</th><th colspan="2">Negative emotions
Motive-Inconsistent
Appetitive | Aversive</th><th></th></tr>
<tr><td rowspan="5">Circumstance - Caused</td><td>Unknown</td><td colspan="4">Surprise</td><td></td></tr>
<tr><td>Uncertain</td><td colspan="2">Hope</td><td colspan="2">Fear</td><td rowspan="2">Weak</td></tr>
<tr><td>Certain</td><td>Joy</td><td>Relief</td><td>Sadness</td><td>Distress</td></tr>
<tr><td>Uncertain</td><td colspan="2">Hope</td><td rowspan="2">Frustration</td><td rowspan="2">Disgust</td><td>Strong</td></tr>
<tr><td>Certain</td><td>Joy</td><td>Relief</td><td></td></tr>
<tr><td rowspan="4">Other – Caused</td><td>Uncertain</td><td colspan="2" rowspan="4">Liking</td><td colspan="2">Dislike</td><td>Weak</td></tr>
<tr><td>Certain</td><td colspan="2" rowspan="3"></td><td></td></tr>
<tr><td>Uncertain</td><td colspan="2">Anger</td><td>Contempt</td><td>Strong</td></tr>
<tr><td>Certain</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="4">Self – Caused</td><td>Uncertain</td><td colspan="2" rowspan="4">Pride</td><td colspan="2">Regret</td><td>Weak</td></tr>
<tr><td>Certain</td><td colspan="2" rowspan="3"></td><td></td></tr>
<tr><td>Uncertain</td><td colspan="2">Guilt</td><td>Shame</td><td>Strong</td></tr>
<tr><td>Certain</td><td colspan="2"></td><td></td></tr>
</table>

Fig. 2. Roseman's model [18]

whether the user has been started and the system gets the first user reply. Then, the first thing to do is to ascertain if the answer is correct.

If it is correct, the system checks the **second appraisal** of Roseman's model; whether this is unexpected or not. For achieving this information we use the relative frequency ($f_s = n_s \div n$) which is a number that describes the proportion of successes happening in a given test exam. If the system gets an unexpected reply, the avatar will show the *SURPRISE* emotion.

If this is an expected response, the **third appraisal** to treat is whether it is motive-consistent or not. An event is motive-consistent whereas it helps to achieve one of the subject's goals and it is motive-inconsistent if it threatens it. Anyway, the main goal here is pass the exam. As we are evaluating a correct answer, the user will be in a motive-consistent. Inside the set of emotions generated by motive-consistent event we get *JOY* if the event is motivated by the desire to obtain a reward (the player is wining) or *RELIEF* if the desire to avoid punishment. If the answer is not correct, the event is motive-inconsistent. It follows the same sequence rules than above. If it is unexpected, then we get *SURPRISE*. If not, the system checks whether it is appetitive or not.

In the case of a failed reply the emotion is also affected by the **forth appraisal**, the user potential to control the situation. For guessing it (if he/she can still win) we use the Eq. 1. For achieving this equation we start with the binomial distribution function ($P(X = k) = \binom{N}{k} P_{ok}^{k} (1 - P_{ok})^{N-k}$) which gives us the discrete probability distribution of obtaining exactly k successes out of N trials, taking into account that the probability of getting right one question is P_{ok}. Knowing that the user goal is to answer k correct questions for passing the exam and he/she answered n questions, we need to calculate the winning probability at each point of the test exam, depending on the x previous correct answers. We follow the Eq. 1. If the user can control the situation and the event is appetitive, then we get the *FRUSTRATION* emotion. If he/she can not control the situation, the avatar will show the *SADNESS* emotion. In the case that the event is aversive we get the *DISTRESS* emotion if he/she has not potential control and again *FRUSTRATION* if he/she has it.

$$\sum_{i=k-x}^{N-n} \binom{N-n}{i} P_{ok}^{i} (1 - P_{ok})^{N-n-i} \tag{1}$$

All of this occurs when the event is certain (the student has already answered the question). Whereas the event is certain or not, is the **fifth Roseman's appraisal**. For assessing this appraisal, the system calculates the time that the student has to answer by means of an internal clock. While the user is not answering, the system gets an uncertain event. In this case, the computational emotional model looks at the success probability which is also calculated through the relative frequency. If the user has a high probability of getting right then the system gives us the *HOPE* emotion. If not, then the control potencial is achieving again through the equation 1. If the user could not control the situation, then the avatar will show the *FEAR* emotion, if not, we will get *FRUSTRATION*.

The first Roseman's appraisal that we assessed is the agency of an event. At this point we got the events caused by the circumstances but Roseman contemplates two more kinds of event-causes, the other-caused events and the self-caused. The emotions generated by the assessments of this kind of events will appear when the system know if the student pass or not. The first ones will show the avatar feeling about the user game and the other ones will be the avatar prediction about the user feeling. The rules followed for obtaining this emotions are the ones related with the appetitive and control potential appraisals. Then we will get the *LIKING*, *DISLIKE* and *ANGER* emotions for other-caused events and *PRIDE*, *GUILT* and *REGRET* for self-caused events.

The last appraisal, the kind of problem, describes whether an event is noticed as negative because it blocks a goal or because it is negative in its nature. In this kind of application we always get the first kind of problem.

4 Animated Pedagogical Agent

4.1 The Expression of Emotions

Several researches have been centred in defining how the human express the emotions he/she is experimenting. Darwin was one of the pioneers in studying it. His studies made an emotional theory which have followed researchers as Ekman [25]. The Ekman's theory is maybe the most successful and most followed for representing facial expressions. In 1978 he developed a system for coding the facial actions called FACS (The Facial Action Coding System). FACS is a comprehensive, anatomically based system for measuring all visually discernible facial movement. FACS describes all visually distinguishable facial activity on the basis of 44 unique action units (AUs), as well as several categories of head and eye positions and movements.

In our work we transfer these studies to the emotional dramatization of the avatars. The animation techniques used for performing the facial expressions are explained in chapter 4.2. For the animation models required we use the 14 AUs (Fig.3) which describe the facial activity in each emotion.

The first problem we found for using the Ekman work is that he defined only six basic emotions and we get 17 from the Roseman model. The main reason of using this six basic emotions is that Ekman and his colleagues gathered evidence

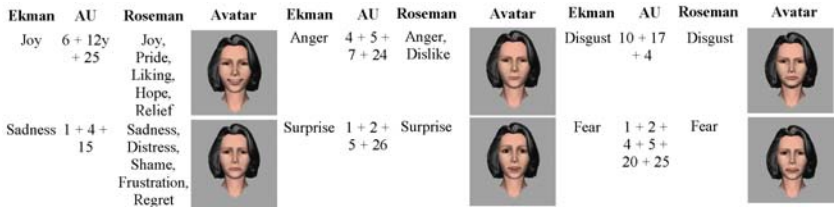


Fig. 3. Relation between Ekman's emotions, AUs and Roseman's emotions

of the universality of this six facial expressions of emotion and they can be combined to obtain other expressions. One of our goals [26] is that the avatar must be multilingual so it should not express emotions dependents on the culture. Kshirsagar in [27] grouped OCC and Ekmans emotions within 6 expressions to represent the emotional states and to reduce the computational complexity. He also makes this categorization using the basic expressions as a layer between visible facial expressions and invisible mood. Following this research, we make the same relations with the Roseman's emotions shown in Fig.3.

4.2 Facial Animation

Facial expressions are obtained through the animation of the head, lips, eyes, pupils, eyebrows and eyelids. These animations are easily mapped for humanoids. Some animations are generated making individual deformations or translations over the object in a determined trajectory. This technique is used for the pupils or the global head pose. Some other animations, like lip motion, are achieved using the morphing techniques developed by Alexa [28]. Let us briefly summarize the morphing technique used: first, we establish an appropriate set of basic objects (B_i in Fig.4 and Eq. 2), in such a way that all face expressions necessary to produce the animation can be obtained from combinations of these basic objects. We use a set of basic objects made by the the 14 Ekman's AUs defined in Fig.3 and another one called default face which shows the neutral face of the avatar.

$$V(i) = \sum_{j=1}^{n-1} a_i B_i = (\sum_{j=1}^{n-1} a_i B_{ij}) \tag{2}$$

The animations are represented by one geometric base and a set of key frames (defined by a vector of weights). Each value of this vector corresponds to the interpolated value (a_i in the facial animation engine module shown in Fig.4 and Eq. 2). The sequences of animations are set defining the operations in eq. 2 with the required input values. The facial animation engine module in Fig.4 illustrates this process.

The architecture works as follows: First, Roseman's model receives the application goal (in this case it recibes the percentage of the successes that the student should get right in order to pass the exam). When the interaction starts, Roseman's model is receiving each user input (in this case, it recibes the reply to each question). Following the rules described in section 3.3, the output of this module is the emotion that the avatar should express. In this point, the system asks if the interaction should be verbal or non-verbal. If the interaction is non-verbal, then the emotion tag goes directly to the animation engine. For a verbal interaction we have a short database of predefined markup text for some emotions. The markup text is transferring to the pre-process module, which interprets the text and extracts the emotions, gestures and the precise moment when they have to be reproduced. This information is transferred to the graphic platform for controlling facial expressions. The text to vocalize, the emotions and events related to them are also transferred to the Text to Phoneme module.

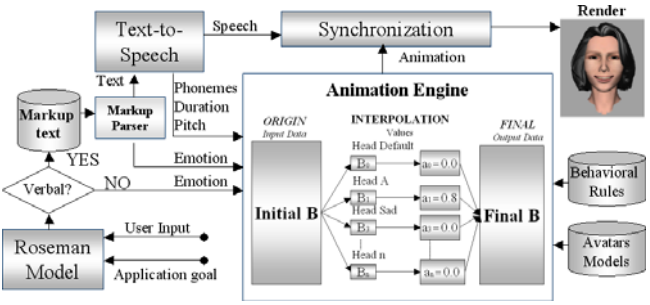


Fig. 4. System Architecture

The Text to Phoneme module calculates the chain of phonemes necessary to vocalize the message contained in the text with the indicated emotion, assigning to each phoneme its prosodic characteristics, mainly its duration and pitch. These prosodic characteristics are transferred to the graphic platform. In the graphic platform, with these prosodic data, each phoneme will be associated to its corresponding viseme (visual representation of the phoneme) by means of morphing techniques. The vocalized facial animation is based on the parameters coming from the Text to Phoneme module and a set of internal behavior rules (associated with emotions).

5 Conclusions

The aim of the ELEIN system is to achieve emotional multimodal interaction and communication in e-Learning environments. The ELEIN system reaches two important issues for e-Learning: the importance of the emotions in the learning process and the presence of the virtual tutor.

Regarding to the emotions, we differentiate between the generation of the emotions when the virtual tutor is explaining the contents of the e-Learning course (static generation of emotions), and the generation of the emotions when the virtual tutor is assessing the student knowledge (dynamic generation of emotions). In the case of Static Emotional Interaction, this is generated as a predefined reaction in the system, so it is necessary for the system to incorporate the suitable tool to define this behavior. After a deep exploration of the existing bibliography, it has been concluded that the most efficient way of providing the system with static emotional characteristics is probably the use of Virtual Human Markup Language (VHML)., i. e. with tags defining emotions, intensities or facial gestures (in the case of avatars) which should be generated by the system in a certain situation. In this research we develop an authoring tool based on VHML, which allows the real tutor to define the emotional behavior of the virtual tutor during the contents explanations without any knowledge in Computer Graphics. As during the bibliographic review no similar tool has been found, this application is considered to be an innovative contribution to the standard VHML. On the other hand, Dynamical Emotional Interaction is generated as a result

of processing and evaluating every interaction event occurred in the system. In order this type of interaction to be natural and similar to human behavior and to evaluate its possible application to emotional interaction through avatars, an initial state of art of different psychological models of emotions has been made. After the analysis of the differences between the two most extended models in emotional computation, OCC and Roseman, it has been concluded that most of the authors usually base their works on OCC model. However, in this work the Roseman model has been selected to be used in the implementation of the Dynamic Emotional Interaction module, mainly because its better suitability for the eLearning course. During the implementation of the Dynamic Emotional Interaction module, the following original contributions have been made. First of all, a rule-based expert system has been defined for generating emotions. Since most of the examples of emotional systems found in the literature are based on OCC model, the design of this expert system is new and original contribution to existing bibliography.

Regarding the presence, we deal with that by means of using an animated virtual tutor. The personification of the emotional educational agent implies to define how emotions should be expressed and which are the animation techniques in order to execute the facial animation. In this work, the avatar produces an emotional expression through facial animation engine based on morphing techniques and based on the conclusions of Ekman's study about facial expression to the emotions of Roseman model and VHML, so that every emotion generated by the Static Emotional Interaction module and the Dynamic Emotional Interaction module can be expressed by the avatar according to Ekman's conclusions.

References

1. Picard, R.: Affective Computing. MIT Press, Cambridge (1997)
2. Mehrabian, A.: Communication without words. Psychology Today 2(4), 53–56 (1968)
3. Hernandez, Y., Noguez, J., Sucar, E., Arroyo-Figueroa, G.: Incorporating an affective model to an intelligent tutor for mobile robotics. In: Frontiers in Education Conference, 36th Annual (October 2006)
4. Nass, C., Steuer, J., Tauber, E.R.: Computers are social actors. In: CHI 1994: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 72–78. ACM Press, New York (1994)
5. Prendinger, H., Ma, C., Yingzi, J., Nakasone, A., Ishizuka, M.: Understanding the effect of life-like interface agents through users' eye movements. In: ICMI 2005: Proceedings of the 7th international conference on Multimodal interfaces, pp. 108–115. ACM Press, New York (2005)
6. Koda, T., Maes, P.: Agents with faces: The effects of personification of agents. In: 5th IEEE International Workshop on Robot and Human Communication, Tsukuba, Japan (November 1996)
7. Kim, Y.: Pedagogical agents as learning companions: the effects of agent affect and gender on student learning, interest, self-efficacy, and agent persona. PhD thesis, Department of Educational Psychology and Learning Systems. Florida State University, Tallahassee, FL, USA. Major Professor-Amy L. Baylor (2004)

8. Hongpaisanwiwat, C., Lewis, M.: Attentional effect of animated character. In: INTERACT (2003)
9. Nijholt, A.: Agents, believability and embodiment in advanced learning environments: Introduction to a panel discussion, 457 (2001)
10. Nkambou, R.: A framework for affective intelligent tutoring systems. In: Information Technology Based Higher Education and Training, July 10-13, pp. nil2–nil8 (2006)
11. Okonkwo, C., Vassileva, J.: Affective pedagogical agents and user persuasion. In: Stephanidis, C. (ed.) Universal Access in Human - Computer Interaction (UAHCI), New Orleans, USA, pp. 397–401 (2001)
12. Carretero, M., Oyarzun, D., Ortiz, A., Aizpurua, I., Posada, J.: Virtual characters facial and body animation through the edition and interpretation of mark-up languages. Computer & Graphics 29(2), 189–194 (2005)
13. Marriot, A.: Vhml: Virtual human markup language. In: OZCHI, Fremantle, Western Australia (November 2001)
14. RRL: The neca rrl (2006), http://www.ai.univie.ac.at/NECA/RRL/
15. Sloman, A.: Emotions in humans and artifacts. In: How many separately evolved emotional beasties live within us. MIT Press, Cambridge (2002)
16. Lazarus, R.S., Averill, I.R., Opton, E.M.: Feeling and emotion. In: Toward a Cognitive Theory of Emotion, pp. 207–232. Academic Press, London (1970)
17. Ortony, A., Clore, G., Collins, A.: The Cognitive Structure of Emotions. Cambridge University Press, Cambridge (1998)
18. Roseman, I., Antoniou, A., Jose, P.: Appraisal determinants of emotions: Constructing a more accurate and comprehensive theory. Cognition and Emotion 10 (1996)
19. Velasquez, J.: Modeling emotions and other motivations in synthetic agents. In: AAAI Conference, Providence, pp. 10–15 (1997)
20. Elliot, C.: The Affective Reasoner: A process model of emotions in a multi-agent system. PhD thesis, Norhwestern Universtiy, Evanston, IL (1992)
21. Bates, J.: The role of emotion in believable agents. Source Communications of the ACM archive 37(7), 122–125 (1994)
22. El-Nasr, M., Yen, J., Ioerger, T.: Flame:fuzzy logic adaptive model of emotions. Autonomous Agents and Multi-Agent Systems 3, 219–257 (2000)
23. Buy, D.: Creating emotions and facial expressions for embodied agents. PhD thesis, University of Twente (2004)
24. Bartneck, C.: eMuu - An Embodied Emotional Character for the Ambient Intelligen Home. PhD thesis, For the ambient intelligent home i Technische Universiteit Eindhoven (2002)
25. Ekman, P.: Facial Expression and Emotion. American Psychologist 48(4), 384–392 (1993)
26. Aizpurua, I., Ortiz, A., Oyarzun, D., Arizkuren, I., Posada, J., Andrés, A., Iurgel, I.: Adaptation of mesh morphing techniques for avatars used in web applications. In: Perales, F.J., Draper, B.A. (eds.) AMDO 2004. LNCS, vol. 3179, pp. 26–34. Springer, Heidelberg (2004)
27. Kshirsagar, S.: A multilayer personality model. In: Press, A. (ed.) 2nd international symposium on Smart graphics, New York, NY, USA, pp. 107–115 (2002)
28. Alexa, M., Behr, J., Müller, W.: The morph node. In: VRML 2000: Proceedings of the fifth symposium on Virtual reality modeling language (Web3D-VRML), pp. 29–34. ACM Press, New York (2000)

Tangible Drag-and-Drop: Transferring Digital Content with a Remote Control

Mathieu Hopmann, Daniel Thalmann, and Frédéric Vexo

VRLab, EPFL
Switzerland

Abstract. Despite the fact that dematerialization of all our multimedia content brings advantages, the absence of physical medium brings also a lack of tangibility. This paper presents a gesture-based interface to bring back tangibility in our dematerialized multimedia content. Our concept is to apply the drag-and-drop paradigm in the real world, using a remote control as a portal between virtual content and physical devices. In order to validate our concept, we designed a prototype focused on the transfer of digital pictures between two different devices: from a TV screen to a digital photo frame. User experiment has proven that our concept brings efficiency, easiness and a natural way to interact with digital multimedia content.

1 Introduction

Multimedia content has become more and more dematerialized over last years. Physical medium sales are decreasing whereas dematerialized offer becomes more various and popular.

Dematerialization brings advantages: you can carry all your music, video and photos in a single device. It could be your MP3 player, your external hard drive, or a place accessible from the web, allowing you to reach your content from everywhere. But dematerialization also brings an inconvenient: the lack of tangibility. With a physical medium, the possible actions are concrete: put the compact disk in the Hi-Fi system to play music, looking photos of the family album, etc. Using digital files is not that easy, especially for people who are not familiar with computers. But if dematerialized content is not tangible, it doesn't mean that interact with it could not be more concrete and tangible.

Thus, we target the problem of the interface, and how to bring back tangibility using purely virtual content. Our concept is inspired by two well-known paradigms: the remote control and the drag-and-drop paradigms.

Remote controls are widely used to control a variety of devices and are familiar to many people. They are one of the most used electronic devices, and are omnipresent in developed countries. For these reasons we think that a remote control is a good bridge between dematerialized content and the real world.

On the other side, drag-and-drop is a well-known technique from computer graphical user interfaces. This is the action of clicking on a virtual object and

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 306–315, 2009.

drags it to another location. This is a fast and easy-to-learn technique, and generally an efficient way to perform some tasks in graphical interfaces.

Our concept is to gather these two paradigms to enhance the user experience, by providing both tangibility and efficiency. Tangibility is provided by the fact that we have a familiar object in hands (the remote), and by the possibility of using a gesture-based interface using this remote control. The drag-and-drop paradigm, associated to the gesture-based interface, adds the efficient aspect. In this paper we propose a tangible drag-and-drop system intended to select dematerialized content in real world, and move it to another place. We designed a proof of concept to demonstrate our principle: the idea is, when you are looking at your photos in front of your TV screen, to point at your TV screen with your remote control, and drag-and-drop the current picture from the TV to your digital photo frame.

The paper is organized as follows: first we present an overview of the tangible user interface field and the previous works that lead us to this concept. We continue with a section describing our complete scenario, before continuing on the implementation of our proof of concept. Finally, we conclude with the user experiment and results.

2 State of the Art

As digital multimedia content is becoming more and more present in every home, new interaction techniques are necessary to make its manipulation more concrete and easy. Using tangible user interfaces (TUI) is probably the best way to facilitate the manipulation of digital content. A tangible UI is an interface in which the user interacts with digital data using the physical environment.

The concept has been introduced by Fitzmaurice et al. with a different name: Graspable User Interface[3]. They proposed to allow direct control of virtual objects through physical handles, named bricks. Ishii and Ullmer continued on this way with Tangible Bits[7], where they proposed to "grasp and manipulate" bits using everyday physical objects and architectural surfaces.

For some domains, designing tangible interfaces is easier than for others: using molecule objects to learn chemistry[4], a ping-pong paddle for gaming[8], or buildings for urban planning[11]. Bring tangibility to abstract content such as multimedia data is not that easy, and have to be done in a different way. For example, in [2], Ferscha et al. used physical shortcuts with remote controllers, where hand gestures of the user are converted in control commands sent to devices.

The idea of taking advantage of tangible user interface in order to manage digital multimedia content has been explored for many purposes. In order to make digital music more tangible, Alonso and Keyson designed the MusicCube[1]. Users interact with the MusicCube using gestures to shuffle music and a rotary dial for song navigation and volume control. Graham and Hull proposed iCandy[5], a tangible interface designed to restore the benefits of physical albums for digital music in the iTunes library. Zigelbaum et al. focused on the digital video content, with the tangible video editor[12]. The idea is to use tangible objects for editing sequences of digital video clips. About digital pictures,

Hsu et al.[6] presented a gesture-based design concept of a tangible interface for browsing image contents.

Tangibility is also an interesting approach for multiple-device interaction. Rekimoto suggested the pick-and-drop[10] interface, where the user pick up an object on a display, and drop it on another display as if he were manipulating a physical object. The tangible object used to "carry" the digital data were an identifiable pen. Rekimoto proposed the same pick-and-drop approach for supporting whiteboard-based interactions[9]. Zigelbaum et al. worked also on the grasping of digital data with the Slurp project[13]. Slurp takes the appearance of an eyedropper, and provides haptic and visual feedback while extracting and injecting pointers to digital media between physical objects and displays.

Our idea has been built on this multiple-device interaction concept, and addresses the problem of tangibility in digital multimedia content. Tangible drag-and-drop is a multiple-device user interface, designed to bring easiness and efficiency in the manipulation of digital multimedia content. Next section describes a concrete scenario about the transfer of digital pictures and how the drag-and-drop paradigm could be used to perform that.

3 Concept

We present here an everyday life situation, how we perform it now and how we propose to perform it using the drag-and-drop paradigm.

3.1 Scenario

You are looking at your last holiday digital photos on your TV screen, comfortably seated in your sofa, and want to select this beautiful picture to add it on your photo frame.

3.2 Using Existing Solutions

After having plugged the laptop on your TV screen with a VGA/DVI or HDMI cable, you look at your pictures using the classic keyboard/mouse combo or a more multimedia oriented device such as the Logitech®DiNovo Mini™or the remote control provided with Apple®products.

Then, there is this picture, and you want to add it on your photo frame. To perform that, you have to take the photo frame memory card, plug it in your laptop, quit the slideshow mode, find the picture in your hard drive, and copy it on the memory card.

3.3 Using Tangible Drag-and-Drop

You point your TV screen with your remote control and click on the drag-and-drop button, move your arms to point to the picture frame with the remote and release the button. Then the picture is automatically transferred in your photo frame memory and appears on its screen.

Fig. 1. Tangible drag-and-drop: take your picture on your TV and drop it on your photo frame

4 Implementation

We describe in this section the hardware and software needed to conceive our proof of concept.

4.1 Hardware Description

To provide our tangible drag-and-drop experience, we need:

- A big screen to display photos as a slideshow (the TV screen)
- A digital photo frame with network capabilities to send pictures programmatically on it
- A remote control to select the picture on the TV and to perform the drag-and-drop action

To display the pictures, we have chosen a laptop connected to a video projector. The video projector allows to comfortably display the photos on a big screen, and the laptop lets us the freedom to run our application.

The digital photo frame is the Parrot®photo viewer[1]. This photo frame is wireless oriented and allows to send pictures on it using the Bluetooth technology. Designed to send pictures from mobile phones, we could use this ability to send pictures from our application.

Finally, the remote control was the most problematic hardware to choose. It has to manage the photos (at least allow to go to the next picture on the TV), but most of all it has to manage the drag-and-drop action. We had two possibilities at this point: we could use a complex remote control with all the hardware embedded in it (gyroscopic motion capture system, or a webcam for example) to detect where the user is pointing; but also, we could use a simple device and perform the pointing direction detection by another hardware. We have selected the second approach, in order to have a smaller and comfortable remote control, and have chosen a standard mouse. The mouse buttons are working as follows: left button to go to the previous image on the TV screen, right button to go to the next image, and middle button to perform the drag-and-drop action. For

[1] http://www.parrotphotoviewer.com/

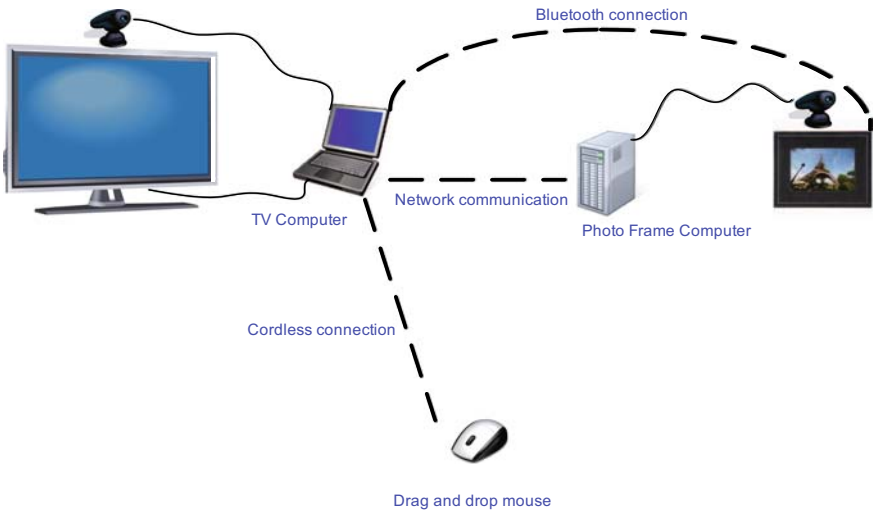


Fig. 2. Schema of our installation

the last one, the user as to push the button in front of the TV screen to select the picture, and release the drag-and-drop button in front of the photo frame to launch the transfer.

It remains the pointing problem: how to detect where the mouse is pointing? To perform that, we have decided to use webcams (one under the TV, the other on the photo frame) and stick a LED under the mouse. Each webcam is connected to a computer which processes the video signal. The idea is to detect if the LED is visible to know if a device is pointed or not. Figure 2 summarizes our installation in a schema. Next section gives software details about the remote detection and the Bluetooth file transfer.

4.2 Software Description

General description. Our software is composed of a server and two clients which communicate using TCP.

The client, developed in C++, has only one purpose: analyzing the video stream to detect if the remote control is pointing in our direction or not, and sending the information to the server. One client is based on the TV screen computer, the other on the photo frame computer. The server, developed in Java and also running on the TV screen computer, is the part of the application that manages the slideshow, the remote control(the mouse), and the drag-and-drop part. For the slideshow, the server just has to display pictures in full screen, go to the previous picture on a left click, and to the next picture on a right click. For the drag-and-drop action, the server is continuously informed by the two clients if the TV or the photo frame is pointed or not by the remote control. When the user clicks on the drag-and-drop button, the server checks if the TV

Fig. 3. The photo frame with the webcam sticked on it. The video signal given by the webcam is analyzed in order to detect if the remote control is pointing it or not.

is pointed or not. If yes, the current picture is memorized and we are considered in drag mode. When the user releases the button, it checks if the photo frame is pointed. If yes, and if we are in drag mode, the memorized picture is transferred to the photo frame. In other cases, nothing happens.

Detect the remote control direction. As described before, the remote control direction detection is done by the two clients. Each client reads the webcam video stream and analyzes it to detect if the remote LED is in range or not. We perform that in two steps. The first step is manual, and has to be done only the first time, before launching the client. It consists in settle the webcam

Fig. 4. The mouse with its LED

parameters (frames per second, brightness, contrast) to obtain the darkest image on which the LED is still visible. This way we eliminate all external light pollution to only focus on the LED.

The second step is the client code, which detects the LED. To perform this, we have used a home-made framework previously designed for a multi-touch table. The purpose was indeed the same: detecting fingers enlightened by LEDs, and returning their positions. The only difference is that we are directly detecting one LED, and ignore the position. OpenCV[2] (Open Source Computer Vision) could have been an alternative way to perform the LED detection.

Picture transfer. The picture transfer is launched when the drag-and-drop process has been successful, as mentioned in the general description. To perform the Bluetooth transfer, we have chosen the easiest way. Because we are running Ubuntu[3], a Linux-based operating system, we take advantage of the available applications. bluetooth-sendto is one of these applications, specially designed to transfer files over Bluetooth. It only takes two parameters: the MAC address of the destination device (the photo frame), and the path of the file to send, which is the path of the photo currently displayed on the TV. An advantage of using bluetooth-sendto is that the application opens a progress bar window to inform the user about the transfer position. It gives a feedback which could be interesting for the user after the drag-and-drop action (for example if the picture is heavy and doesn't appear immediately on the photo frame screen).

5 Experiments

5.1 Test

In order to evaluate our proof of concept, we asked twelve users to test our application and rate it. For the test assessment, we designed a SUMI[4]-like questionnaire[5] to measure the software quality from the user's point of view. It consists in a list of 35 simple questions to which the user has to reply "yes", "no", or "I don't know". The criteria evaluated by these questions are mental and physical effort, efficiency and how much our interface is natural.

Regarding the test, we asked users to follow the scenario described in section 3. They had to look at the pictures on the TV screen, navigate using the remote control, and select their three favorite photos. Except that, we did not give any instruction about how to use the drag-and-drop remote.

5.2 Results

After the tests, users' feedback was really enthusiastic. All the users answered positively to the questions relative to the usability and the interest using our

[2] http://sourceforge.net/projects/opencvlibrary/
[3] http://www.ubuntu.com
[4] http://sumi.ucc.ie/
[5] http://vrlab.epfl.ch/ hopmann/dragdrop/questionnaire.txt

application. They all have thought that using our tangible drag-and-drop allows to be more efficient than using existing solution, with an intuitive manner. Physical and mental effort has been qualified as normal and not excessive.

Concerning the easiness of using our proof of concept, all the users took less than one minute to perform the first drag-and-drop, without giving any instruction about how to use it. We can deduce that our application requires a low learning curve in order to be fully usable. If this result is really satisfying about the easiness and intuitive aspect of our concept, we have to take account that users were people from our lab and school. They use computer every day and are already familiar with the classical drag-and-drop concept. The good point is that the transfer from the graphical interface to the physical world seemed very natural for people used to computers.

Concerning the inconvenient aspects of our application, some users experienced problems with the LED detection. During our tests, four persons missed one time the drag-and-drop process for being not precise enough in their movement. The field of view of the webcam is indeed intentionally limited to avoid the false positive (when the picture transfer is started whereas the user did not point the photo frame or TV). Thus, users have to precisely point a device when they want to select it. If missing the drag-and-drop process seems frustrating, precision is inevitable to detect which device is pointed. Adapting precisely the field of view of each webcam (maximizing detections and at the same time avoiding false positive) is a possibility to solve this issue.

Another inconvenient pointed by the users is the lack of output given by the application. For example, if you point the TV with your remote and click on the drag-and-drop button, nothing indicates that the TV has been successfully selected. Thus, when nothing happens after a bad selection, you have no feedback to help you understand why the drag-and-drop process failed: TV was not selected, photo frame was not pointed during the drop, the application was not working, etc. Different solutions could be implemented to solve this issue. A simple sound feedback for example, to indicate that the user successfully selected the devices. Another solution could be to give a visual feedback: when you select the picture on the TV, the picture could move according to your movement, and disappear when you leave the visual field of the webcam TV.

Finally, one user mentioned the impossibility of cancelling the drag-and-drop action (during the transfer of the picture).

6 Conclusion and Future Works

In this paper, we described the drag-and-drop concept applied in the physical world on dematerialized content: tangible drag-and-drop. Our idea is to bring back tangibility and easiness in the manipulation of digital multimedia content. To support our idea, we conceived a proof of concept dedicated to digital photos. The principle is to use the drag-and-drop paradigm to transfer a picture from a TV to a digital photo frame, using a remote control to detect our gestures.

Users' feedback was really enthusiastic, proving that our concept is easy to use, efficient and very natural. Our test also permits to find some issues that could be solved to enhance the user experience: different solutions have to be explored in order to compensate the lack of feedback during the drag-and-drop process. It could be an audio, or a visual feedback displayed on the remote for example (which requires a remote control with a screen). We also thought about using a micro projector connected to the remote control in order to display information in front of the user. These projectors start to become popular and could be embedded in cell phones soon, thus it could be interesting to take advantage of this possibility.

Another point to explore is how far our concept could be applied. In this paper we saw the efficiency of the tangible drag-and-drop concept using pictures, but it could be interesting to explore how manipulate video, music or text using the same paradigm.

Acknowledgment

This work has been supported by the Swiss National Science Foundation (FNS) under the framework of Semantic Based Tangible interface: the remote control paradigm project.

References

1. Alonso, M.B., Keyson, D.V.: MusicCube: making digital music tangible. In: CHI 2005 Extended Abstracts on Human Factors in Computing Systems, Portland, OR, USA, April 2-7, 1995 (2005)
2. Ferscha, A., Vogl, S., Emsenhuber, B., Wally, B.: Physical shortcuts for media remote controls. In: Proceedings of the 2nd international Conference on intelligent Technologies For interactive Entertainment, ICST, Cancun, Mexico, January 8-10 (2008)
3. Fitzmaurice, G.W., Ishii, H., Buxton, W.: Bricks: laying the foundations for graspable user interfaces. In: Proceedings of the SIGCHI conference on Human factors in computing systems, CHI 1995, Denver, Colorado, USA, May 7-11 (1995)
4. Fjeld, M., Fredriksson, J., Ejdestig, M., Duca, F., Bötschi, K., Voegtli, B., Juchli, P.: Tangible user interface for chemistry education: comparative evaluation and redesign. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2007, San Jose, California, USA, April 28-May 3 (2007)
5. Graham, J., Hull, J.J.: Icandy: a tangible user interface for itunes. In: CHI 2008 Extended Abstracts on Human Factors in Computing Systems, CHI 2008, Florence, Italy, April 5-10 (2008)
6. Hsu, S.H., Jumpertz, S., Cubaud, P.: A tangible interface for browsing digital photo collections. In: Proceedings of the 2nd international Conference on Tangible and Embedded interaction, TEI 2008, Bonn, Germany, February 18-20 (2008)
7. Ishii, H., Ullmer, B.: Tangible bits: towards seamless interfaces between people, bits and atoms. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 1997, Atlanta, Georgia, United States, March 22-27 (1997)

8. Ishii, H., Wisneski, C., Orbanes, J., Chun, B., Paradiso, J.: PingPongPlus: design of an athletic-tangible interface for computer-supported cooperative play. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: the CHI Is the Limit, CHI 1999, Pittsburgh, Pennsylvania, United States, May 15-20 (1999)
9. Rekimoto, J.: A multiple device approach for supporting whiteboard-based interactions. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Los Angeles, California, United States, April 18-23 (1998)
10. Rekimoto, J.: Pick-and-drop: a direct manipulation technique for multiple computer environments. In: Proceedings of the 10th Annual ACM Symposium on User interface Software and Technology, UIST 1997, Banff, Alberta, Canada, October 14-17 (1997)
11. Underkoffler, J., Ishii, H.: Urp: a luminous-tangible workbench for urban planning and design. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: the CHI Is the Limit, CHI 1999, Pittsburgh, Pennsylvania, United States, May 15-20 (1999)
12. Zigelbaum, J., Horn, M.S., Shaer, O., Jacob, R.J.: The tangible video editor: collaborative video editing with active tokens. In: Proceedings of the 1st international Conference on Tangible and Embedded interaction, TEI 2007, Baton Rouge, Louisiana, February 15-17 (2007)
13. Zigelbaum, J., Kumpf, A., Vazquez, A., Ishii, H.: Slurp: tangibility spatiality and an eyedropper. In: CHI 2008 Extended Abstracts on Human Factors in Computing Systems, CHI 2008, Florence, Italy, April 5-10 (2008)

Adaptation in Collaborative Virtual Environments for Training

Stéphanie Gerbaud[1,3], Valérie Gouranton[1,2,3], and Bruno Arnaldi[1,2,3]

[1] INRIA, Centre Inria Rennes - Bretagne Atlantique, Rennes, France
[2] INSA de Rennes, IRISA (- UMR6074), Rennes, France
[3] Université Européenne de Bretagne, France
{stephanie.gerbaud,valerie.gouranton,bruno.arnaldi}@inria.fr

Abstract. Virtual environments for training, especially collaborative ones, require adaptability in order to be used in various situations. In this paper, we classify the needs for adaptation into two levels. The first one concerns the application setting. The second one is a dynamic adaptation, at runtime. The models proposed in this paper fulfill these two levels of requirements. Virtual world, virtual humans' behavior, scenario and application configuration can be adapted to a specific training situation. Moreover, an action selection mechanism enables actors to dynamically adapt their action scheduling to a situation. This situation is defined by a current context, past actions and a goal to achieve, namely a scenario. Finally we validate our models by presenting an illustrative scenario: the collaborative assembly of a piece of furniture.

Keywords: virtual environment, training, adaptation, collaboration.

1 Introduction and Related Work

Virtual training can be applied to various situations. Requirements for a virtual environment change depending on training context: number and type of people involved (from individual to collaborative training, supervised by a trainer, working with virtual humans), the object of the training (e.g. procedure, technical gestures, decision skills), pedagogical expectations, etc. Ideally, a virtual environment dedicated to training should be able to take into account those different demands and be adaptive. For instance in Figure 1, two different training situations are shown. The left picture is an extract from a military maintenance procedure. A trainee is using a remote control while his companion is pulling a cable. On the right picture, a trainee and his companion collaboratively assemble a piece of furniture.

As an introduction, let us take an actual instance of adaptation in real life. Because of clumsiness, a trainee has injured his hand but he must perform a sequence of actions that requires both his hands. He starts this sequence but can no longer perform any action. A learning companion detects that situation and interrupts his own actions in order to help the trainee. This reaction may be obvious for a real companion. We would like a virtual companion to automatically detect this situation as well and to behave in the same way.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 316–327, 2009.

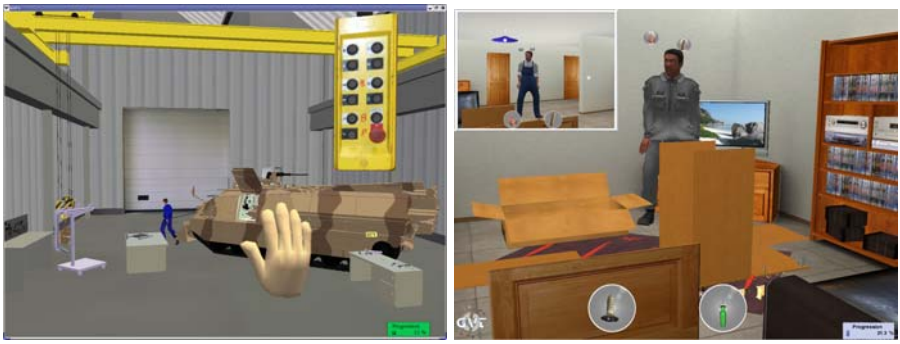


Fig. 1. Different training situations in a virtual environment for training: GVT

In this paper we present models to bring adaptability to a virtual environment for training. Virtual world, virtual humans' behavior, scenario and application configuration can be adapted to a specific training situation. Moreover, an action selection mechanism enables actors to dynamically adapt their action scheduling to a situation, at runtime.

An actor is an entity which acts in the virtual world. Actors can be either real users (trainees and trainers) or virtual companions. A virtual companion may play different pedagogical roles such as collaborative companion or troublemaker. A virtual environment for training is thus composed of three major elements: the virtual world, the scenario and the actors. Adaptation can then occur on each of these elements. In the following state of the art, we describe three features that adaptation can concern in virtual environments for training: scenario description, distribution of scenario actions between participants and virtual humans' behavior.

Scenario Description. Depending on the scenario language used, a scenario may be very precise whereas another may turn out to be more flexible. Indeed, three major ways exist to describe a scenario. The first one consists in writing all the actions to perform. This way of description provides a scenario not adaptable at all but enables the system to control that trainees strictly respects a reference procedure. For instance, it was the choice made in the first version of LORA [1] as it was designed for training on military maintenance procedures. The second way is to underspecify the scenario by describing only key actions while letting basic actions be implicit. A reasoning algorithm is then used to infer on the actions to perform in order to satisfy the preconditions of key actions. In the MASCARET model [2] used in SecuReVi [3] the scenario describes "actions trade" (e.g. for firemen: *sprinkle a fire*) while letting implicit actions "at a generic semantic level for human" (e.g.: *go to a point*). This method enables actors to adapt their actions to context while respecting the scheduling of key actions. The third way is to use plans of action with constraints and goals. In STEVE [4] a naval maintenance procedure is described thanks to tasks, each one written as a standard plan representation [5]. A task is composed of steps and makes

explicit causal links and ordering constraints between these steps. This type of description makes the re-adaptation of the scenario possible when a non-predicted event happens. Nevertheless, this flexibility can be a problem when the aim is to learn an exact procedure. Indeed, the system can not ensure that trainees will follow a specified sequence of actions.

Distribution of Scenario Actions. The previous section shows that, in virtual environments for training, the scenario may be adaptable to context. When these environments are collaborative, the scenario could also be adaptable concerning the distribution of scenario actions between actors. If several roles can be associated with a scenario action, or if several actors can play the same role, this flexibility is possible. In STEVE [4], both a trainee and his virtual tutor can perform a given scenario action, as the tutor plays the same role as his associated trainee. However, there is no ambiguity about who will perform this action: the trainee has priority and if he asks for help, his tutor may perform the action. If an application allows actors to dynamically distribute actions among them, then a mechanism should be in charge of dynamically determining the best candidate for an action, depending on the current context. The context consists of the state of the virtual world (including the state of the actors) and the state of the scenario. Such a mechanism is sometimes proposed for teamwork simulation, as described by Zhang et al. in [6], but not in collaborative virtual environments for training where the distribution of scenario actions between actors is static rather than dynamic [7].

Virtual Humans' Behavior. Several approaches exist to model the possible interactions between a virtual human and an object, such as Kallmann's Smart Objects [8]. Then, the behavior of a virtual human consists in selecting interactions. When a collaborative virtual environment for training offers virtual humans, another type of adaptation thus concerns the behavior of these virtual humans. Indeed, various authors suggest that virtual humans should play pedagogical roles in order to enhance training. Chou et al. identify in [9] two categories of pedagogical roles: teacher (coach, tutor, guide) and learning companion (collaborator, troublemaker, etc). In STEVE [4], agents can play two roles: either tutor or substitute for missing team members. The tutor can answer trainee's questions or show the actions to perform whereas the substitute for missing team members simulates the behavior of an expert. The latter is the only pedagogical role proposed in SecuReVi [3]. Even if the learning companion category contains many different roles, only one is available in existing virtual environments for training. This role consists in following the procedure and performing the scenario actions expected at the right moment. As a consequence, virtual humans in virtual environments for training have limited adaptive behaviors as they only perform expected actions, without making any mistake.

After this short state of the art about adaptation in virtual environments for training, we identify in section 2 two levels of adaptability requirements. Then, we describe the models that we propose in order to satisfy those needs in

section 3, followed by an illustrative scenario: a cupboard assembly procedure, in GVT environment, in section 4.

2 Needs for Adaptability

In our state of the art, we point out a lack of adaptability in virtual training applications. Indeed, such training applications should meet various levels of demand from an application, depending on training domain, as well as from users. For instance, military training demands that trainees respect a strict sequence of actions whereas assembly training expects trainees to adapt themselves to the situation. To answer a wide range of requirements from various training situations, a virtual environment for training, and especially a collaborative one, needs to be able to show adaptability. The first adaptability level consists in enabling session creators to adjust the application setting. This level is detailed in section 2.1. A second level of adaptability consists in a dynamic adaptation at runtime. The application is able to dynamically adapt itself to a changing context, as mentioned in section 2.2. Those two levels are complementary and both needed for learning environments. Indeed, the first level allows the creators of virtual training applications to build applications that fit their training requirements. The second level allows trainees to interact within an application able to adapt itself to their activities.

2.1 First Adaptability Level: Application Setting

Virtual World. A training session creator should be able to easily create a reactive virtual world adapted to a training session. Interactive objects endowed with behaviors are part of this virtual world.

Virtual Humans' Behavior In collaborative virtual environments, virtual humans are sometimes proposed. They are special behavioral objects. In a training session, a trainer should be able to adjust virtual humans' behavior depending on the training level of a trainee. The trainer could for instance give a pedagogical role to a virtual human. Thus, an inexperienced trainee could be associated with collaborative companions who could help him when needed. An expert could face disturbing companions in order to evaluate his capability to complete a procedure in a perturbing situation. The disturbing companion may tend to monopolize the required tools for instance.

Scenario. A scenario author must transform the taught procedure into a scenario written in a scenario language. The resulting scenario can turn out to be more or less flexible, depending on the language used. An author should have a scenario language that let him decide on the level of adaptability of the scenario, and on the way to make it flexible. In our state of the art, we point out two ways to make a scenario adaptable: by underspecifying the scenario or by allowing different people to perform a given action.

Training session. A session author should define performance criteria to evaluate in a specific training session such as the time spent to perform a procedure. Displacements could also be a criterion and thus actors should minimize their movements. If the number of actions performed is a performance criterion, actors should avoid to exchange tools and try to reuse the ones that they already own. Continuity is also another possible criterion. Consequently, actors should complete a sequence of actions before switching to another. Thus, actors should choose what action to perform depending on those performance criteria.

2.2 Second Adaptability Level: Dynamic Adaptation at Runtime

The training session runs once configuration is achieved. The second level of adaptability then appears.

Contextual Adaptation. Actions performed by virtual humans, or suggested to trainees, should depend on context. The context consists of the current state of the world (including the state of the actors) and the current state of the scenario, as shown in Figure 2. In this Figure, a cog wheel represents a state that can evolve. This diagram shows that the action performed by an actor is influenced by the current context (blue arrows) and then makes this context evolve (green arrows, that make the cog wheels turn). Thus, we expect an actor to adapt his scheduling of actions (scenario actions or implicit actions) to context. For instance if a trainee already owns a hammer, he should not be asked to take a hammer before nailing. Moreover, for pedagogical use, it could be interesting to offer a trainee the opportunity to be temporarily replaced by a virtual human, in order to observe the actions to perform.

Adaptation to Other Actors Activity. In a collaborative context of training, virtual humans should also adapt their actions to their companions activity, by

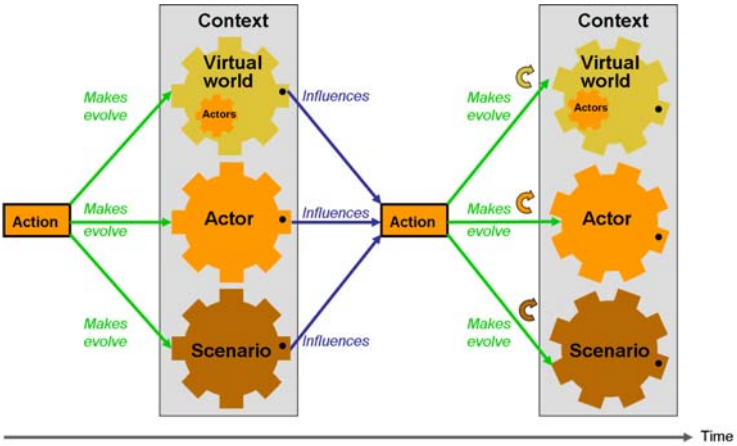


Fig. 2. Contextual Adaptation (one actor involved)

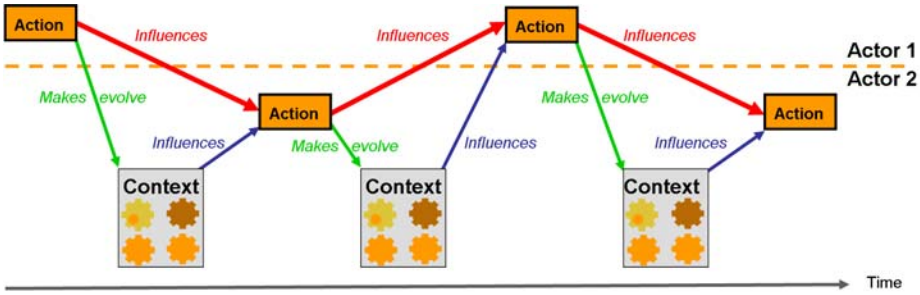


Fig. 3. Adaptation to the activity of companions (at least 2 actors involved)

analyzing their previous actions. In this way, they could optimize the distribution of actions between them and avoid conflict. For instance, a conflict could occur if two actors plan to perform the same action. The context in Figure 3 is the same as the context in Figure 2 and has the same influence on an actor's choice of action. Here, two actors are involved and the context contains two actors' state. An actor's action is also influenced by the previous actions of his companions. Once performed, this action will then influence the next action of the companion, etc. Actors should also try to help their companions when they are in difficulties because they can not perform any action (an example of *implicit collaboration* can be found in [7]).

3 Proposed Models for Adaptability

We now present our contributions, focussing on the adaptation needs identified in section 2. The first contribution deals with the application setting. The second one is an action selection mechanism that allows actors to dynamically adapt their actions, at runtime. Figure 4 illustrates these models. The elements concerned by the setting appear on hatched areas. The rack-and-pinion gear represents a dynamic part: states jointly evolve during a training session, thanks to the action selection process.

3.1 Application Setting

To carry out the application setting, we have to configure different components: scenario, virtual world, actors and training session. Features that can be set appear in hexagons in Figure 4 and in italics in the next sections.

Description of Scenario Actions. LORA, a scenario language proposed in [1], was designed to describe individual scenarios for virtual training applications. We extend it to collaborative scenarios as proposed in [10]. The first novelty is the specification of *roles* allowed for each action, associated with a priority. Thus, we propose a flexible distribution of scenario actions between actors, unlike existing virtual environments for training, which imposed a fixed distribution

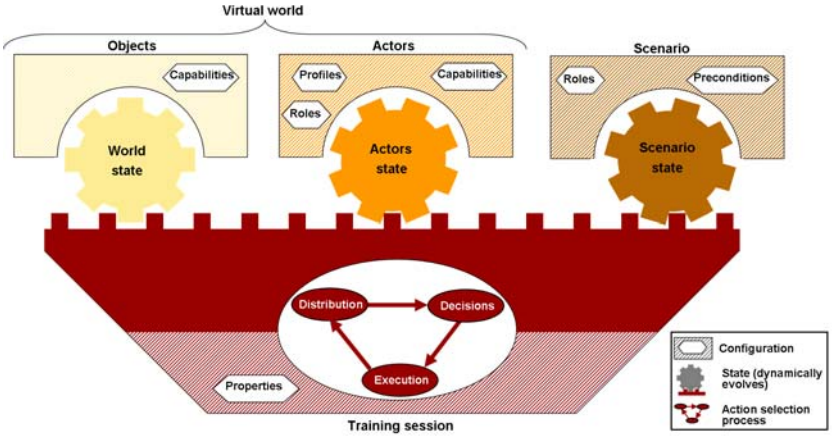


Fig. 4. Models involved in adaptation

(given that only one role can be associated to each scenario action). The second one is an underspecification of the scenario. We make implicit some basic actions as, for instance, the action of taking a tool and the action of putting an object down. Instead of writing all the actions to perform in the scenario, the author only describes key actions and uses *preconditions* to specify the state of the hands required for these actions. Actors can then perform these basic actions whenever they want. To sum up, the scenario describes a fixed scheduling of key actions while letting actors dynamically determine the distribution of these actions between them and the moment when they want to perform basic actions.

Virtual World Setting. Virtual world must consist of behavioral objects in order to be interactive. We choose the STORM model, proposed in [11], to describe those behavioral objects. STORM objects are objects endowed with *interaction capabilities*, which enables them to interact with each other and with actors. These objects can then benefit from a generic interaction mechanism based on generic interaction links. These links can create an interaction between any objects with compatible capabilities.

Actor Setting. An actor is considered as a STORM behavioral object because we want him to be able to interact. As a result, he has *interaction capabilities*. In addition, an actor has a *role*. This role allows him to know what he should do in the scenario. A role gives an actor additional capabilities (for instance the capability to give order for a leader and the capability to control a pressure level for a technician). An actor's behavior is defined in his *collaborative profile*. This profile consists of a set of weighted behavioral rules and may correspond to a pedagogical role such as those mentioned in our state of the art.

Setting of the Training Session. A training session creator must define general *properties* for a session. These properties define global trends or performance

criteria for a specific session. Actors will then try to respect those properties when they will select an action to perform. For instance, the creator can specify if it is more important to complete a scenario sequence of actions before switching to another or to reuse an object that an actor already owns.

3.2 Dynamic Adaptation at Runtime: Action Selection Mechanism

Each of the four components concerned by the setting has a proper state that dynamically evolves. The current context consists of the set of these states at a given time (objects, actors and scenario). Actors have to decide what action to perform depending on this context. Moreover, due to our scenario description, there may be more than one actor allowed to perform a scenario action. An action selection mechanism is in charge of dynamically adapting the execution of a training session to the current context. This mechanism aims at first determining the best candidate depending on the properties defined in section 3.1, then choosing a hypothetical action for each actor and finally performing an action chosen by either a real user or by a virtual human. These steps are illustrated in Figure 4. We now shortly describe each one of these steps. Further details on the action selection mechanism can be found in [7].

Multicriteria Action Distribution. An action distribution module aims at analyzing all active scenario actions. Active scenario actions are actions currently allowed in the procedure. This module ranks actors for each possible scenario action according to their abilities to make the procedure progress, taking into account the properties mentioned in section 3.1. Once various criteria have been evaluated, an algorithm based on weighted criteria is used to calculate a score for each couple of an actor and an action. Consequently, this module is able to dynamically evaluate who the best candidate for each action is. Then, this information is transmitted to the actors to suggest them a good way of sharing the scenario actions in order to make the scenario progress.

Decisions. The module of action distribution proposes a global distribution of actions between actors, respecting the scenario requirements. But it is only a suggestion and it is up to each actor to make an individual choice thanks to their own decision-making module. As a consequence, there is one decision and therefore one selected action per actor. This module uses the weighted behavioral rules contained in an actor's collaborative profile (see section 3.1) to choose the action with the highest score.

Action Execution. An action request can come from a real user or a virtual human. In both cases the action is execute in the same way and the previous steps in the action selection mechanism are also the same. The only difference between the modelling of a real user and a virtual human is the link between the decision step and the execution step, as illustrated in Figure 5. If the actor is a virtual human, the selected action is automatically performed. If the actor is a real user, it is up to him to select an action to perform. Nevertheless, the action selected

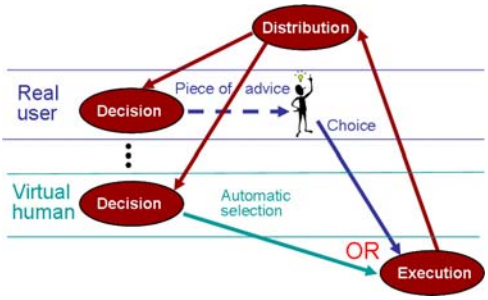


Fig. 5. Action selection mechanism, for a real user and a virtual human

in the decision step may be suggested to him, if needed, as a pedagogical piece of advice. As a consequence, a real user can easily and dynamically be replaced by a virtual human, and reversely, only by changing the connection between the decision-making step and the execution step. The execution of the action leads to a new context and then the action selection process loops back.

4 Integration in GVT

The models proposed in this paper are integrated into the GVT platform described in section 4.1. A cupboard assembly procedure, presented in section 4.2 illustrates the adaptability of our models.

4.1 Industrial Application: The GVT Project

GVT[1] (Generic Virtual Training) project is developed in research/industry collaboration, involving three partners: INRIA and CERV laboratories and Nexter Training. The latter is a French company specialized in military equipment, such as Leclerc tank. GVT is a software platform for building virtual training applications in which trainees have to learn a procedure. The commercialized version of GVT proposes individual virtual training on procedures such as maintenance procedures or diagnosis procedures. A prototype is also available in our laboratory, illustrated on the left of Figure 6. This prototype is an evolution and proposes virtual training on collaborative procedures where real users and virtual humans collaborate. Further details about GVT can be found in [12].

4.2 Illustrative Scenario: Cupboard Assembly Procedure

A scenario, in which actors have to collaboratively assemble a kitchen cupboard, illustrates the adaptability offered by the models introduced in this paper. This scenario, which actually runs under GVT, is based on true visual assembly instructions for a kitchen cupboard (from a well known Swedish trademark). It

[1] http://www.gvt-nexter.fr/

contains more than 100 actions including collaborative ones (e.g. to hold planks). This scenario is interesting because the assembly instructions describe the different actions to perform and the number of people required (at least two) but they do not specify the distribution of those actions between the involved people. The distribution is thus flexible and should be adapted to context.

During a configuration phase, the visual assembly instructions are translated into a scenario written in LORA. Preconditions are used when tools or free hands are needed. Sequences of actions that could possibly be done in parallel are identified. In this scenario, any role is allowed for each scenario action which means that any actor is allowed to perform this action. Three collaborative profiles are available: active learning companion, lazy companion and troublemaker. The active learning companion simulates a trainee's behavior: he performs the action he is expected to and helps the trainee when needed. The lazy companion only performs actions when one of his companion is at a deadlock and can not perform any action. This situation can occurs for instance if an actor is waiting for another actor to perform a collaborative action or has his two hands busy but is not allowed to free them for the moment. The troublemaker tends to steal objects to the trainee and tries to perform unexpected actions (which can lead to conflict with the trainee in the choice of actions).

Let us take a short sequence of this scenario, illustrated on the right of Figure 6. Screws must be placed on a plank and screwed. These two sequences of actions may be performed in parallel. Actors are a trainee and his virtual companion. The development of the scenario depends on the collaborative profile of the virtual companion.

- If the trainee collaborates with a lazy companion, he will have to perform all these actions.
- If the trainee has an active learning companion, his companion will try to perform complementary actions. If the trainee takes the screwdriver, the virtual human will automatically deduce (thanks to the distribution step)

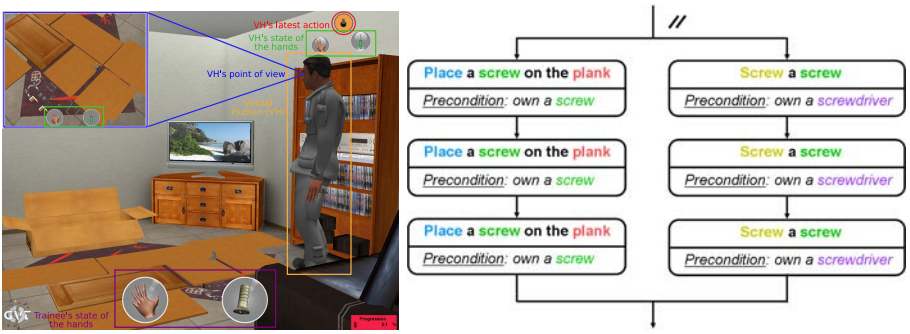


Fig. 6. Cupboard assembly procedure: on the left the GUI of GVT prototype, on the right an extract from the scenario

that the trainee is willing to screw and thus he will take a screw in order to place it. Next, if the trainee decides to put the screwdriver down and to take a screw, the virtual human will deduce that the trainee is willing to place the screws and so he will take the screwdriver to screw the placed screws (see Figure 6, on the left). The virtual human dynamically adapts his actions to the actions performed by the trainee in order to have a clever distribution of actions between them.
- If the trainee is an expert, he may have a disturbing companion. This companion, for instance, will take the screwdriver but will not use it. It is up to the trainee to adapt his behavior by choosing other actions to perform or by getting the screwdriver back.

Other extracts from this assembly scenario can also illustrate different kinds of adaptability due to our models. For instance, a situation extracted from this scenario is described in [7]. A trainee is hurt and can not perform any action. As a result his virtual companion interrupts what he is doing in order to help him.

5 Conclusion

The models that we propose in section 3 enable our collaborative virtual training environment to be adaptable in different ways and to satisfy the needs identified in section 2. Indeed, two levels of adaptation are provided: the first one consists in the application setting, taking into account the demands from the session creator. The second one appears during the execution of a training session: actors adapt their actions to the current context and also to the previous actions of their companions. These two ways of adaptation enable our virtual environment for training, GVT, presented in section 4, to be used in various training situations. For instance, GVT can be applied to individual or collaborative training, procedure training (from military maintenance procedures to furniture assembly procedures) or diagnosis training. Moreover, among those different adaptation possibilities, three of them are new in virtual environments for training. The first one is the setting of virtual humans by giving them pedagogical roles (including roles such as disturbing companion that have not been proposed in such environments yet). The second one is the possibility of specifying more than one role for a scenario action. The third one is our action selection process. This mechanism makes a dynamic and clever distribution of actions between actors, whereas in existing training environments this distribution is fixed.

Future works will consist in studying the pedagogical use of these models. We could for instance provide new opportunities to trainers, such as to dynamically adjust the collaborative profile of a virtual human. We could also use the result of the action selection process to provide a trainee more complete explanations about the best action to choose in a specific situation.

References

1. Mollet, N., Arnaldi, B.: Storytelling in virtual reality for training. In: Pan, Z., Aylett, R., Diener, H., Jin, X., Göbel, S., Li, L. (eds.) Edutainment 2006. LNCS, vol. 3942, pp. 334–347. Springer, Heidelberg (2006)
2. Buche, C., Querrec, R., Loor, P.D., Chevaillier, P.: Mascaret: Pedagogical multi-agents system for virtual environment for training. In: CW 2003: Proceedings of the 2003 International Conference on Cyberworlds, Washington, DC, USA, pp. 423–430. IEEE Computer Society, Los Alamitos (2003)
3. Querrec, R., Buche, C., Maffre, E., Chevaillier, P.: SécuRéVi: virtual environments for fire-fighting training. In: Richir, S., Richard, P., Taravel, B. (eds.) 5th virtual reality international conference (VRIC 2003), Laval, France, pp. 169–175 (2003)
4. Rickel, J., Johnson, W.L.: Virtual humans for team training in virtual reality. In: Proceedings of the Ninth International Conference on Artificial Intelligence in Education (1999)
5. Russell, S.J., Norvig, P.: Artificial intelligence: a modern approach. Prentice-Hall, Inc., Upper Saddle River (1995)
6. Zhang, Y., Cao, S., Volz, R.A.: Towards a role-based framework in agent teams. In: Workshop of Role-Based Collaboration, The 20th International Conference in Computer Supported Cooperative Work (CSCW 2006) (2006)
7. Gerbaud, S., Arnaldi, B.: Scenario sharing in a collaborative virtual environment for training. In: VRST 2008: Proceedings of the 2008 ACM symposium on Virtual reality software and technology, Bordeaux, France, pp. 109–112. ACM, New York (2008)
8. Kallmann, M., Thalmann, D.: Modeling Objects for Interaction Tasks. In: Eurographics Workshop on Animation and Simulation, 1998, pp. 73–86 (1998)
9. Chou, C.Y., Chan, T.W., Lin, C.J.: Redefining the learning companion: the past, present, and future of educational agents. Computers & Education 40, 255–269 (2003)
10. Gerbaud, S., Mollet, N., Arnaldi, B.: Virtual environments for training: From individual learning to collaboration with humanoids. In: Hui, K.C., Pan, Z., Chung, R.C.k., Wang, C.C.L., Jin, X., Göbel, S., Li, E.C.L. (eds.) EDUTAINMENT 2007. LNCS, vol. 4469, pp. 116–127. Springer, Heidelberg (2007)
11. Mollet, N., Gerbaud, S., Arnaldi, B.: Storm: a generic interaction and behavioral model for 3d objects and humanoids in a virtual environment. In: IPT-EGVE the 13th Eurographics Symposium on Virtual Environments, pp. 95–100 (2007)
12. Gerbaud, S., Mollet, N., Ganier, F., Arnaldi, B., Tisseau, J.: Gvt: a platform to create virtual environments for procedural training. In: IEEE Virtual Reality Conference, VR 2008, Reno, NV, USA, pp. 225–232 (2008)

Pushdown Automata Simulator

Mohamed Hamada

Languages Processing Lab
The University of Aizu, Aizuwakamatsu, Fukushima, Japan
hamada@u-aizu.ac.jp

Abstract. This paper introduces a pushdown automata simulator as a component of our evolving integrated virtual environment project for learning computational models and automata theory. The twofold contribution of this work is a novel use of modern technology to improve learning and a longitudinal quasi-experimental evaluation of its use in context.

1 Introduction

Learning science research indicates that engineering students tend to have active and sensing learning preferences, and engineering related educators are recognizing the need for more active learning pedagogy [23]. So far several learning models have been developed (e.g. [4, 10, 13, 14, 18]) for the realization of the learning preferences of science and engineering learners. Among these models, Felder-Silverman [4] is simpler and easier to implement through a web-based quiz system, as in Felder-Soloman [22]. The model classifies engineering learners into four axes: active vs. reflective, sensing vs. intuitive, visual vs. verbal, and sequential vs. global. Active learners gain information through a learning-by-doing style, while reflective learners gain information by thinking about it. Sensing learners tend to learn facts through their senses, while intuitive learners prefer discovering possibilities and relationships. Visual learners prefer images, diagrams, tables, movies, and demos, while verbal learners prefer written and spoken words. Sequential learners gain understanding from details and logical sequential steps, while global learners tend to learn a whole concept in large jumps.

In Rosati [21] a study of this model was carried out to classify the learning style axes of engineering learners. The study showed that engineering learners tend to have strong active, sensing, visual, and sequential learning preferences.

The concepts in the theory of computation and automata theory courses have important use in designing and analyzing computational models of several hardware and software applications. These concepts are abstract in nature and hence used to be taught by a traditional lecture-driven style, which is suitable for learners with reflective preferences. Since computer engineering learners tend to have strong active preferences, a lecture-driven teaching style is less motivating for them.

In our previous work [6] we introduced an integrated environment (IE) that meets the active learning preferences for computer engineering learners. IE can be used as a

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 328–338, 2009.

supporting tool for active and collaborative learning not only for the theory of computation course, but also for several other courses such as automata and formal languages, discrete mathematics, computational models, principles of programming languages, compiler design and other related courses. Such courses cover a variety of topics including finite state machines (automata), pushdown automata, and Turing machines, in addition to grammars and languages. We covered such important topics in our integrated environment. In this paper we add a pushdown automata simulator (PDA) as a new component to IE. The PDA simulator will be written in Java as applets and then integrated into the IE environment using the Java2D technology of Sun Microsystems [11]. This implies that our environment is portable, machine independent and web-based enabled, which makes it a useful tool as an interactive and online collaborative learning environment.

The environment integrates several different materials to support the learners' preferred style. It includes a movie-like welcome component, an animated hyper-text introduction for the basic concepts, a finite state machine simulator with several operations, a set of visual examples for learners' motivation, a Turing machine simulator, a chat tool to support learners' online collaboration, and an interactive set of exercises for self assessment. The PDA simulator will be the new IE's component.
To show the effectiveness of our integrated environment as a model of interactive online collaborative learning tool, several classroom experiments were carried out. The preliminary results of these experiments showed that using our environment not only improved the learners' performance but also improved their motivation to actively participate in the learning process of the related subjects and seek more knowledge on their own.

The paper is organized as follows. Following the introduction, section two discusses some related work. Section three introduces a review of our integrated environment and its components including finite state machines, visual machine examples, and Turing machines. In section four we introduce pushdown automata (PDA) topics, followed by the PDA simulator as a new component of our virtual integrated environment. The performance evaluation of the environment will be presented in section five. Finally, we conclude the paper and discuss the results and possible future extensions in section six.

2 Related Work

There are a number of finite state machine simulators which have been developed (e.g. [1, 2, 3, 9, 17, 20]) to enhance the learning of automata topics. Most of them suffer from one or more flaws that make them less effective as a learning tool, particularly for less advanced students. For example, JFLAP [20] is a comprehensive automata tool but it requires skilled learners who already know the basics of automata to make full use of its rich operations. The automata tools in [17] are a powerful tool, but do not provide a convenient mechanism for displaying and visually simulating the finite state machines. The ASSIST automata tools in [9] are difficult to setup and use. The tools in [1] lack visual clarity and dynamic capability. Almost all have been designed as tools for advanced learners. These tools work on the assumption that the

learners have already grasped the fundamental concepts. They are also dependent on advanced mathematical and idiosyncratic user interactions. On the contrary, our tools are designed as an easy-to-use, easy-to-learn, stand-alone, and all-in-one integrated environment. In addition it provides a unique feature for online communication among learners through the incorporation of an integrated chatting tool. This unique feature is designed to support online collaboration among learners regardless of their location.

3 Integrated Environment

Our environment contains nine components which have been integrated into a single unit to make all topics easily accessible for learners. The components include the following: an animated (movie-like) welcome component, a hyper text introduction to the theory of computation topics, a finite state machine simulator, a Turing machine simulator, a self assessment exercises, a chatting component for supporting online collaborative learning, and the other three components showing the visual examples of finite state machines. The welcome and introduction components use plain and animated text, which are suitable for learners with sequential learning preferences. The simulators and visual examples of components are best suited for learners with active and sensing learning preferences which most computer engineering learners prefer. In the sequel of this section, we will describe all the components of our integrated environment.

The first two components of the environment introduce the principle ideas of finite state machines. One component presents a short movie-like introduction that welcomes the learners to the topic. The other one is a rich hyper-text introduction to the basic concepts. Learners can navigate through the component and learn about the basic concepts (see Figure 1(a)). The animated text is combined with an optional audio narration, which is convenient for learners who have difficulties reading text. It is also presented bilingually; in English and Japanese.

The finite state machine simulator is integrated as a basic component of the environment. It allows learners to draw an automaton visually and apply several operations to it. The possible operations include: NFA to DFA transformation, λ-NFA to NFA transformation, DFA to regular expression, and regular expression to λ-NFA. In addition to these transformations, learners can minimize the given automaton, check the acceptance/rejection of an input to the automaton, zoom-in and out, and auto layout the automaton. The simulator interface is shown in Figure 1(b).

The Turing machine simulator is integrated into the environment as well. This simulator is based on the work of [12]. Learners can write their machine in the input window, and then write the input of the machine on the (infinite) tape.

After that, they can start to operate the machine on the input and observe how it works. For example, to add two positive integers m and n, the function $add(m, n) = m+n$, can be represented by a set of Turing machine rules. A rule in the form $a\ b\ c$ >means that if the current state is a and the current input tape symbol is b, then the

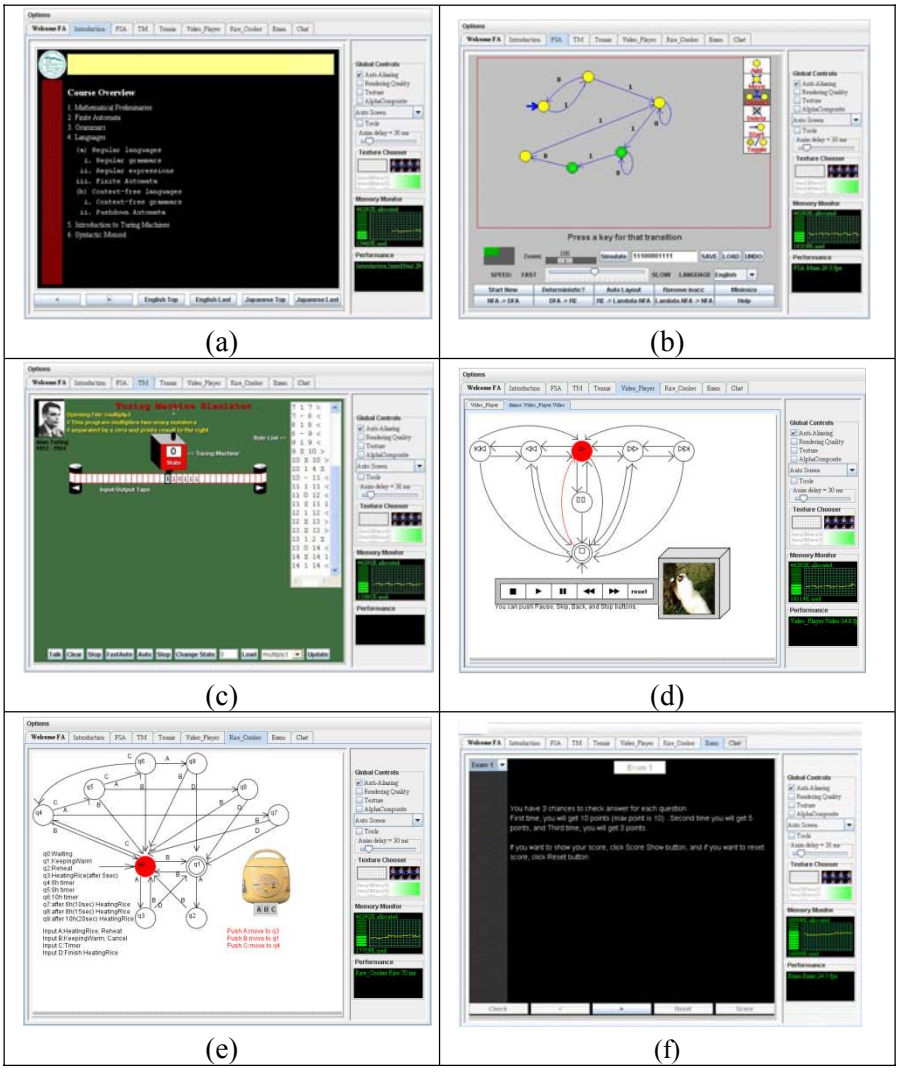


Fig. 1. The Automata Integrated Environment components

controller changes the current state to *c* and moves one step to the right (right is represented by > and left by <). A rule in the form *a b c d* means that if the current state is *a* and the current input tape symbol is *b*, then the controller changes the current state to *c* and the current input tape symbol to *d*. If the learner wants to add, for example, 2 and 3, i.e. compute the function *add*(2,3)=2+3, then he/she must write 2 as 11 and 3 as 111 separated by 0 on the input tape, which means the input string will be 110111. Running the machine on this input by clicking the run button will result in

the machine halting with the output string 11111 written on the tape, which means 5. Learners can see the machine running on the input symbol in a step-by-step manner which can help the learner to see how the Turing machine acts on input and how it can compute functions. All operations of the Turing machines can be simulated by this simulator. The component interface showing the Turing machine simulator is shown in Figure 1(c). While the Turing machine operates on its input, a number of short comments also appear on the editor to give the learners more information about the theory of Turing machines. The Turing machine simulator also includes sound effects to make learning more fun and interesting to learners.

In our integrated environment, a set of visual finite state machines examples are introduced with the aim of motivating learners in courses that include such topics. These selected examples represent useful daily life machines, games, and a puzzle. We have created six examples: an elevator, a vending machine, a man, a wolf and a goat puzzle, a tennis game, a video player, and a rice cooker. In this section, we will describe the last two due to the lack of space.

The operations of a video player, a common and useful machine in our daily lives, can be modeled by a finite state machine. Video player operations such as play, pause, forward, fast forward, backward, fast backward and stop can be represented by the finite automaton states. The video player simulator is designed to play a movie showing a wild cat in response to the change in the finite automaton states. The operations are represented by buttons labeled with real video player symbols. When the user pushes a button, the corresponding automaton state is highlighted and the appropriate screen shot takes place. Figure 1(d) shows the video player simulator interface in which the operations of the video player are simulated and the corresponding finite automaton is displayed.

Rice cooker operations can also be modeled by a finite state machine. Examples of the operations include cooking, reheating, and keeping warm. A timer is also considered in this model. The student can operate the rice cooker simulator by pressing the operations, and then the corresponding state of the underlying automaton is highlighted. In the rice cooker automaton model, every state represents an operation, for example, the state labeled q_0 represents the waiting (initial) state, q_1 represents the keep warm (final state) operation, and q_2 represents the reheating operation. A snapshot of the rice cooker simulator interface is shown in Figure 1(e).

A set of exercises with different levels is also integrated with the environment. There are various types of quizzes: some are multiple choice, some are fill in the blanks, and some test for Turing machines, finite automata or regular expressions. Learners can perform a pre-assessment, an in-assessment, or a post-assessment. The assessment interface is shown in Figure 1(f). First, the learner must select an exercise (upper-left corner in the window), and then a description of the test and the evaluation method will be shown in the main window. Learners can navigate among the quizzes by using the navigation buttons at the bottom of the main window. Learners can check the score at any time by clicking on the 'score' button. While answering a quiz, learners can get hints or click on the introduction button on the top of the window to go to the introduction component and read more about the topics related to the quiz.

4 Pushdown Automata (PDA)

A pushdown automaton is a finite automaton that can make use of a stack containing data. Pushdown automata differ from normal finite state machines in two ways:

1. They can use the top of the stack to decide which transition to take.
2. They can manipulate the stack as part of performing a transition.

A schematic representation of PDA is given in Figure 2.

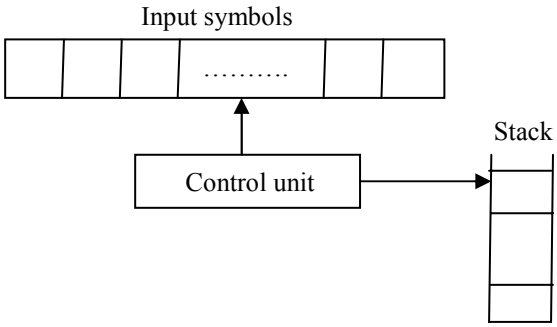


Fig. 2. A schematic description of PDA

The control unit scans the input symbols from left to right starting from the left-most one. Each move of the control unit reads a symbol from the input, while at the same time changing the contents of the stack through the usual stack operations such as *push* and *pop*. Each move of the control unit is determined by the current input symbol as well as the symbol currently on top of the stack. The result of the move is a new state of the control unit and a change in the top of the stack.

A PDA is formally defined as a 7-tuple: $A=(Q, \Sigma, \Gamma, \delta, q_0, Z, F)$ where

- Q is a finite set of *states*
- Σ is a finite set which is called the *input alphabet*
- Γ is a finite set which is called the *stack alphabet*
- $\delta: Q \times \Sigma_\lambda \times \Gamma_\lambda \rightarrow P(Q \times \Gamma_\lambda)$ is the *transition function,*
- q_0 is the *start state*
- Z is the *initial stack symbol*
- $F \subseteq Q$ is the set of *accepting (final) states*

Where *P*(S) denotes the power set of S, λ is the empty string, $\Sigma_\lambda = \Sigma \cup \{\lambda\}$, and $\Gamma_\lambda = \Gamma_\lambda \cup \{\lambda\}$.

The relevant factors at any time are the triplet (*q*, *w*, *u*), where *q* is current state of the control unit, *w* is the unread part of the input string, and *u* is the current contents of the stack. The triplet (*q*, *w*, *u*) is called *instantaneous description* (ID). A move for one ID to another will be denoted by the symbol $\vdash$;thus:

$$(q_1, aw, bx) \vdash (q_2, w, yx) \text{ is possible if and only if } (q_2, y) \in \delta(q_1, a, b).$$

Moves with arbitrary number of steps will be denoted by $\vdash^*$. There are two classes of pushdown automata: deterministic (DPDA) and nondeterministic (NPDA). Unlike finite automata, DPDA and NDPA are not equivalent. NPDA have more expressive power than DPDA.

4.1 Pushdown Automata Simulator

The Pushdown Automaton Simulator allows learners to draw an automaton visually and then apply operations on it. During these operations they can observe any change that may happen to the automaton. For example they can check the acceptance/rejection of an input while observing the corresponding changes in the automaton states and in the stack contents. They can also zoom-in and out and do auto outlay to enable more clear view for the automaton. These last operations are particularly useful when the underline automaton is large. The PDA simulator interface is shown in Figure 3.

In Figure 3 the numbers from 1 to 7 are explained as follows.

1. Number 1 represents the action view area. In this area the user can watch the PDA state changes in every step during the PDA operating in a given input.
2. Number 2 represents the stack view area. In this area the user can watch the stack changes in every step while the PDA operating in a given input.

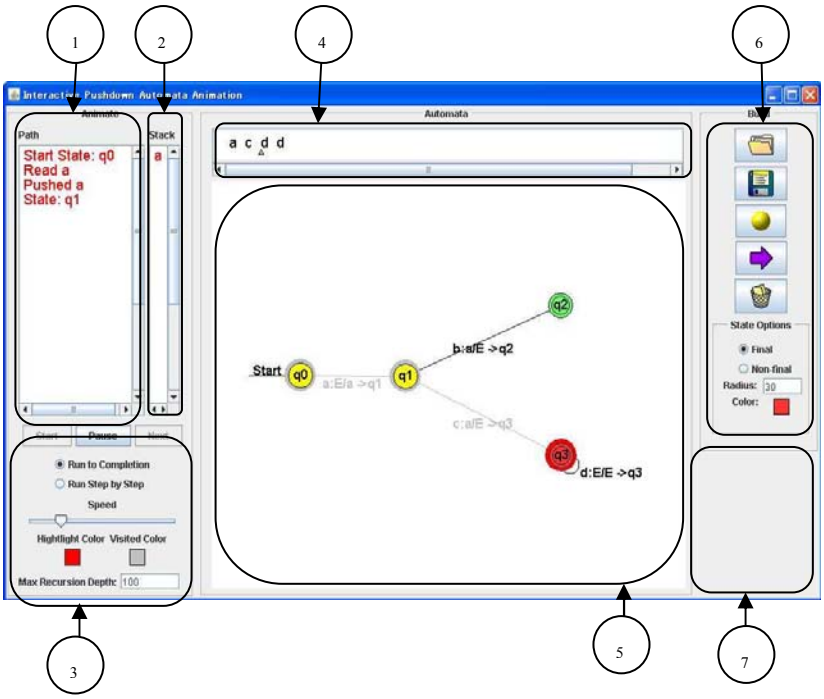


Fig. 3. The PDA simulator interface

3. Number 3 represents the animation control panel. In this control panel the user can control the PDA animation speed (fast/slow/step-by-step), zoom-in and out, and layout the edited PDA.
4. Number 4 represents the input edit/display area. In this area the user can insert any valid string as an input for the PDA. This input string will be scanned and processed by the PDA from left to right.
5. Number 5 represents the PDA edit/display area. In this area the user can create/modify the PDA state by state and link by link, define the start and final states, connect the states, move the states, change the state color, etc.
6. Number 6 represents the editing control area. In this area the user can save/load PDAs, chose action to perform on the edited PDA, chose editing color, etc.
7. Number 7 represents a reserved area for possible future extensions.

After designing the automaton, we can start to simulate with input strings. The input window is displayed after we push the "start" button. Input strings in the editing window and click "OK" button. Then PDA Simulator judge whether that automaton accepts or rejects those input strings. Users can see the simulation in a step-by-step manner or as a whole.

5 Evaluation

We carried out two experiments in order to evaluate the effectiveness of our integrated environment tools on the learning process of engineering students. The first experiment evaluates the improvement in the students' motivation. The second experiment evaluates the effectiveness of using the tools on the students' performance.

The purpose of introducing the visual automata examples is to enhance the students' motivation. To measure the effectiveness of these visual examples, we performed two experiments in the automata and formal languages course. The first one was for students who already completed the course; the sample population included 52 students who studied the topics in different classrooms. The following question was asked: "If the course was an elective course, would you choose to study it? And, do you recommend other students to study it?" Five options were given for responses: (a) don't know, (b) no, (c) maybe no, (d) maybe yes, and (e) yes. The responses were as follows: 3 answered a, 3 answered b, 6 answered c, 27 answered d, and 13 answered e. Then, we demonstrated our visual examples to the students and repeated the same question again. Their responses (after seeing the examples) were: 1 for a, 3 for b, 2 for c, 29 for d and 17 for e. Comparing the results from "Before" and "After" exposure to the examples, there was a slight improvement in motivation. For choices a, b, and c, if the number of responses decreased, it indicates a positive response, which is what occurred. While for the other choices d and e, the increasing number of responses indicates positive response, which also occurred.

We note that there was only a small improvement in the students' motivation, which is natural in this case because the students had already completed the course. In the next experiment we noted a better improvement in the motivation of students who were new to the course.

In the second experiment, a total of 69 students were included, and they were all new to the course. The same steps, as with the pervious experiment, were repeated with a slight modification in the question. The question was "If the course was an elective one would you chose to study it?" As before, students were allowed to choose from among the five responses: a, b, c, d, and e. Their responses (before seeing the examples) were as follows: 22 answered a, 6 answered b, 10 answered c, 23 answered d, and 8 answered e. Next, we demonstrated our visual examples to the students and presented the same question to them again. Their responses (after seeing the examples) were as follows: 9 answered a, 4 answered b, 8 answered c, 34 answered d, and 14 answered e. Comparing the results "Before" and "After" exposure to the examples, we can see a better improvement in their motivation. As with the previous experiment, for choices a, b, and c, if the number of responses decreased it meant a positive response, which is what occurred. While for the other choices d and e, an increasing number of responses meant a positive response, which also occurred.

We note that the motivation in the case of junior students (second experiment) was better than that of the senior students (first experiment). This result might be explained by the fact that the juniors had not studied the course before.

A preliminary study shows that the integrated environment can improve the learning process of computer engineering students who study the theory of computation course and related courses. Last semester, the students were divided into four groups, each group containing 20 students. A set of 40 randomly selected exercises was distributed among the groups, 10 for each group. Each group members could collaborate inside their group but not with any other group members. No group could see the exercises of other group. Two groups were asked to answer their assigned exercises using the integrated environment and the other two groups without using it. An equal time period was provided to all the groups. The result showed a better performance for the two groups using the IE. Then, the experiment was repeated by redistributing the exercises among the four groups. Again, the two groups with the IE showed better performance.

6 Conclusion

With the vast advance in technology, the traditional lecture-driven classroom is giving way to a new and more active environment, where students have access to a variety of multimedia and interactive course materials. Such interactive course materials have already been introduced for several topics in engineering courses; see for example [5, 7, 8, 15, 16, 19].

In this paper, we followed the same path and introduced a pushdown automata simulator as a new component in our environment which integrates a set of visual tools to support interactive learning in the theory of computation course. It can also be used in other courses such as model of computations, language processing, automata and formal languages, compiler design, discrete mathematics, and other similar courses. Through the results of our experiments, we also showed that our visual tools can enhance learners' motivation and performance. In addition an opinion poll showed a

positive feedback on the environment tools from the students. In future work, we plan to enhance our visual tools by adding more features, more visual examples and games, and by performing more performance evaluation experiments.

References

1. Bergstrom, H.: Applications: Minimization, and Visualization of Finite State Machines. Master Thesis. Stockholm University (1998), http://www.dsv.su.se/~henrikbe/petc/
2. Bovet, J.: Visual Automata Simulator, a tool for simulating automata and Turing machines. University of San Francisco (2004), http://www.cs.usfca.edu/~jbovet/vas.html
3. Christin, N.: DFApplet, a deterministic finite automata simulator (1998), http://www.sims.berkeley.edu/~christin/dfa/
4. Felder, R., Silverman, L.: Learning and teaching styles in engineering education. Engineering Education 78(7), 674–681 (1988)
5. Hadjerrouit, S.: Learner-centered Web-based Instruction in Software Engineering. IEEE Transactions on Education 48(1), 99–104 (2005)
6. Hamada, M.: An Integrated Virtual Environment for Active and Collaborative e-Learning in Theory of Computation. IEEE Transactions on Learning Technologies 1(2), 1–14 (2008)
7. Hamada, M.: Web-based Tools for Active Learning in Information Theory. ACM SIGCSE Bulletin 38 (2007)
8. Hamada, M.: Visual Tools and Examples to Support Active E-Learning and Motivation with Performance Evaluation. In: Pan, Z., Aylett, R.S., Diener, H., Jin, X., Göbel, S., Li, L. (eds.) Edutainment 2006. LNCS, vol. 3942, pp. 147–155. Springer, Heidelberg (2006)
9. Head, E.: ASSIST: A Simple Simulator for State Transitions. Master Thesis. State University of New York at Binghamton (1998), http://www.cs.binghamton.edu/~software/
10. Herrmann, N.: The Creative Brain. Brain Books, Lake Lure (1990)
11. Java2D of Sun Microsystems (2009), http://www.sun.com
12. Java Team, Buena Vista University, http://sunsite.utk.edu/winners_circle/education/EDUHM01H/applet.html
13. Keller, J.: Development and use of the ARCS model of motivational design. Journal of Instructional Development 10(3), 2–10 (1987)
14. Kolb, D.: Experiential Learning: Experience as the Source of Learning and Development. Prentice-Hall, Englewood Cliffs (1984)
15. Li, S., Challoo, R.: Restructuring an Electric Machinery course with Integrative approach and computer-assisted Teach Methodology. IEEE Transactions on Education 49(1), 16–28 (2006)
16. Masters, J., Madhyastha, T.: Educational Applets for Active Learning in Properties of Electronic Materials. IEEE Transactions on Education 48(1) (2005)
17. Mohri, M., Pereria, F., Riley, M.: AT&T FSM Library. Software tools (2003), http://www.research.att.com/sw/tools/fsm/
18. Myers, I.: Gifts Differing. Consulting Psychologists Press, Palo Alto (1980)

19. Nelson, R., Shariful Islam, A.: Mes- A Web-based design tool for microwave engineering. IEEE Transactions on Education 49(1), 67–73 (2006)
20. Rodger, S.: Visual and Interactive tools. Website of Automata Theory tools at Duke University (2006), http://www.cs.duke.edu/~rodger/tools/
21. Rosati, P.: The learning preferences of engineering students from two perspectives. In: Proc. Frontiers in Education, Tempe, AZ, pp. 29–32 (1998)
22. Soloman, B., Felder, R.: Index of Learning Style Questionnaire, http://www.engr.ncsu.edu/learningstyle/ilsweb.html
23. Transforming undergraduate education in science, mathematics, engineering, and technology. In: National Research Council (ed.) Committee on Undergraduate Science Education, Center for Science, Mathematics, and Engineering Education. National Academy Press, Washington (1999)

Construction Knowledge Transfer through Interactive Visualization

Paul Woodard, Shafee Ahamed, Roberto Canas, and John Dickinson

National Research Council Canada, 800 Collip Circle, London, On N6G 4X8

Abstract. Changing population demographics and infrastructure demands are having a significant impact on the average level of worker expertise in the North American construction sector. Experienced employees with specialized knowledge are leaving the workforce, and their replacements are required to install and maintain a broader variety of complex systems. Because of this, it is imperative that construction knowledge be quickly and effectively transferred to practitioners through educational processes. However, recent history has demonstrated that traditional techniques may not be effective at transferring sufficient knowledge to eliminate many common mistakes. It has been suggested that new forms of knowledge transfer may be more effective and result in fewer construction errors, especially those which result from installing components out of sequence. In this paper, the authors describe efforts to adapt a traditional paper-based best practice guide into an interactive 3-D tool that can be used on a variety of devices, from laptop computers to commercially available entertainment systems.

Keywords: Construction Knowledge, Knowledge Transfer, Visualization.

1 Introduction

Canada, like many other developed nations, is facing a dramatic change in demographics, where experienced workers are reaching retirement age, and being replaced by less experienced members of the workforce. In the construction sector, this trend is illustrated by the fact that there is expected to be a shortage in nearly all classifications of skilled trades [1]. To meet the expected demand, new workers, combined with increased productivity of existing workers will be required.

Errors made by practitioners come in many forms, but most common errors fall into three broad categories, errors in sequence, position, and material. Errors in sequence occur when there is a discrete set of steps that must happen in a particular order and one or more of these steps occur out of order or omitted. Position errors are generated by components that are installed in the correct sequence; however, they are in an incorrect location or orientation, such as a one-way membrane being installed backwards, or an air vent being improperly located. Material errors occur when the materials used in the design are replaced, as a cost-cutting or supply availability measure, with substitutes lacking the same performance characteristics. An example of this would be the use of lower-than-expected grade fasteners.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 339–350, 2009.

One set of case studies, where each of these sets of errors can be seen, is the "leaky condo" crisis in British Columbia, Canada. From approximately 1982 to 1999, a housing boom in Vancouver led to numerous high rise condominiums being built and occupied. After occupancy, many owners and tenants began having mold and other moisture-related problems. According to reports [2,3], between 50,000 and 75,000 units may be affected with severe moisture damage, and more than 40,000 still require significant repairs, with one estimate of $696 million in financing required for the 10,000 units that can be repaired by 2012.

In a report to the government of British Columbia, the "Commission of Inquiry into the Quality of Condominium Construction in British Columbia" found numerous systemic issues with the design and construction of these condominiums. For example, in one case, an owner reported: *"In our case, the concrete on a number of floors was poured incorrectly, resulting in some window openings being as much as 3/4" too small from floor to ceiling. Rather than disassembling the window units, cutting pieces smaller and reassembling the window to the correct dimension the window installer trimmed 3/4" off the bottom of the window. Moreover, instead of cutting the glass to fit, the contractor crammed the window into the opening, making it impossible to remove the glass without completely disassembling the window unit" L.L. Wright, Condo Owner [2].*

In this example, the errors of the window installer (altering materials, and presumably changing the positioning of components) compounded apparent sequence errors (failure to inspect that openings were poured correctly) that happened earlier in construction. Since the proper techniques had not been effectively communicated to the labourers, errors were compounded, and the result was a poor structure.

Given the drivers above, there is a need for alternative approaches that can be used to communicate construction knowledge and provide training and evaluation materials. Some of the requirements would be the ability to update information and best practice scenarios, give users defined access to views and information, and have a mechanism for testing their understanding of the information being conveyed. In this paper, the authors describe their work with interactive visual training software and validating its effectiveness for transferring construction knowledge.

2 Current Knowledge Transfer

Before looking at improving communication, it is important to first consider some of the primary methods of knowledge transfer in the construction sector. In Canada, the most fundamental of these are the Provincial building codes. These are a set of legal requirements that guide the minimum standards that any new building must meet, in terms of structural, electrical, and plumbing performances. While the building code specifies performance, even to the point of describing what a finished structure must be like, it does not specify how to construct a building to meet that performance, nor does it specify the details that are required. For this reason, many organizations provide best practice guides that are a step-by-step set of instructions on how to build something that will meet the building codes, and provide good performance.

One example of a best practice guide was a direct result of the aforementioned "leaky condo" crisis. The Homeowner Protection Office, British Columbia, Canada

created a book called the "Building Envelope Guide for Houses". This is a reference book that gives step by step instructions for many construction tasks, each illustrated with color drawings to help a practitioner avoid errors, particularly sequence ones.

While these guides also proven to be effective, they also have typical drawbacks. While they are usually illustrated for added clarity, often several steps are combined in a single drawing. This can lead to ambiguity, and even when only a single element is being represented, static, isometric drawings do not always allow the practitioner to see the element they are interested in. For this reason, they may not be as effective in reducing position and material errors. Also, because these guides are static, they can be used for years, and are not necessarily updated when there are revisions to the codes, changes in accepted best practices, or when a new material comes to the market.

Formal learning practices in the construction sector are based on hands-on experience as typified by apprenticeship programs. Initially, the student, with the supervision of an instructor or mentor, assimilates the information by reinforcing the knowledge through continuous practice of individual tasks. This learning mechanism is related to the behaviourism theory and provides feedback to the student in the form of positive and negative reinforcement. A project-based learning scenario requires that the student have specific content knowledge or skills to produce an end-product. A typical example is the installation of a window, which involves the understanding and the implementation of a multi-step process. A problem-based learning scenario provides the student with a challenge they must solve or improve. A typical example is the installation of the electrical wiring, which requires the students to exercise their own judgment to find a good solution to the problem. These learning mechanisms are related to the constructivist model of human cognition and rely on dynamic interactions with the environment [4,5].

Conventional training is performed by formal classes and on-the-job training; however, this may not be sufficient to train and retain new workers who are used to accessing digital information. For these workers, there are likely better ways of transferring the knowledge. The subject and the related content are often not the issue, however the way the information is conveyed nowadays could deter acceptance by the younger generation immersed in visual, social and communication technologies. Conversely, the baby boomer generation working in the construction sector may find video games unrealistic and a frivolous way of learning. A middle ground is possible, Michael Zyda [6] describes a Serious Game by: "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives". Traditional virtual reality (VR) training systems are very efficient at providing problem-based learning and project-based learning scenarios focusing on-the-job training. Concrete applications, using "what if" scenarios, are successfully used in space and aviation, military, medicine, manufacturing etc. These simulations allow the trainees to comprehend the consequences of their actions, improve their confidence and prevent exposure to unnecessary danger until the task familiarity is acquired [2,7].

Many researchers have reported that advanced visualization and virtual environments assist and enhance users learning experience [8,9,10,11,12,13]. Also, it is realized and widely accepted that effective training is important both for learning and to prevent accidents and disasters due to faulty workmanship [14]. To address these issues, interactive training systems [15] are being developed. With the help of these

systems the users can visualize and have appropriate interactions with the computer-generated models, thus minimizing physical training requirements and avoiding costly and hazardous mistakes. Research has shown that visualization and VR techniques enhance communication among stake-holders and allow them to visualize design and constructability errors earlier in the project [16]. Recent studies have shown that if advanced technologies such as visualization and VR are integrated appropriately within built environment academic curriculums, they will provide a good foundation for the new workforce [17]. A recent report on the VR Roadmap "A Vision for 2030 in the Built Environment" [18] suggests the training of workers is a big challenge and needs significant R&D.

For some jobs, there have been examples of highly immersive training environments which are very efficient for skills training and allow the students to learn "by doing" and "by feeling" through multiple tactile feedbacks from the simulation environment. Similarly, the technology is very efficient for situation training which allows the students to learn "by seeing", "by experimenting" and "by socializing" through feedback from other team members in the scene, supported by a greater degree of coordination between team members. However, several challenges remain when implementing advance simulation and visualization technologies into the construction industry depending on the focus of the training. The classical one is cost; a traditional VR environment requires significant financing with the consequence that the potential return on investment may only be appropriate for highly skilled and potentially dangerous tasks like operating heavy equipment. However, commercial video game platforms are mature enough to take the lead in more common skills and situation training. The second problem is how to move the simulation and visualization technology from the secure place of an office to where the construction workers need the technology i.e. the work site. The third would be to develop applications with the construction industry specificities in mind, i.e. education background, generation differences, multiple ethnicities and languages [19].

Work towards the development of training systems, especially involving visualization and VR, are fast progressing as the technology becomes more affordable. Researchers in Australia [20] have developed an augmented reality system that trains the novice operators in a real worksite environment populated with virtual materials and instructions. The developed system assists the user to operate the heavy equipment, previously limited to off-site training programs that restrict the novice's experience of real working conditions. It is to be noted that, on-the-job operator training is not only costly but also prohibitive due to requirements for specialized equipment and an on-the-job trainer. Additionally, in environments where the climate is harsh, learning on-site is difficult and the probability of making mistakes is high and the resulting consequences can be significant. A review of literature, specifically in the context of the Canadian construction industry, shows that very few researchers are working in the areas of developing the workforce, their productivity and safety [21,22,23].

3 Approach

While the previously described technologies all contain promising elements and do much to advance the state of knowledge transfer, they may not have the combination

of effectiveness, affordability, and flexibility that will be required to address the challenges the construction sector faces on a day to day basis. Most current VR-based training systems rely on a technically adept operator, either a sophisticated user or an instructor who will operate the system. In the construction sector, it is anticipated that the users of these systems will be individuals with little experience in computer based training. For this reason, it is important that any framework must be intuitive and fault tolerant.

The construction knowledge transfer framework proposed in this paper consists of a step-by-step software tool that combines interactive visualization, audio cues, and feedback mechanisms, all displayed on a commercial entertainment system. The goal is to allow the practitioners to have a better understanding of the installation sequences and make fewer errors when they are at the worksite. Though 100% perfection may not be expected by following this framework, the practitioner will certainly have a better understanding of the process and hence become more productive. Figure 1 shows screenshots illustrating steps that are involved in the virtual window assembly, using the developed system.

The initial applications that are considered are those that can be described as a series of discrete steps, where, in a given step, one or more tasks are performed until a certain level of performance is achieved. Typically, these tasks are the installation of a proper component combined with any inspections needed to ensure that the component is in the correct location. These types of step-based applications are especially suited, because they can be easily represented by format independent model languages, such as XML, and lend themselves to implementation using object-oriented software.

The second element of the framework is an interactive visualization where the user can move, rotate, and focus the viewpoint to better understand the context of the current step compared to the existing assembly. In the visualization, the current step instructions are presented. These instructions can be provided as some combination of text, audio, or images.

To advance from one step in the sequence to the next, the framework supports several options. In addition to allowing a user to directly cycle from one step to the next, there is also a context-sensitive palette that displays multiple tools or parts. The user is required to interpret the text and choose the palette object that best represents the current task. When the correct palette object is selected, the animation continues, and the user sees an animation of the step being performed. If needed, the user can adjust the viewpoint during or after the sequence, and view the part being moved in real-time. This provides a useful feedback mechanism to force the user to consider the instructions, which studies have shown, greatly increases comprehension and retention.

The developed tool satisfies several epistemological objectives. First, the pedagogical material defines the process to assemble the window based directly from the guide. Second, the conduit to provide the knowledge uses interactive visualization, which is more appealing to the contemporary students. The dynamism, the interactivity and the realism of the simulation allows the student to learn by exploring the potential solutions. Once the playfulness aspect of the simulation has overcome initial inhibitions, the older generations are not reticent about using the technology. Third, the tool can be used by novices or experts, depending on the configuration. For a novice, the goal is to acquire the skills required from the pedagogical material and the understanding behind the task and they will be assessed by how they follow the rules.

Fig. 1. Components of Developed System

For an expert, the goal is to acquire the understanding of the overall context and potentially propose alternative solutions for doing the tasks and their assessment will be based on self-evaluation and by peers [24,25].

4 Implementation

To demonstrate the proposed framework, the authors have constructed two interactive guides and have applied them to describe the assembly of windows on an airtight drywall with an air barrier. The guides present the same content as found in the guide but in 3D, in an interactive challenge-based format where the users can not only review the material to be learned but assess their knowledge. It is important to remember for these initial applications that the content being conveyed is limited to sequences of steps. Future work could consider training for more elaborate problem solving applications where multiple solutions might be applicable. As an example, the assembly steps were taken from Section 3.3.08 of "Building Envelope Guide for

Table 1. Assembly procedure to install a window assembly on an airtight drywall

Step No.	Description for Airtight Drywall Air Barrier, Simple Window on Exterior 2x6 Stud Wall
1	Complete the rough framing for the window opening.
2	Ensure adequate space is provided between the rough framing and the window to accommodate sealants between the window and the rough opening, and to facilitate drainage of the sub-sill region.
3	Apply compatible sealant to framing connections between the sub-sill and the jamb as well as the framing connections where the jamb meets the head.
4	Install a stripping ply of sheathing membrane.
5	Install a waterproof membrane to the sub-sill, continuous up the jamb of the rough framing.

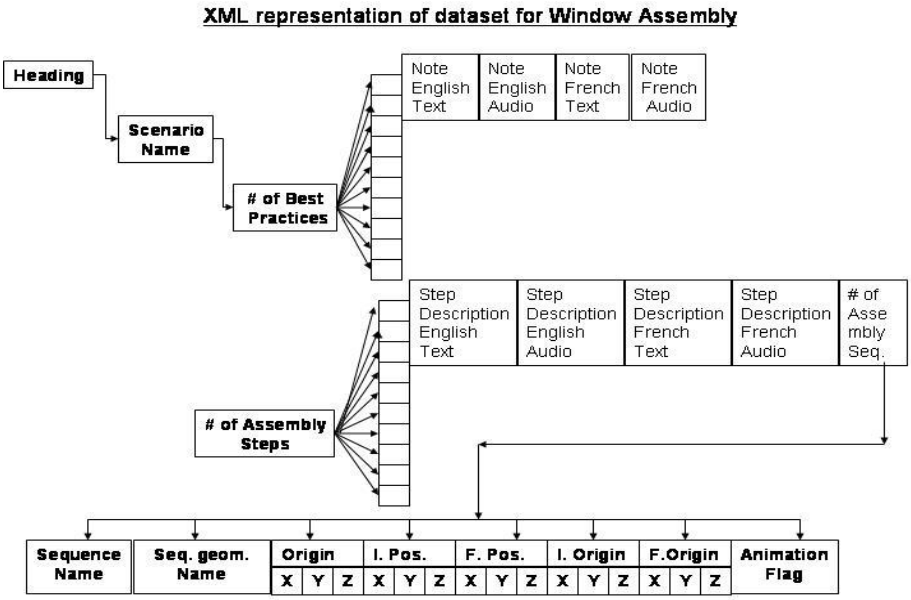


Fig. 2. Hierarchical view of scenario representation

Houses" [26]. In total, there are 26 individual steps described, the first 5 of which are provided in Table 1.

A hierarchical description of the necessary elements is shown in Figure 2. As can be seen, the data required to create the virtual environment and run the assembly sequence interactively is large and can be time consuming. At a minimum the required data for each sequence includes: the description of the components, the geometry details, the rendering details, the sequence of performing the task, assembly rules, and sequences. To address this issue, simulation rules have been integrated into a

spreadsheet-based planning process. This tool assists the user to quickly generate an error-free XMLdataset required for simulation.

Guides were built for the personal computer (PC) platform and for the Microsoft Xbox360™ (Xbox360) gaming system. These two hardware systems were chosen to allow the authors to investigate the potential of two common platforms. The developed guides share significant similarities and offer the same basic functionality but in ways typical to their respective platforms. The basic functionality of both platforms includes:

- An introduction to the challenge at hand
- A navigable 3D rendered environment allowing the user to move their viewpoint around the window assembly and review its current state close up or from further away
- Text instructions state the objective of each step
- Text based best practice notes can be triggered
- Audio recitation of the text instructions that can be triggered
- Audio and text available in Canada's two official languages
- Audible feedback for making correct and incorrect choices are included

Both versions share the XML representation of the scenario, so that content only needs to be developed once, and can be used on either of the two implementations. Differences in the two implementations are described below.

The Xbox360 version of the guide was built to examine how easily, and naturally a best practice guide could be implemented on a gaming system. Console gaming systems are naturally rich in graphics and audio interaction and generally perceived to be simpler to own and operate than a computer. The XNA development platform for the Xbox360 is open and free in comparison to other common gaming systems, and has a well established developer community. Nevertheless, it is envisaged that what was built for one platform can likewise be implemented on other platforms. Due to the fact that games are controlled using controllers with multiple pads, joysticks and buttons compared to a PC, the interaction of the user with the guide is a little different than the PC version. Control of navigation and selection of actions was implemented with

Fig. 3. Xbox360™ Screenshot

Fig. 4. Xbox360™ Version

common gaming platform elements like trigger-toggled menus and joysticks for navigation. As shown in Figure 3 and 4 the interface also has a look more consistent with gaming systems.

Significant elements were implemented based on feedback from education pedagogues. First, configuration options were provided, including settings for playing at a difficult or easy level, clues such as instructions, step number, score and time feedback on and off. Second, the option to play the game in reverse was added to allow an alternative approach to learning the sequence material. Third, ambient sounds, typical of a construction zone were included and audio feedback was made more appropriate for the application. Finally, steps can be skipped or redone to enable people already familiar with construction practices to review only sections they need. This is consistent with the goal of making a tool useful for novices as well as experts wishing to review the latest recommended practices.

The PC implementation is intended to be accessible to as large a segment of construction practitioners as possible. It was decided that the visual elements of the tool be built around a game engine and if possible to use freely available tools. After considering several options, the version 1.5 of the Panda3D game engine was chosen. This engine is currently maintained by Carnegie Mellon University, who makes it freely available (with certain requirements, such as attribution) under a modified version of the common BSD license [27]. A prime consideration of this tool is the capacity to use it to conduct research into the effectiveness of knowledge transfer. For this reason, it has been built with internal diagnostic tools that are transparent to the end user. These diagnostic tools will allow researchers and educators to gather data on the behaviour patterns of end users, such as task timing, choice, and button presses. These can be correlated with studies of student's behaviour of practical tests to help validate learning hypotheses. Unlike the Xbox360 implementation, the Window PC version does not require content to be pre-compiled. For this reason, it is expected that models and scenarios will be much more easily updated and tailored to end users.

These applications remain simple but provide an important dynamic to the learning process where self-evaluation is possible, and where learning is reinforced by active participation in the training program. Experts can quickly test if their knowledge allows them to intuitively understand new practices or products without reading whole guides, while novices can learn from the ground up with extra available embedded learning material relevant to understanding why operations are done in certain ways. Computers are especially good platforms for showing cause and effect through dynamic mechanisms like embedded videos or animations to illustrate points.

Future extensions of these applications can include tracking of individual student performance or class performance, logging of tasks that cause particular difficulties and extensions to include an entire curriculum of content. Initial feedback for educators suggest most significantly would be the expansion of content in multiple ways to better teach the material in question. For example: 1) providing links to other learning material, reference manuals and product documentation. 2) making better use of the multi-media -rich capabilities of today's computers and gaming systems to include video of current content related to the material being learned (e.g. interviews of people studying the BC condo crisis) 3) allow the user to make mistakes and then show the consequences of their mistakes (e.g. leaky windows or lack of space to install a window).

5 Future Work and Conclusions

This paper reports the ongoing work on developing an interactive visualization guide for best practices for performing the assembly of windows. Introduced is a new concept of advanced interactive system. The prototype described in this paper demonstrates a system that can be used to train in an economical way. The implementation of planning rules from the best practice guides assists the user and prevents possible errors which normally occur during the construction phases.

Knowledge transfer in the construction industry through visually-orientated tools needs not be limited to training applications. More complex knowledge, included in things like design guides, is often most useful in software tool form. The goal is to automate tedious or difficult calculations or table look ups and create a friendly interface that guides less experienced users through, and supports more experienced users during, a process or decision. For example, the authors have been working on a sound insulation design guide for multi-residential wood frame buildings. The guide encapsulates significant knowledge typically found in tables and product specifications and presents possible choices and their impact in a very visual way (Figure 5). There is a very real potential for interactive training tools and games and guides to converge into singular applications supporting all uses. As a rule though, these tools will only be as useful as long as their content is kept fresh and relevant.

The authors are planning significant future work including the development of more sophisticated systems, and conducting systematic research into which elements of interactive guides are the most effective at eliminating construction errors.

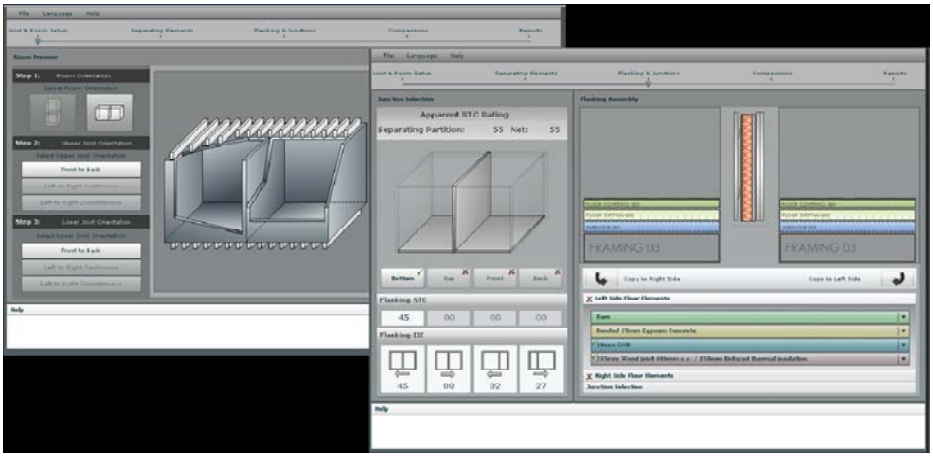


Fig. 5. Screenshots from the Flanking Sound Transmission Guide in Development

Acknowledgements

The authors would like to thank Professors Kathy Hibbert and Ron Hansen of the University of Western Ontario for their insight into educational paradigms. They

would also like to thank Denisa Ionescu of the Homeowner Protection Office for providing the best practice guide used in the demonstration application.

References

1. The National Steering Committee for Innovation in Construction: Priorities for Action, A Response to the Federal Government Announcement on Canada's Innovation Strategy (2002)
2. Barrett, D.: The Renewal of Trust in Residential Construction, Commission of Inquiry into the Quality of Condominium Construction in British Columbia, Report to the Lieutenant-Governor in Council, Government of British Columbia (1998)
3. Peer, L.B.: Field Performance of Rainscreen Wall Assemblies in Coastal British Columbia. In: 10th Canadian Conference on Building Science and Technology, Ottawa (2005)
4. Panko, M.: Learning Styles of Those in the Building and Construction Sector, Report for Building Research (2005)
5. Øhra, M.: Pedagogical Aspects of Simulator Training. In: International Users Conference, Newcastle Maritime Simulators & Training System Kongsberg Norcontroll System AS (1988)
6. Zyda, M.: From Visual Simulation to Virtual Reality to Games. IEEE Computer Society, Los Alamitos (2005)
7. Ponder, M.: Immersive VR Decision Training: Telling Interactive Stories Featuring. In: Advanced Virtual Human Simulation Technologies, Workshop on Virtual Environments (2003)
8. Bowman, D.A., Wingrave, C.A.: Design and Evaluation of Menu Systems for Immersive Virtual Environments. In: Proceedings of the Virtual Reality Conference (2001)
9. Schabel, M.A., Kvan, T.: Interaction in Virtual Building Space. In: CIB W78 Conference, Distributing Knowledge in Building (2002)
10. Messner, J.I., Yerrapathruni, S.C., Baratta, A.J., Riley, D.R.: Cost and Schedule Reduction of Nuclear Power Plant Construction Using 4D CAD and Immersive Display Technologies. In: Computing in Civil Engineering: Proceedings of the International Workshop of Information Technology in Civil Engineering (2002)
11. Haymaker, J., Fischer, M.: Challenges and Benefits of 4D Modeling on the Walt Disney Concert Hall Project, Working Paper #064, CIFE, Stanford University, Stanford, CA (2001)
12. Lipman, R., Reed, K.: Using VRML in Construction Industry Applications. In: Web3D - VRML 2000 Symposium, Monterey, CA (2000)
13. Opdenbosch, A., Hastak, M.: Virtual Reality Environment for Design and Analysis of Automated Construction Equipment. In: 2nd Congress for Computing in Civil Engineering, Atlanta, GA, pp. 566–573 (1994)
14. Neville, H.: Workplace Accidents. Industrial Management 40(1) (1998)
15. Barsoum, A., Hadipriono, S.F.C., Larew, R.E.: Avoiding Falls from Scaffolding in Virtual World. In: Proceedings of the 3rd Congress in Computing in Civil Engineering, ASCE, pp. 906–912 (1996)
16. Mohd Fairuz, S., Tuilo, S.: A Comparison of Virtual Reality Displays Suitability. Detail, Dimensions and Space. In: 9th International Conference on Engineering Education (2006)
17. Margaret, H., Neveen, H.: Integration of VR within the Built Environment Curriculum. ITcon 11, 311–324 (2006)

18. Nashwan, D.: VR Roadmap: A Vision for 2030 in the Build Environment. In: 6th International Conference on Construction Applications of Virtual Reality (2006)
19. Von Baeyer, A., Sommer, H.: Educational Conditions for Successful Training with Virtual Reality Technologies. In: Human Performance Goals Workshop, Netherlands (2000)
20. Xiangyu, W., Philips, S.: Design Strategies and Issues Towards An Augmented Reality-Based Construction Training Platform. ITcon 1, 36–380 (2007)
21. Froese, T., Zonghai, H., Michael, A.: A Study of IT Development for the Canadian Construction Industry. Canadian Journal of Civil Engineering (2005)
22. Froese, T.: Report on Construction Process Technologies An Inventory of Canadian Research (2007)
23. Chimay, A., Zeeshan, A.: Case Studies of Intelligent Context-Aware Services Delivery in AEC/FM, pp. 23–31. Springer-Verlag, EG-ICE, Heidelberg (2006)
24. Dreyfus, H.L.: Apprenticeship, Experts and Intuition. An Interview with Hubert and Stuart Dreyfus. I Nordisk Pedagogikk 17(3) (1997)
25. Dreyfus, H.L., Dreyfus, S.E.: Mind over Machine, The Power of Human Intuition and Expertise in the Era of the Computer. Basil Blackwell, Malden (1986)
26. Building Envelope Guide for Houses, Part 9 Residential Construction, Homeowners Protection Office, Vancouver, B.C, Canada
27. Panda 3D Reference Manual, `http://panda3d.org`

Pathfinding Strategy for Multiple Non-Playing Characters in 2.5 D Game Worlds

Jason MacGregor and Steve Leung

Athabasca University, 1 University Drive, Athabasca, AB T9S 3A3, Canada
Jason.macgregor@calgary.ca, stevel@athabascau.ca

Abstract. This paper investigates and determines the optimal pathfinding strategy for non-playing characters (NPCs) in 2.5D game worlds. Three algorithms, Dijkstra's, Best-first Search (BFS) and the A* algorithm using Manhattan distance, Euclidean distance and Diagonal distance heuristics, are tested under different interaction schemes and test environments consisting of different levels of obstacles. The result shows that the A* algorithm is the optimal algorithm under the Manhattan distance Heuristic. Our tests did not reveal significant difference among the cooperative, non-cooperative or competitive interaction schemes.

Keywords: Pathfinding Algorithms, Game AI.

1 Introduction

The main purpose of this paper is to investigate and design a workable pathfinding strategy in a 2.5D game world for multiple Non-Playing Characters (NPCs) that is optimal in terms of the number of steps taken and resources required. The outcome of this paper is based on investigation of existing pathfinding algorithms and interaction schemes with the intent of determining the optimal pathfinding strategy through analysis and testing.

Several pathfinding algorithms will be discussed, including Dijkstra's algorithm, the Best-first search (BFS) algorithm and the A* algorithm using different heuristics including Manhattan distance, Euclidean distance and Diagonal distance. Additionally, we will investigate several interaction schemes, including cooperative, non-cooperative and competitive, which will dictate how the NPCs and agents react to one another when determining their paths to their goal.

This research problem is significant for several reasons. Firstly, the technology that goes into computer gaming is almost always at the cutting edge of what is possible with graphics, hardware, artificial intelligence, etc, and pathfinding is no different. Additionally, the study of pathfinding opens up other significant areas of interest in computing, specifically the field of Artificial Intelligence (AI) which is increasing in importance as technology continues to become a part of everyday life. Finally, our test results will help game designers to develop appropriate pathfinding strategies for NPCs.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 351–362, 2009.

2 Literature Review

There has been an abundance of research into pathfinding strategies over the years which make the act of reviewing related research daunting at best. As such, this paper has made the attempt to bring together some of the more significant research into pathfinding for review in light of the research statement. This review was conducted with the intent to assist the reader in seeing the historical and logical progression of research and study in pathfinding strategies.

E.W. Dijkstra's paper, *A Note on Two Problems in Connexion with Graphs* introduces the algorithm that becomes known as Dijkstra's algorithm. Dijkstra's algorithm solves the problem of finding the shortest path from a starting point to the destination in a graph as long as the edges between the points are not negative [1, 2]. In order to find the shortest path from the starting point to the destination, Dijkstra's algorithm has to discover all the paths to all points on the graph meaning that in order to find the shortest path from the source to the destination we have to find the path from the source to all other points. This problem is sometimes referred to as the single-source shortest paths problem [2] and occurs because Dijkstra's algorithm expands all adjacent nodes to the source node instead of doing a directed search towards the goal node [3].

Although Dijkstra's algorithm does successfully find the shortest path from a starting vertex to a destination vertex in a graph if one exists and as such is admissible, it is easy to see that it does have substantial overhead associated with it due to the single-source shortest paths problem. As such it is not considered optimal for most pathfinding applications.

BFS algorithm is an informed search strategy meaning that it uses specific knowledge that is obtained beyond the definition of the problem in order to solve the problem. It is easy to see that informed search algorithms can be more efficient then uninformed search algorithms, like Dijkstra's algorithm, due to this additional knowledge that helps the informed algorithm to solve the problem. There is a whole family of BFS algorithms based on their different evaluation functions. The evaluation function is used by the algorithm to select a node for expansion and is commonly denoted by $f(n)$ [4].

A key component of the evaluation function is called the heuristic function. The heuristic function, commonly denoted as $h(n)$, is the estimated cost of the cheapest path from the current node, denoted as n, to the goal node. The current node is the node that is being evaluated at that time. The BFS algorithm explores a graph by expanding the most promising node based on its heuristic. As such, BFS acts completely opposite of Dijkstra's algorithm.

A* algorithm is a widely used pathfinding strategy. A* is actually in the same family as the BFS algorithm but changes the evaluation function, $f(n)$, to the following:

$$f(n) = g(n) + h(n)$$

Where $\boldsymbol{g(n)}$ is the actual cost of an optimal path from the source to the current node, the cost to reach the node and $\boldsymbol{h(n)}$ is the actual cost of an optimal path from the source node to the goal node, the cost to get from the node to the goal [4, 5, 6].

Making this change in the evaluation function made the A* algorithm admissible but also, compared to Dijkstra's algorithm, uses reduced memory and time requirements. Effectively, A* combines the best characteristics of Dijkstra's algorithm and the BFS algorithm.

3 Method

The analysis performed on the three algorithms, Dijkstra's, BFS and A*, involved general algorithm analysis techniques based on those used in [7] as well as other analysis techniques to determine which algorithm would perform better in terms of speed and steps taken to navigate to the goal in specific types of environments. Additionally, for the A* algorithm, a comparison of the three primary heuristics was undertaken, comparing them in regards to speed and accuracy.

Additional analysis was conducted on the interaction schemes. Using knowledge of the schemes and how they control the behaviours of the NPCs and agents it was possible to make a prediction on which scheme would enable the NPCs and agents to reach their goals first.

The purpose of this analysis was to formulate a conclusion that we could then confirm or disprove through the testing performed using our testing application.

Our analysis concluded that we could expect the A* algorithm to routinely perform optimally or almost optimally compared to the other algorithms, Dijkstra's and BFS, using any of the identified heuristics but especially with the Manhattan distance heuristic. Additionally, our analysis seemed to point to the non-cooperative interaction scheme being the most optimal.

By interaction scheme we mean the strategy that is used by the NPCs when they encounter another NPC during their navigation to the goal. The three interaction schemes that we used were cooperative, in which NPCs and Agents must find non-colliding routes from one location to separate destinations with knowledge of the routes of others, non-cooperative, where NPC and Agents have no knowledge of each others plans and, finally, competitive where the NPC or Agents try to maximize their performance measure which may minimize other NPC or Agents performance measure [4, 8].

With our analysis based conclusions in hand we prepared to use our testing application to determine the validity of the results.

The testing application that was used created a basic 2.5D isometric environment where NPCs can move freely in all squares that are not marked as obstacles. All other squares have no penalty to the NPC for passing through them. For our testing the location of the goal was fixed and did not change from test to test. Its location was on the far right of the environment and vertically in the middle. The starting locations for the NPCs was to the far left of the environment and, again, in the vertical middle.

Several test environments were developed that consisted of different obstacle placements meant to test specific qualities of the algorithms. The starting locations for the NPCs and the goal were the same for all test environments. The four test environments were as follows:

- Environment 1 did not contain any obstacles and was used to create a benchmark for each test conducted. With this test the single or multiple NPCs would arrive at the goal square in the least number of steps and fastest time.
- Environment 2 contained a large reverse 'C' like obstacle in the middle of the environment. This was designed to force the NPCs to navigate around an obstacle. This test was designed as a test for greedy algorithms.
- Environment 3 extended the design of Environment 2 by extending the top part of the reverse 'C' obstacle all the way to the far right side of the environment. This was designed to test algorithms that may not search deep enough when developing their path to the goal.
- Environment 4 contained a line of obstacles from the top of the environment to the bottom with only a single square opening in the middle. It was designed to test the different interaction schemes.

Another feature of the test environment was that each test could be customized to utilize either single or multiple NPCs. For our testing we created tests for a single NPC and for three NPCs. When three NPCs were used their starting locations were with the number one NPC in front with the number two NPC behind it to it's left with the number three NPC behind the number one NPC but to its right. This formed an arrow shape pointing to the right.

A further important feature of the test application is that it was developed to allow using collision detection to realize the competitive interaction scheme. When enabled, the collision detection would determine if another NPC was in the node that the current NPC was attempting to move to. If so, the current NPC would skip a turn and try again next turn to move to the node.

To realize our cooperative interaction scheme within our test application, each NPC in turn, based on their priority, would verify it's path against the one that was developed before it and if a collision was detected it would add an additional step that, similar to collision detection, would make the NPC wait one step prior to the collision, giving the node a chance to clear before the NPC moved into it.

For the non-cooperative interaction scheme, there is no prior knowledge shared among the NPCs and no collision detection enabled. Additionally, NPCs pathfinding using this interaction scheme can pass through each other and rest on the same node as another NPC at the same time.

Each test environment had the same tests run against it in what we termed a testing group. Each testing group consisted of the following tests:

- Test 1: single NPC using Dijkstra's algorithm.
- Test 2: single NPC using the BFS algorithm
- Test 3: single NPC using the A* algorithm, based on Manhattan distance
- Test 4: single NPC using the A* algorithm, based on Euclidean distance
- Test 5: single NPC using the A* algorithm, based on Diagonal distance
- Test 6: 3 NPCs using Dijkstra's algorithm in a cooperative scheme
- Test 7: 3 NPCs using BFS algorithm in a cooperative scheme
- Test 8: 3 NPCs using the A* algorithm in a cooperative scheme, based on Manhattan distance

- Test 9: 3 NPCs using the A* algorithm in a cooperative scheme, based on Euclidean distance
- Test 10: 3 NPCs using the A* algorithm in a cooperative scheme, based on Diagonal distance
- Test 11 to Test 15 repeats Test 6 to Test 11 using the non-cooperative interaction scheme
- Test 16 to Test 20 repeats Test 6 to Test 11 using the competitive interaction scheme.

The next step involved running the identified tests in the test environment and recording the results which included the number of steps used for the NPC to reach the goal, and the time it took for the test to run. Notice that the latter included the time for the NPC to develop the path as well as the time taken by the NPC to reach the goal. In competitive and cooperative scheme, the time will include calculation of collisions.

For each testing group, each test was run three times with the average runtime and steps used for comparison. This was done due to the possibility of anomalies encountered during testing. Since each test was being run at different times which would have different factors influencing the test, comparison of the times that each test ran can only be done in generalizations and not compared directly to each other. The use of multiple tests averaged out was a strategy to try and eliminate any anomalies that could cause widely inaccurate and thus, incomparable results.

The possible anomalies that could occur during the testing cycles were a result of the computing hardware being used to run the testing application. The test application was written in and run on Java version 1.6.0_11 running on Microsoft Windows XP with service pack 3. The hardware was a Toshiba laptop with a T5600 Intel Core 2 CPU running at 1.83 GHz with 3.00 GB of RAM. A listing of processes running on the PC and the amount of memory being used during each test was not recorded and is presumed to be consistent during the testing but anomalies were still possible and appear to be reflected in the test results.

4 Tests Results

The results of the testing conformed to what we had concluded during our analysis of the algorithms and interaction schemes. Table 1 summarized the results of the findings. A full list of results is listed as the appendix at the end of this paper.

Test environment 1, which did not contain any obstacles, resulted as expected that each single NPC test would navigate to the goal in the least number of steps possible and in the fastest times of any other test. As well, the paths for each test were identical to each other except for those that utilized the A* algorithm with the Diagonal distance heuristic. The path for this test used large diagonal paths up and down until the goal was reached. Surprisingly, the number of steps used by the tests using the Diagonal distance heuristic was exactly the same as the other single NPC tests.

Table 1. Summarized Test Results

Interaction Scheme Average Test Time Results			TE1	TE2	TE3	TE4
Interaction Strategy	Algorithm	Distance	Average Time	Average Time	Average Time	Average Time
Cooperative	Dijkstra's	N/A	3.61	4.16	4.11	3.80
Cooperative	BFS	N/A	3.53	4.92	5.02	3.73
Cooperative	A*	Manhattan	3.62	3.89	4.12	3.73
Cooperative	A*	Euclidean	3.61	3.93	4.14	3.74
Cooperative	A*	Diagonal	3.60	3.96	4.12	3.78
Cooperative	A*	Manhattan	3.63	3.88	4.18	3.79
Non-Coop	Dijkstra's	N/A	3.52	4.09	4.22	3.79
Non-Coop	BFS	N/A	3.53	5.05	5.04	3.68
Non-Coop	A*	Manhattan	3.53	3.88	4.14	3.72
Non-Coop	A*	Euclidean	3.58	3.95	4.21	3.64
Non-Coop	A*	Diagonal	3.54	4.01	4.22	3.74
Non-Coop	A*	Manhattan	3.59	3.99	4.11	3.73
Competitive	Dijkstra's	N/A	3.75	4.20	4.21	3.78
Competitive	BFS	N/A	3.49	5.22	5.13	3.46
Competitive	A*	Manhattan	3.61	3.88	4.12	3.59
Competitive	A*	Euclidean	3.54	4.10	4.18	3.68
Competitive	A*	Diagonal	3.62	4.08	4.11	3.73
Competitive	A*	Manhattan	3.67	4.06	3.86	3.69

Additionally, for this environment is was expected that the BFS algorithm would perform the best because it is less memory and processing intensive and without any obstacles, the problems with it being a greedy algorithm, would not be a factor.

Of the remaining algorithms, not surprisingly, Dijkstra's was the slowest due to the number of nodes it must expand in order for it to determine a path to the goal. All the tests that utilized the A* algorithm placed somewhere between the fastest and the slowest with the tests using the Manhattan distance heuristic being, on average, the fastest of all the A* tests. This was shown to be the case in our analysis due to the Euclidean distance heuristic expanding more nodes then Manhattan distance and Diagonal distance being very expensive due to the number of calculations required.

Again, it was no surprise that the tests using multiple NPCs performed similar to the single NPC tests with, once again, the tests using the BFS algorithm being the fastest, with Dijkstra's algorithm being the slowest and the A* algorithm tests being in between with Manhattan distance being the fastest of the three heuristics.

Another interesting result from this group of testing was that for the cooperative and competitive groups of tests the NPCs arrived at the goal one at a time based on their pre-assigned priorities which was the intended result of both of these interaction schemes. Also, as expected, the non-cooperative interaction scheme performed the best of the three interaction schemes.

Additionally, during tests that used the competitive interaction scheme, there was usually only one collision recorded between the NPCs. This is what resulted in the NPCs arriving at the goal in their pre-assigned order as mentioned above.

For the cooperative interaction scheme, there is no collision detection, instead the three NPCs determine before hand what will be the optimal routes for each other where they will not interfere with each other. This requires prior knowledge of each other paths and results in the NPCs arriving at their goal based on their priority.

The main feature of test environment 2 was the large, reverse 'C' placed in the middle of the environment. As predicted, all tests that utilized the BFS algorithm had trouble negotiating around this obstacle resulting in additional steps and time being recorded for these tests.

Similar to test environment 1 we expected that tests utilizing Dijkstra's algorithm would still be slower then other tests, except tests utilizing the BFS algorithm and this was indeed the case. The results of all the tests in this test environment came out exactly as expected from our initial analysis including what we expected from the different heuristics used for the A* algorithm.

The tests utilizing the A* algorithm were the fastest for this test environment with the tests using Manhattan distance heuristic being the overall fastest with the other two heuristics being slower but still faster then the tests that used Dijkstra's algorithm which once again was slow due to the number of nodes it needs to expand as it develops a path to the goal.

In regards to the number of steps taken by the NPCs to reach the goal, it should be no surprise that all the tests using the BFS algorithm used many more steps then was necessary and that the tests using the A* and Dijkstra's algorithm developed the same path and used the same number of steps to the goal, although, the tests using Dijkstra's did take longer due to the issues discussed above.

In regards to the interaction schemes, the overall timings that were compared did present a different picture then that seen for test environment 1. For test environment 2 the cooperative group of tests were, on average, as fast and actually nominally faster then the non-cooperative interaction scheme that our analysis told us would be the fastest.

It is not known if additional test iterations would prove that this was an anomaly and would prove that the non-cooperative interaction scheme is indeed the fastest as expected. More testing would be required and is beyond the scope of this paper.

Test environment 3 consisted of obstacles that built upon what was used in test environment 2. In this environment the top part of the reverse 'C' was extended to the far right of the test environment. The reasoning behind this test environment was to see if creating an obstacle that goes essentially nowhere along with having only a small corridor to the goal would cause any issues with the different algorithms and heuristics.

All tests utilizing the BFS algorithm were the slowest and took the most number of steps. Additionally, all other tests followed what we expected from our initial analysis although, several tests utilizing Dijkstra's algorithm were faster on average then was expected but not to the point that it would contradict our earlier analysis. The faster test times could be the result of anomalies that occurred during this group of tests. Additional testing iterations could prove or disprove that this is the case but is beyond the scope of this paper.

A* algorithm proved to be the optimal algorithm with the Manhattan distance heuristic once again proving to be the best, or almost best heuristic.

As we have seen in the other tests, especially the tests from test environment 2, the number of steps taken by the BFS tests were proven to take the most number of steps to the goal while the steps needed by the tests using Dijkstra's algorithm and the A* algorithm were the same for all tests.

The comparative times for our interaction schemes did not arrive at the results we had expected. The result for each of the interaction schemes where essentially the same.

The obstacles for test environment 4 created a vertical line in the middle of the environment with only a small opening in the middle for the NPCs to pass through while navigating to the goal. The primary purpose of this environment was to test instances where multiple NPCs attempt to pass through the same point at the same time causing a type of 'log jam' where, under the right interaction scheme, one NPC can block another from one to several turns.

As can be expected from this type of environment, tests utilizing the BFS algorithm were once again the fastest or almost fastest. This is because there was no obstacle placed to make these tests pursue a path that does not lead to the goal. The opening in the obstacle was placed in a direct line from the starting location for the NPC to the destination.

The BFS algorithm was, similar to test environment 1, the fastest overall with the tests using Dijkstra's algorithm being the slowest and with the tests utilizing the A* algorithm being between the other two algorithms with the tests using the Manhattan distance heuristic being the fastest, or close to the fastest, of all the tests that used the A* algorithm.

All tests took almost the same number of steps to the goal based on their priority. As seen in test environment 1, when using the cooperative or non-cooperative interaction scheme the NPCs arrived at the goal based on their priority. When using the non-cooperative interaction scheme, the number one priority NPC always arrived at the goal first with the number two and three NPC arriving at the same time, usually from the same node since it is common for their paths to combine into the same path.

The timings for the interaction schemes did not have the expected results. This time the competitive interaction scheme turned out to be the fastest with the cooperative and non-cooperative interaction schemes having almost the exact same times. Again, this appears to be a pattern seen throughout our testing and does not seem to be caused by any anomalies.

Overall, there were several interesting results from our testing, but except for several instances that can be explained by anomalies in the testing environment, all the tests conformed to the results of the analysis preformed previously.

When there was an absence of obstacles or the obstacles were easily navigated around, the BFS algorithm would be the fastest algorithm but if an obstacle was created that played to the greedy nature of the BFS algorithm and had it follow a path that would not lead to the goal, the BFS algorithm would be significantly slower and take more steps to the goal then the other algorithms tested.

It was also not surprising that Dijkstra's algorithm was almost always the slowest due to the number of nodes that the algorithm expands as it develops a path to the

goal. This was, again, expected and did not come as any surprise based on our previous analysis.

Consistently, the A* algorithm performed either the best or close to the best for all tests and in all test environments. Furthermore, of the heuristics that were tested, the Manhattan distance heuristic was repeatedly the best and fastest heuristic.

These results held true for all the single and multi NPC tests no matter which interaction scheme was used.

Unfortunately, the same can not be said for the comparison of the interaction schemes. It was thought that the non-cooperative scheme would prove to be the fastest but this was only the case for test environment one.

5 Conclusion and Future Work

The results of the tests contained in each testing group conformed almost exactly for all the different test environments. This means that different tests that were conducted within each test group performed as expected with only a few variations that can be explained by anomalies in the test environment.

One interesting outcome was that none of the three tested interaction schemes seemed to be better then any of the others. In the analysis that was conducted, it was thought that the non-cooperative interaction scheme would be the fastest but this was not confirmed by the testing, in fact the testing did not show any interaction scheme being better or worse then the others.

There are several implications of these results in regards to the statement of purpose for this paper which was to investigate and design a workable pathfinding strategy in a 2.5D game world for multiple NPCs that is optimal in terms of the number of steps taken by the NPCs to the goal and in the resources required, measured by the time taken by each NPC to pathfind to the goal.

The single NPC tests gave a baseline for each of the pathfinding algorithms and showed the fewest amount of steps that were needed for the NPC to reach the goal as well as the least amount of time needed by the algorithm to develop the path to the goal and implement it. For each of the multi NPC tests there were at least one NPC that matched the number of steps to the goal as was seen in the single NPC tests. As well, if the test involved using collision detection, which essentially implements the competitive interaction scheme, the NPCs would reach the goal one step ahead of each other suggesting that the collision detection actually forced priority ordering on the NPCs. This affect was also seen when the NPC interaction scheme was cooperative which pre-calculates the paths for all the NPCs prior to their navigating to the goal.

Unlike the cooperative and competitive interaction schemes, the non-cooperative scheme would have the NPCs arrive at the goal in the same order they started in. For our testing, this meant that the number one NPC would arrive first followed by the number two and three NPCs arriving at the same time and usually from the same node meaning that the number two and three nodes paths usually became the same after the few first initial steps. This was made possible because of the absence of collision detection and avoidance.

Another interesting point to make regarding the BFS algorithm and the number of steps taken for the NPC to reach the goal is that the BFS algorithm performance depended greatly on the layout of the obstacles in the test environment. This algorithm was very susceptible to being 'fooled' by obstacles into following paths that did not lead to the goal but if there were no such obstacles, this algorithm usually performed the best. The reason for this lies in the BFS algorithm being a greedy algorithm that always follows the path that appears to be optimal at each step.

Along with the BFS algorithm, the testing results seem to show that all the algorithms were impacted by the design of the obstacles in the testing environment but not to the extent that the BFS algorithm was affected. A look at the results shows that for all testing groups, the overall times for the tests are faster for test environments one and four and longer for test environments two and three. This points to the conclusion that all the algorithms incurred a slight penalty developing a path around the obstacles in test environments two and three which were the backwards 'C' shaped obstacles, where as test environments one and four had either no obstacles or no obstacles that would cause a serious problem or penalty for any of the algorithms to develop a path to the goal.

Pathfinding is a large and complex topic with many different facets and, as such, it is impossible to address all possible research directions in one paper. As a result, there is plenty of room for additional future research that can build upon the work of this paper. Some of the possible research directions are discussed here.

This paper dealt exclusively with a fixed goal, fixed obstacle test environment. Further research could look into the performance of the various pathfinding strategies when dealing with a moving goal and/or moving obstacles. This would force the NPCs to constantly reevaluate their paths and develop new paths on the fly.

A further extension to the research performed and documented in this paper would include performing the tests using a larger test environment. This would enable true resource testing where the amount of memory could be monitored if the test environment was large enough. With the resources available to modern computers, it would take an exceptionally large environment to push the memory availability of a computer but it is a possibility and not overly difficult to develop.

Additional testing could adapt the test application to have the NPCs function as true autonomous agents so they could be compared to each other in the same test environment. This would allow for more exact testing where the times recorded from the tests can be compared to each other in the same test directly and exactly without having to consider that the times are generalizations. This would be the best method for truly determining the optimal pathfinding strategy.

The purpose of this paper was to determine which pathfinding strategy was best under most circumstances in a 2.5D game world. This paper used analysis and testing in an attempt to satisfy this goal with the result being that the A* algorithm using the Manhattan distance heuristic came out as the best algorithm and heuristic combination. Unfortunately, we were not able to effectively make a decision of which interaction scheme was better overall. As such, our recommended pathfinding strategy, which is a combination of an algorithm and interaction scheme, would have to be the aforementioned A* algorithm utilizing Manhattan distance with any of the three interaction schemes since they performed equally well.

References

1. Dijkstra, E.W.: A Note on Two Problems in Connexion with Graphs. Numerische Mathematik 1(1), 269–271 (1959), http://dx.doi.org/10.1007/BF01386390
2. Morris, J.: Data Structures and Algorithms: Dijkstra's Algorithm, http://www.cs.auckland.ac.nz/software/AlgAnim/dijkstra.html
3. Wichmann, D.R., Wuensche, B.C.: Automated Route Finding on Digital Terrains. In: Proceedings of IVCNZ 2004, Akaroa, New Zealand, pp. 107–112 (2004)
4. Russell, S., Norvig, P.: Artificial Intelligence: A Modern Approach. Prentice Hall, Englewood Cliffs (1995)
5. Hart, P.E., Nilsson, N.J., Raphael, B.: A Formal Basis for the Heuristic Determination of Minimum Cost Paths. IEEE Transactions on Systems Science & Cybernetics 4(2), 100–107 (1968), http://dx.doi.org/10.1109/TSSC.1968.300136
6. Matthews, J.: Basic A* Pathfinding Made Simple. In: Rabin, S. (ed.) AI Game Programming Wisdom, pp. 105–113. Charles River Media, Inc., Rockland (2002)
7. Goodrich, M.T., Tamassia, R.: Data Structures and Algorithms in Java, 3rd edn. John Wiley & Sons, Inc., Chichester (2004)
8. Silver, D.: Cooperative pathfinding. In: Proceedings of the First Artificial Intelligence and Interactive Digital Entertainment conference, pp. 117–122. AAAI Press, Menlo Park (2005)

Appendix – Full List of Test Results

Test Results					TE1 (Average)		TE2 (Average)		TE3 (Average)		TE4 (Average)	
	IS	A	H	NPC	S	T	S	T	S	T	S	T
1	Single	DIJ			24	3.45	28	3.96	28	3.91	24	3.44
2	Single	BFS			24	3.01	36	4.96	34	4.55	24	3.42
3	Single	A*	Man		24	3.13	28	3.83	28	3.95	24	3.52
4	Single	A*	Euc		24	3.28	28	3.93	28	3.94	24	3.52
5	Single	A*	Diag		24	3.20	28	3.98	28	3.98	24	3.52
6	Coop	DIJ		1	24	3.48	28	4.21	28	4.11	24	3.66
		DIJ		2	25	3.61	27	4.07	29	4.24	25	3.80
		DIJ		3	26	3.75	28	4.21	27	3.98	26	3.93
7	Coop	BFS		1	24	3.40	36	4.80	34	4.89	24	3.59
		BFS		2	25	3.53	37	4.92	35	5.02	25	3.73
		BFS		3	26	3.66	38	5.05	36	5.16	26	3.86
8	Coop	A*	Man	1	24	3.49	28	3.93	28	4.12	24	3.60
		A*	Man	2	25	3.62	27	3.80	29	4.26	25	3.73
		A*	Man	3	26	3.74	28	3.93	27	3.98	26	3.87
9	Coop	A*	Euc	1	24	3.48	28	3.97	28	4.14	24	3.61
		A*	Euc	2	25	3.61	27	3.84	29	4.28	25	3.74
		A*	Euc	3	26	3.75	28	3.97	27	4.00	26	3.88

Test Results					TE1 (Average)		TE2 (Average)		TE3 (Average)		TE4 (Average)	
	IS	A	H	NPC	S	T	S	T	S	T	S	T
10	Coop	A*	Diag	1	24	3.47	28	4.00	28	4.12	24	3.64
		A*	Diag	2	25	3.60	27	3.87	29	4.26	25	3.78
		A*	Diag	3	26	3.73	28	4.00	27	3.99	26	3.92
11	Non-Coop	DIJ		1	24	3.44	28	4.18	28	4.22	24	3.69
		DIJ		2	25	3.56	27	4.04	29	4.36	25	3.83
		DIJ		3	25	3.56	27	4.04	27	4.08	25	3.83
12	Non-Coop	BFS		1	24	3.45	36	4.97	34	4.95	24	3.59
		BFS		2	25	3.58	37	5.10	35	5.09	25	3.72
		BFS		3	25	3.58	37	5.10	35	5.09	25	3.72
13	Non-Coop	A*	Man	1	24	3.44	28	3.97	28	4.14	24	3.63
		A*	Man	2	25	3.58	27	3.84	29	4.28	25	3.76
		A*	Man	3	25	3.58	27	3.84	27	4.00	25	3.76
14	Non-Coop	A*	Euc	1	24	3.49	28	4.04	28	4.21	24	3.55
		A*	Euc	2	25	3.62	27	3.91	29	4.35	25	3.68
		A*	Euc	3	25	3.62	27	3.91	27	4.07	25	3.68
15	Non-Coop	A*	Diag	1	24	3.46	28	4.10	28	4.23	24	3.65
		A*	Diag	2	25	3.59	27	3.97	29	4.36	25	3.78
		A*	Diag	3	25	3.59	27	3.97	27	4.08	25	3.78
16	Comp	DIJ		1	24	3.61	29	4.34	28	4.21	24	3.64
		DIJ		2	25	3.75	28	4.20	29	4.35	26	3.92
		DIJ		3	26	3.90	27	4.05	27	4.07	25	3.78
17	Comp	BFS		1	24	3.36	36	5.09	34	4.99	24	3.34
		BFS		2	25	3.49	37	5.22	35	5.13	25	3.46
		BFS		3	26	3.61	38	5.36	36	5.26	26	3.59
18	Comp	A*	Man	1	24	3.47	29	4.01	28	4.12	24	3.46
		A*	Man	2	25	3.60	28	3.88	29	4.26	25	3.59
		A*	Man	3	26	3.77	27	3.75	27	3.98	26	3.72
19	Comp	A*	Euc	1	24	3.41	29	4.23	28	4.18	24	3.54
		A*	Euc	2	26	3.67	28	4.10	29	4.32	25	3.67
		A*	Euc	3	25	3.54	27	3.96	27	4.04	26	3.81
20	Comp	A*	Diag	1	24	3.49	29	4.21	28	4.12	24	3.60
		A*	Diag	2	25	3.62	28	4.08	29	4.25	26	3.86
		A*	Diag	3	26	3.76	27	3.94	27	3.98	25	3.72

Research on Using Cult3D and Java to Realize Virtual Assembly

Ruwei Yun[1], Baoyun Zhang [1], and Zhigeng Pan[1,2]

[1] Edu-game Research Center, Nanjing Normal University, 210097, China
yunruwei@njnu.edu.cn
[2] State Key Lab of CAD&CG, Zhejiang University, Hangzhou, 310027, China

Abstract. According to the needs of model-based assembly in virtual experiments, at the base of making full use of Cult3D, applying Java to expand the function of Cult3D was proposed to realize the interactive model assembly in virtual experiment. The paper analyses the mode of collision detection in procedure of assembling models in virtual experiment, the correspondence between Java and Cult3D and the application of Java multithreading in virtual assembly, which are key technologies for virtual laboratory. Then an example of water tower simulation teaching experiment is supplied.

Keywords: Virtual experiment, Virtual assembly, Cult3D, Java technology.

1 Introduction

Web-based virtual reality technology has received full attention and application in the domain of instructional technology. In the premise of limiting the hardware consumption, virtual reality simulation takes full advantage of the superiority of simulation software technology and achieves the goals of teaching and training visually. Besides, web-based virtual experiment can make the network resources fully shared, including saving the cost of training and improving the training effective further. As an important section in the field of training, virtual experiment is attached more and more importance by educators. Virtual model assembly is one of the key technologies for virtual laboratory foundation, but it is also a choke point that cumbers the development of virtual laboratory now. However, Cult3D and Java technologies can be applied to solve the problem of model assembly in virtual experiment, which successfully supplies an important guide and reference to virtual laboratory foundation.

A great deal of instruments or facilities which would be enclosed in experiments usually has complex structure and principle, so that many students usually have difficulties to learn them. At the same time, it is hard for students to observe the inside of instruments at the scene of an experiment. Virtual assembly technologies based on Cult3D and Java can easily solve the problem, because it makes assembling the complex models sequentially come true, also it can show the locations of the sub-models and the relationships among models, furthermore, it realizes interactive self-learning on the web.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 363–370, 2009.

2 Related Works

There are an increasing number of educators moving towards more learner-centered models nowadays in which students are engaged in problem solving and inquiry [1], [2]. As virtual reality becomes more and more mature for engineering application, the research on virtual experiment and virtual assembly has been rapidly increasing in recent years [3], [4].

Hong Yang [5] introduces the study of virtual assembly experiments based on Sensor node, Script node and event transfer of VRML, a virtual assembly of complicated machine can be realized. But the process is rather trivial. Her study aimed at actual need of education and sufficiently utilized inherent function of VRML, especially flexibly used Switch node, a concise implement mode is proposed. And the scene romance and interactive mode is optimized also.

Kiyoshi's paper [6] describes an empirical study on object assembly in a virtual environment. The paper describes an experiment for evaluating the effectiveness of the manipulation supporting methods described above in two-handed and collaborative assembly. Fig.1 shows the configuration of the experiment.

Virtual laboratory is a complex system for experiment, which has the characters of complex structure, openness and randomness etc. Some 3D technologies such as VRML and OpenGL has been adopted to develop simple scene, but the developing procedure of them is often so complex that we usually cannot achieve our anticipate simulation goals. Therefore, we introduce the Cult3D which is prevalent at the markets to the virtual experiment field. It is feasible for us to make use of Cult3D to establish 3D models for experiment instruments, and with the control of models by Java programs it is easy to implement random assembly of experiment 3D models [7].

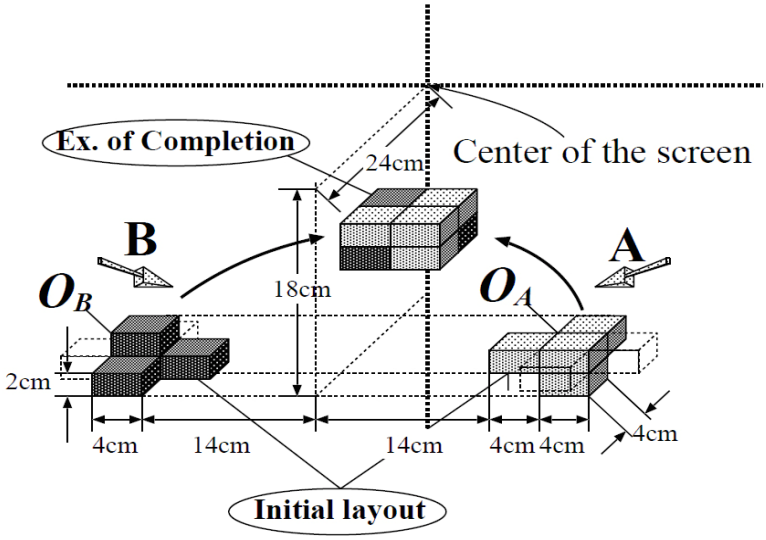


Fig. 1. Configuration of blocks

3 Key Technologies of Assembly

3.1 Communication between Cult3D and Java

Founding advanced interactive actions by Java program can control the states and appearances of objects, which is deemed to another measure to achieve the interactivity of virtual environment. The realization at Java-level having been achieved by plug-in of browser allows programs to access virtual scenes at basal level, and manipulate object or even change its properties. Therefore, it has more flexibility comparing to working in the environment of Cult3D Designer [8].

The interactivity of Cult3D behaves at two different levels. One level is the radical interactivity that can be completed by the events and activities in Cult3D Designer. The other level is Java-level. Activities founded by Java program can be called by events in Cult3D Designer. The appointed event called the appointed program which has been defined in Java. User who wants to control virtual models by compiled Java classes should manifest a class as an interface of *com.cult3d.Cult3DScript* in Java source program (.java) firstly.

```
import com.cult3d.*;
com.cult3d.Cult3DScript in Cult3D project
public class Tower implements Cult3DScript
{  public Tower()
    {}
   public void cult3dDestroy()
    {}
}
```

Then, it is required to write Java programs to meet the needs of controlling virtual movement, such as translation, rotation, magnification, contraction and stop etc. of virtual models.

The Java driven Cult3D technology is adopted in the interactive system, and there are the radical steps in the following [9]:

- Create virtual models in 3DS Max firstly, which are needed in virtual experiment, then save the ".max" file, and export a ".c3d" file with the help of *Cult3D Exporter* (a plug-in for 3DMax).
- Write the Java source programs to control virtual models with making use of Cult3D API supplied by Java and functions of interface. And then compile Java source file to the relevant ".class" file.
- Open the Cult3D Designer, and then export the ".c3d" file created in step (1) and the compiled Java files (with a ".class" suffix) created in step (2), in order for the virtual models to be given the Java Actions.
- At last, select the option of "Save internet file" from the main menu of Cult3D Designer. Sign a relevant name for the file, and click the menu of "Save", and then a Java driven Cult3D file (with a ".co" suffix) will be completed.

The engine of Cult3D is compiled by Java. Therefore, the engine can make use of Java classes to realize some especially effects such as: real time shadow, vector-level animation, matrix-level animation, collision detection and so on, which are all realized only by means of java3D/GL4java in former studies or applications. With the helps of Cult3D and Java three-dimensional virtual lab environment would be easily

established in the web. The virtual environment is full of third dimension, innervations, and it has the characters of mighty interactivity, steady continuity, veritable immersion and natural manipulation. In the virtual experiment environment the experimenter can conveniently interact with the models by the means of clicking or dragging the mouse or inputting parameters by keyboard. It just likes going to the real experiment for us, in which can we obtain the result equaling to the result obtained in real world.

3.2 Collision Detection Technologies in Assembly

Collision detection is a very important section in the procedure of virtual assembly. Suppose there are N models in a three dimension space, these models are altering their locations and states all the while. Generally speaking, collision detection is the judgment of that if detection has happened among models. Form the aspect of computing geometry we can comprehend collision detection like this: we suppose the three dimensions geometry space to R which is denoted by three dimensions geometry coordinate Fw. In Fw we take Fa to denote the set occupied by model A, then Fa is a subset of Fw. Up to now a four dimensions space coordinate system has been constructed with the altering along with time of Fw. In the coordinate system, the model A move along a certain orbit to construct Cw which is a subset of Ca. Collision detection is to determine whether $C1 \cap C2 \cap C3 \cap \ldots \cap Cn \neq \Phi$ is actual or not[10] .

For the reason that a great many of experiment models make up of the virtual environment (VE), VE has a complex environment. Collision detection plays an important role in boosting the operating speed of VE, and it also plays an important role in enhancing the immersion of virtual experiment environment. The above-mentioned detecting method is an original and simple collision detection method. But it is an exhausting method, namely detecting models each other chose from all the geometry models. Although the method can obtain corrected results, but it calculated amount is so exhausting that the intersecting tests will be too slow for us to tolerant, especially when the facilities of an experiment contented too many models [11]. That is the reason why the collision detection method can not meet the needs of virtual experiment in practice. There is no need 100% collision detection for us in common virtual experiment, and usually it is expedient for us to test whether collision has happened between two models. Therefore, we adopt the method that assembly models and display models are divided in two separations. If the distance between an assembly model and its testing model is smaller than a given value, then we consider that the collision has happened.

Java API for Cult3D supplies relevant methods to help us to put up collision detection. Let us take the collision detection between two models for example. Obtain the location of two models differently, which is type of *Vector3*, by applying the method of *getPosiotion()*, and these locations content three relevant values in three direction of X, Y, Z. Then we can obtain the difference of location between two models by applying the method of *sub()*, besides we can obtain the difference of location in each direction by functions of *getX()*, *getY()*, *getZ()*. At last, let the judgment sentence in Java judges whether the distance between the two models in direction of X, Y, Z is smaller than the given value. If so, collision detection will happen.

3.3 Applications of Java Multithread

Concurrency of Java language is adopted in controlling programs for models now, which is an effective method for us to solve the problem of controlling too many models in VE. Multithread technology of Java allows developers to add more than one thread in program. Each thread achieves one part of function, and it also can be executed with other thread at the same time [12]. Java language is the only one programming language supplying wide, effective and subsequent source language operations for PC programmer. It content multithread source language operations itself, having convenient and effective multithread mechanism, so it empowers programmers to employ multithread more conveniently.

In the procedure of assembly simulation and realizing dragging in virtual experiment more than one model are concerned. There are two approaches to realize multithread in Java: extending *Thread* class and implementing *Runnable* interface. Thread is a class defined in JDK to control objects of thread, in which encapsulates some methods to control threads. The following is the program example:

```
import com.cult3d.Cult3DScript;
public class Tower extends Thread implements
Cult3DScript
{   private volatile boolean  stillRunning;
    private volatile boolean  finishedLoading;
    public Tower()
    {     stillRunning = true;
          finishedLoading = false;
          Thread t=new Thread();}
    public void run()
    {     finishedLoading = true;
          while(stillRunning)
          { try{Thread.currentThread().sleep(10);}
            catch(InterruptedException e){}
          }
    }
    public void cult3dDestroy()
    {}
}
```

Another method to realize multithread application in Java language is making use of multithread objects to implement Runnable interface, and defining run() method in the class to startup thread. The two methods above-mentioned can be applied flexibly.

In order to control virtual models agilely in assembly procedure, we write an inner class for every concerned model, and make every model has its own special thread with the help of multithread of Java. In order to control certain model individual, model control method should be called in Cult3D first, then the *start()* method should be called to start up a certain thread. These model control methods are achieved in the main class of Java. The following is the program example:

```
  public void towerGo(String s)
{  Mainclass.Tower obj=new Mainclass.Tower();
   obj.start();
}
```

4 An Example—Water Tower Simulation Experiment

4.1 Modeling in Virtual Experiment

Initial models for water tower simulation were created in 3DMax 8.0. Owing to the needs of its popularity on the internet, its size should be limited in a small range. Only in this way can we browse it fast on the Web. So we imported the principle of low ploy model to limit the resolution of a model and reduce the vertex as soon as possible [13]. Three dimensional modeling parts involved in the water tower simulation experiment are as follows: water tanks, local water level, water installations, high water level detecting probe, low water level detecting probe, water pipes, pumps, wires, laboratory table and the control circuit etc. In order to save the system resources and quicken the collision detection speed, the example adopted the manner which assembly models and display models had been divided into two parts. So every kind of three dimension models should be modeled for three parts: assembly model, display model and testing model. Furthermore, it was needed to model a panel to place the assembly models.

In order to control the view accurately in Cult3D, we created a vidicon for the simulation, which can change the place of visual field to make it adapt to the experiment window. Fig. 2 shows models in the view of the water tower simulation experiment with the vidicon vision.

Endued color for each models in 3DMax and operated them such as grouping the relevant configuration, operating texture, dividing models and so on. After arranging the whole scene, we would import them as a Cult3D Designer file (watertower.c3d) by *Cult3D Exporter*. And the water model in the virtual experiment was directly modeled by adopting the particle system in Cult3D Designer.

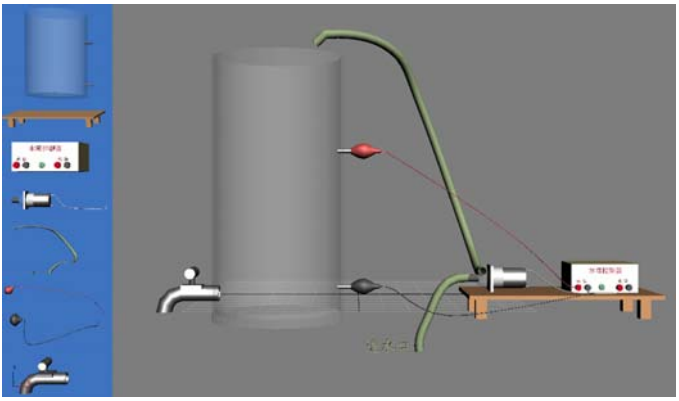


Fig. 2. Models in water tower simulation

4.2 Collision Detection Realized by Java

When to checking whether a collision has happened, we need to recur to the detecting method above. Separate the models into three groups of assembly models, display models and detecting models. Manifested variables for every models as the type of *CultObject*, then made the models of display group invisible by the method of *setVisible()*, and set the transparence of detecting group models to blin. Then the program would judge whether a collision happened by comparing the distance between an assembly model and its detecting model to a given wee value. If the collision happened in the assembly, the *setVisible()* method in Java program would be called to make the relevant models of display group visible, and set the relevant models of detecting group invisible at the same time. Fig. 3 shows the assembly procedure of water tower controller, if the distance between the controller model and the pump model was smaller than the given value 0.1, we would consider the collision happened.

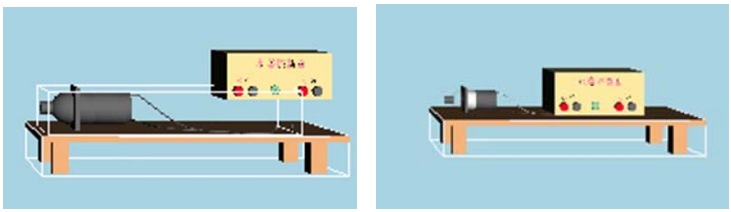


Fig. 3. Assembly of water controller

4.3 Performances Summary

The assembly realized by Java and Cult3D in virtual experiment has some performances as follows: It can execute complex operations, achieving interactive assembly simulation, and having effective collision detection mechanism. It can run in every operating system with a Java Virtual Machine (JVM), because the models are all created by 3DMax and the VE is founded by Java and Cult3D. It supports network completely. The Cult3D adopts its independent and advanced compression technology, sustaining multiple shadows, texture and bilinear filter, so its file size is small, and the downloading speed is fast. Further more, it has upstanding displaying quality, so it is also an ideal manner to display products on the network. Java applications realize the interactivity between human and computers.

5 Conclusions and Future Work

The virtual assembly technologies of experiment device based on Java and Cult3D has the ability of assembling complex parts of virtual experiment device, revealing the location and the relationship among models, and supplying an interactive self-learning environment for students. So it has far-reaching significance in virtual experiment for instruction and training. Controlling models basing on events in Cult3D, and making

full use of functions of Java language can realize complex virtual assembly by a laconic mode, at the same time it improves the interactivity and it has biggish utility value.

The virtual experiment assembly introduced in this paper realized the basal function of controlling in VE, but from the view of engineering design further work need to be done in future. For instance, the abruption of assembly models and display models added the quantities of models, which went against the thought of limiting the file size. So it is needed for us to logically deal with the relation between modeling and algorithm complexity.

References

1. Land, S.M., Hannfin, M.J.: A Conceptual Framework for the Development of Theories I Action with Open-ended Learning Environments. Educational Technology Research and Development 44 (1996)
2. Liu, Y.F., Wang, L.C.: Virtual Demonstration of Physics Experiments Basing on WEB. Journal of Hunan Industry Polytechnic 8, 49–52 (2008)
3. Yoshikawa, M., Kawai, K.: Toward Observation of Human Assembly Skill Using Virtual Task Space. Experimental Robotics VIII, STAR 5 (2003)
4. Jayaram, S., Connacher, H.I., Lyons, K.: Virtual Assembly Using Virtual Reality Techniques. Computer-Aided Design 29 (1997)
5. Hong, Y., Ben, G., Minshu, Z., Jiuyang, Y.: Research on Virtual Assembly and Disassembly Experiment Technology Based on VRML. Journal of Wuhan Institute of Technology 1 (2007)
6. Kiyokawa, K., Takemura, H., Yokoya, N.: An Empirical Study on Two-Handed / Collaborative Virtual Assembly. In: Proc. The Third International Display Workshops (IDW 1996), vol. 2, pp. 477–480 (1996)
7. Pu, Q., Xu, Y.: Implementation of Interactive 3D Facial Animation with Cult3D Technology. Journal of Computer-aided Design and Graphics 16 (2004)
8. Deng, J., Ma, S.F.: Interchange Transport 3D Simulation Based on Cult3d-Java Technology. Computer Simulation 9 (2006)
9. Su, W.Z.: Interactive Three-dimensional Network-Cult3D Application Guidelines. Tsinghua University Press (2001)
10. Zheng, Y., Ning, R.X., Liu, J.H., Du, L.: Survey on Key Techniques of Virtual Assembly. Journal of System Simulation 18 (2006)
11. Zhang, G., Li, H.S., Hou, Q.: Development of Virtual Assembly System Based on VRML-Java. Computer Engineering 34 (2008)
12. Lu, C., Lu, Y.S., Mao, D.Y.: A Control Flow Model for Concurrent Java Programs. HuaZhong Univ. of Sci. & Tech. (Natural Science Edition) 1 (2008)
13. Li, X.T., Tang, S.L., Wan, W.D.: Apply Web3D to Development of Web-based Virtual Lab Environment. Journal of Beijing Radio and TV University 1 (2007)

Design and Implementation of Operation Replay for Virtual Experiment

Jiufei Tang, Xingming Ouyang*, Junqing Yu, and Liefu Ai

Computer College, Huazhong University of Science & Technology,
Wuhan, Hubei, 430074, China
Tangjiufei@hust.edu.cn, ouyangxingming@hust.edu.cn

Abstract. Although virtual experiment systems have been widely used in universities and colleges, many functions, such as experiment demonstration and experiment process analysis, need to be extended. Operation replay is the core and foundation of these 2 functions. Under MFC framework, the mechanism of operation replay is studied. A method based on message capturing and sending is proposed and the feasibility of this method is proved by using DFA theory. Experimental results demonstrate that the proposed method is effective and can be realized in existed MFC-based VESs easily. The idea of operation replay has some referential value for other e-learning system researchers and developers .

Keywords: virtual experiment system; operation replay; valid message.

1 Introduction

E-Learning is becoming more and more popular in recent years. It can improve the flexibility and quality of education effectively. Various kinds of e-learning systems have been developed and implemented. They bring a lot of benefits and conveniences to learners and educators. [1,2]

However, learners can not do experiments in these systems. As a supplement to these e-learning systems, VESs(Virtual Experiment System) have attracted lots of interest. VES is a software-created environment, in which learners can do experiments as if in a real laboratory. VESs can reduce the dependence of experiments on time, space and hardware, can cut down the cost to run and maintain laboratories. The fundamental functions of a VES are to simulate real experiment hardware and real experiment processes. Most of the current VESs fall into this category. [3,4]

Furthermore, after virtualization of experiment systems, with the powerful computing and storage abilities of computer and network, a lot of functions can be extended. Ref[5] proposed a method to monitor and diagnose experiment process, by modeling experiment steps with Petri-Net.

This paper investigates the functional requirements of operation replay in VESs, proposes the mechanism and scheme to design and implement operation replay under MFC framework. Experimental results demonstrate that the proposed method is feasible and effective.

*Corresponding author.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 371–378, 2009.

2 Concept of Operation Replay

Replay or execution replay is not a new concept. It is developed originally to support fault tolerance in distributed computing. It refers to the ability to reconstruct the past execution of a system or program. Ref [6] proposes a context-sensitive method to capture and replay program states for Java software. It is used to debug and analyze execution of the program. Ref [7] describes the design of a tool for capturing and replaying Java program executions. It is used for debugging and execution profiling.

Anyway, the general meaning of "replay" is too wide for VES field, restricting and clarifying need to be made for our research purpose.

Definition 2.1. Operation: Operation refers to the actions experimenter takes to construct or edit a virtual circuit in a VES, including adding, deleting, moving and modifying of virtual instruments or apparatus, by using input devices of a computer. Typical actions include keyboard strikes and mouse clicks. Several continuous operations in an experiment compose an operation sequence.

Definition 2.2. Operation Replay: Operation Replay refers the function described as below: experiment operations during an experiment are recorded and saved into a file. Sooner or later, the experimenter or others can open the file and watch the whole processes of the experiment. The former execution is called "original run", the later is called "replay run".

Based on operation replay, 2 useful applications can be extended in VES. The first is experiment demonstration. This can be realized by recording the operation, sending it to other computers one by one, then the receiver displaying the operation. The second is experiment process and result analysis. Experimenters save the operations to files and hand over the files to the instructor. The instructor can replay the experiment processes later in his own computer, check and analyze the experiments. He can give scores to the experimenters by watching operation replay too.

A direct and simple method of operation recording is screen recording, i.e., record the changes of computer screen during one period of time, and save as a stream media file, and then replay it by standard media players. There is much software to do this, such as Desktop Screen Recorder 5 [8]. Most of teaching supporting systems (such as Blackboard[9]) provides this function too. One advantage of this method lay in that this method is irrelevant to application programs, and can be implemented easily.

Anyway, this method captures and processes screen images, occupies a number of computing resources. The size of the stream media file is quite large too. So, screen recording is not suitable for operation replay in virtual experiment systems.

Ref[6] and Ref[7] propose designs of replay for Java software, but the replay is for debugging or execution analyzing.

In VES, the purpose of replay is to monitor or analyze the operations, to analyze the effects of experiment courses or classes. We need to analyze the particular environment of VES and propose corresponding design and implementation method for operation replay in VES.

3 Design of Operation Replay

According to the definition of operation replay, it can be implemented through 3 steps: operation capture, operation saving and operation recurring. Now we launch on the design for these 3 steps.

3.1 Operation Capture

This section need to determine what can represent user operations, where, when and how to capture them.

For a standard MFC program, the responding procedures are shown as Fig. 1.

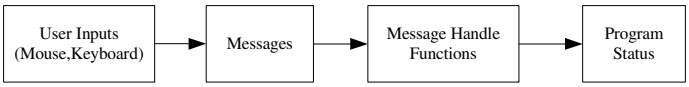


Fig. 1. Responding Procedures of a MFC Program

All operations are taken through input devices in the "User Inputs" layer. Inputs generate messages, MFC maps messages and the message handle functions, message handle functions change program status. Below, we try to determine which layer is the most suitable source for replay.

User Inputs: user's inputs represent operations directly. Operation capture can be implemented by recording all the inputs in this layer. But one problem arises when recurring. There need a virtual mouse and a virtual keyboard to recur the saved inputs. There are lots of things to develop these 2 virtual apparatuses. Therefore, direct user input is not an ideal source for replay.

Program status is the result of operations. It is static, it can not display a relatively integrate process of the operations. There would not get a good effect simply by recurring program status.

Therefore, we should find the capture source in the third layer. Let's check 2 properties of message in MFC.

The first is that message can be handled easily in MFC program. The second is that valid message has high fidelity to the operations. Below is brief analysis of this property.

In a MFC program, suppose that the operation sequence set is: *Operations* = $\{a_1, a_2, a_3, ..., a_M\}$, message sequence set is: *Messages* $=\{b_1, b_2, b_3, ..., b_N\}$. The relationships of operations, messages and message handle functions are shown as Fig. 2.

One operation could invoke several messages; 2 different operations could invoke a same message. So, we need to give out a strict definition of valid operation as below.

Definition 3.1. Suppose that the operation sequence is *Operations*, message sequence is *Messages*, if for any operation $a_i \in$ *Operations*, $\exists b_j \in$ *Messages*, b_j is created by a_i, and there is a message handle function corresponding to b_j, then we call a_i valid operation, all the valid operations compose a valid operation set *validOperations*, all the corresponding messages compose a valid message set *validMessages*.

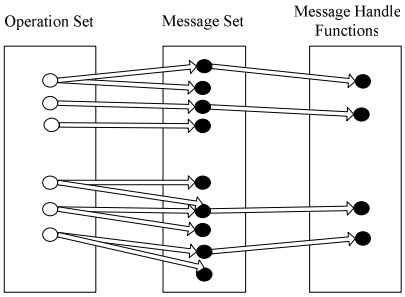


Fig. 2. Mapping of Operation, Message and Message Handle functions

According to Definition 3.1, we obtain a subset of operation sequence *Operations*, that is valid operation sequence *validOperations* = { a'_1, a'_2, a'_3 ,..., a'_N }, the number of element is N. This sequence and the valid message sequence *validMessages* compose a one-to-one map: f(a'_i) = b_i.

This is the property of valid messages: high fidelity to the operations. This property, together with the easily-to-handle property, makes valid message a good source for operation capture. Therefore, we choose the valid message set *ValidMessages* as the source of operation capture.

Operation capture is implemented in the message handle function of a valid message. The order of message handle function invoking is identical with the order of user's operations. Therefore, the message sequence captured in these functions keeps the same order of operations.

3.2 Operation Saving

From the above analysis, the saving of operations is transformed to saving of messages.

The data structure to save message is defined as below:

```
struct Message {  int message; int object;
        WPARAM parameter1;   LPARAM parameter2;  };
```

Here, Object refers to the program classes or objects to send messages. It is coded with integer. "parameter1" and "parameter2" are parameters send to message handle functions in Windows system, the data types are WPARAM and LPARAM respectively.

All the messages are saved to a linked list. This linked list, together with the global setting of VES, is saved into a file. We call this file "operation file" of the experiment.

3.3 Operation Recurring

Two problems need to be solved in this section: to prove that the original operations can recur from the message sequence saved in the file, and to design some methods to implement operation recurring.

3.3.1 Proving of the Feasibility

Definition 3.2. From the starting, if a MFC program reached a certain stable program environment, we call this is a status of the program, marked as S , and the status just after the starting is called initial status, marked as S_0. If a status S_i is reached after the handling of a message b_i , we call that status S_i is corresponded to message b_i , marked as $T(b_i) = S_i$.

Theorem 3.1. After a series of operations, A MFC program reaches to a certain status. Suppose that, the valid message set is *Valid-Messages* = $\{b_1, b_2, b_3 ... b_M\}$, correspongding status set is *Status* = $\{S_0, S_1, S_2, S_3 ... S_M\}$, where S_0 is the initial status, $T(bi) = S_i$, $1 \leq i \leq M$. Then, a DFA (deterministic finite automaton) can be constructed as below: M = {Status, UB, T, S_0, Status}.

The status diagram of this DFA is given in Fig. 3.

Now we prove the feasibility of operation replay by using Theorem 3.1.

Proving: From the linear DFA in Fig. 3., we can make a statement: for 2 runs of a MFC program,if both the initial status and the input sequence are identical, the 2 status sequences of the 2 runs will be identical. Because we record the whole valid message sequence of the original run. The message sequence of the replay run is read from the file, it is identical with the original one. And, we can take some methods to assure the initial status of the 2 runs to be identical.Thus, the staus sequences of the original run and the replay run will be identical.And status squence is the result of user operations. So, operation replay can be realize by message recording and recuring.

Prove finished.

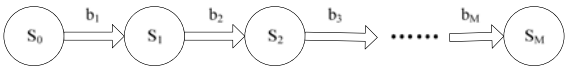


Fig. 3. Status Diagram of the DFA

The core of operation replay is to recreate the status sequence a program responses to operations, because the ultimate purpose of operations is to get expected status changes.

3.3.2 Implementation of Operation Recurring

From the analysis and design upwards, operation recurring can be implemented by steps as below.

Step1. Open the operation file, and initialize program status;
Step2. Read a record and send the message to corresponding program objects;
Step3. Wait until the end of the message handling;
Step4. Repeat step2 and 2 until the end of the operation file;
Step5. Recurring ends.

4 Realization of Operation Replay in IVDLEP

Operation replay has been realized in an actual experiment system: IVDLEP (Interactive Digital Logic Virtual Experiment Platform).

4.1 Introduction of IVDLEP

IVDLEP is a virtual experiment platform developed for experiment teaching of the course "Digital Logic". The platform provides the virtual apparatus of all the physical apparatus used in real experiments, including virtual experimental board, virtual power, virtual chips, virtual sockets, virtual switches, virtual LEDs or lamps, virtual oscilloscope, virtual wires and so on. User can choose a virtual apparatus according to his own design, and place it on the virtual experimental board. Various kinds of combinational logic circuit and sequential logic circuit can be constructed and simulated on this platform. Fig.4 is the virtual circuit of full-adder, a typical combinational logic circuit.

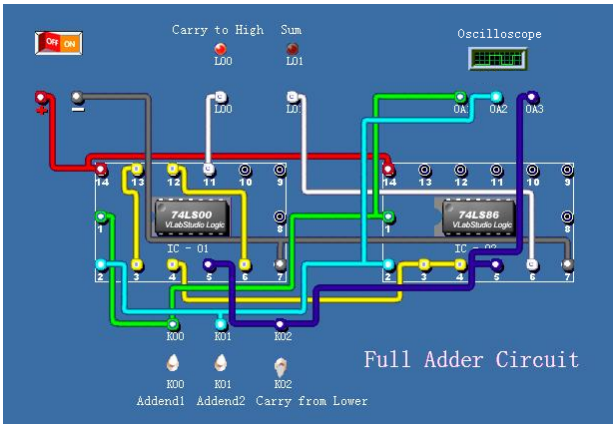


Fig. 4. Virtual Circuit of a Full-Adder

4.2 Realization of Operation Replay

According the analysis and design in section 3, the steps to realize operation replay in an existed system are listed as below.

Step 1.Add definition and declaration of data structures and variables;

Step 2.Read and analyze the design document and code of the system, find out the objects or classes which are related with user inputs, then code these objects or classes;

Step 3.Search for the message handle functions related to user inputs; then add code to capture the corresponding message into the linked list;

Step 4.Add menu items, dialogs and corresponding codes;

Step 5.Compile, link, and test and release the system.

We realized operation replay in IVDLEP by these 7 steps. Some notes are given out as below.

(1) In IVDLEP system, we found 4 classes related to user inputs: CMainFrame, CView, CTreeCtrl, and CMiniPlatform. CMainFrame responds to menu item clicks, toolbar clicks; CView class is corresponding to virtual experimental board, it handles actions of virtual apparatuses on the board, such as placing and moving; Ctreectrl is corresponding to virtual apparatus library, it handles virtual apparatuses choosing; the

last one, CMiniPlatform is a full-view of the virtual board, it handles virtual board navigating. We code these 4 classes as 1,2,3,4, respectively.

(2) In the source codes, we find about 91 message handle functions related to user inputs, and add codes to capture the operations.

(3) Operation replay control panel is designed as shown in Fig.5.

Fig. 5. Operation Replay Control Panel

4.3 Testing Result

Using the new released version of IVDLEP, we re-construct the virtual circuit of full-adder in Fig.4. The message list is saved into a file. Some operations are listed in Table.1. The content of the operation file is shown in Fig.6.

Table 1. Some Operations to construct a full-adder

No.	Operation description	Object to send messages
1	Add a Power switch	3, CTreectrl; 2,CView
2	Add power pins “+”, “-”	3, CTreectrl; 2,CView
3	Add “L00”,”L01” LED	3, CTreectrl; 2,CView
4	Add 2 14-pin sockets	3, CTreectrl; 2,CView
5	Add 3 switches: K00,K01,K02	3, CTreectrl; 2,CView
6	Add a “74LS00” chip	3, CTreectrl; 2,CView

It is easy to understand that the operation sequences to construct a same virtualcircuit are usually different for different experimenters or different times of a same experimenter.

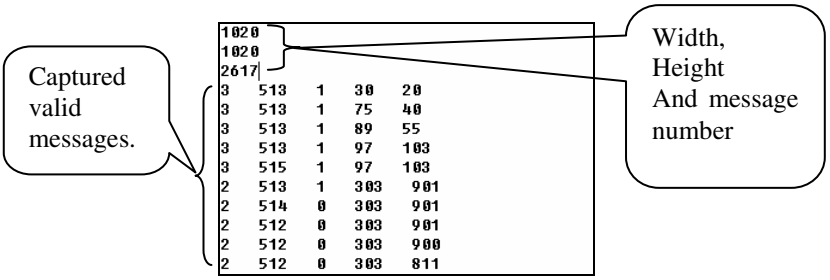


Fig. 6. Content of the Operation file

For coding convenience, a flag with data type “Int” is inserted into the third field of the struct to store the captured messages.

We open the saved file and replay the operations. The experiment processes are recurring with the exact order as the original run. At the end of the replay run, the expected virtual circuit of full-adder as shown in Fig.4 is constructed.

5 Conclusion

This paper investigates the mechanism of operation replay in virtual experiment system, proposes a message-based method to implement. The mechanism and method has been realized in an actual experiment system: Interactive Digital Logic Virtual Experiment Platform. The mechanism and method is applicable for other MFC-frame software. The idea of input capture and message sending might have some referential value for other e-learning system researchers and developers too.

Anyway, there are shortcomings for this method. It is applicable strictly to MFC-based applications. The initial status of original run and replay run must be identical.

For future work, more flexible mechanism or method for operation replay should be investigated. More applications of operation replay in VES or other e-learning system need to be found.

References

1. Zhou, D., Zhang, Z., Zhong, S., Xie, P.: The Design of Software Architecture for E-Learning Platforms. In: Pan, Z., Zhang, X., El Rhalibi, A., Woo, W., Li, Y. (eds.) Edutainment 2008. LNCS, vol. 5093, pp. 32–40. Springer, Heidelberg (2008)
2. Yun, R., Pan, Z., Li, Y.: An Educational Virtual Environment for Studying Physics Concept in High Schools. In: Lau, R., Li, Q., Cheung, R., Liu, W. (eds.) ICWL 2005. LNCS, vol. 3583, pp. 326–331. Springer, Heidelberg (2005)
3. Ma, J., Nickerson, J.V.: Hands-on, Simulated, and Remote Laboratories: A comparative Literature Review. ACM Computing Surveys 38(3), Article 7 (2006)
4. Xingming, O., Xiaolong, Y., Xinrong, X.: Design and Implementation of Virtual Lab Based on Internet. Computer Engineering (in Chinese) 30(4), 185–186 (2004)
5. Chang, J.-C., Li, S.-C.: Monitoring the Experiment Process and Diagnosing the Experiment Mistakes Made by Students with Petri Net Modeling. In: Pan, Z., Aylett, R.S., Diener, H., Jin, X., Göbel, S., Li, L. (eds.) Edutainment 2006. LNCS, vol. 3942, pp. 108–115. Springer, Heidelberg (2006)
6. Xu, G., Rountev, A., Tang, Y., Qin, F.: Efficient Checkpointing of Java Software Using Context-Sensitive Capture and Replay. In: Proceedings of the 6th joint meeting of the European software engineering conference and the ACM SIGSOFT symposium on The foundations of software engineering, pp. 85–94 (2007)
7. Steven, J., Chandra, P., Fleck, B., Podgurski, A.: jRapture: A Capture/Replay Tool for Observation-Based Testing. In: Proceedings of the 2000 ACM SIGSOFT international symposium on Software testing and analysis, pp. 158–167 (2000)
8. Desktop Screen Record5, `http://www.recordscreen.com/`
9. Blackboard (2005), `http://www.blackboard.com/`

Adaptive Lip Feature Point Detection Algorithm for Real-Time Computer Vision-Based Smile Training System

Youngkyoon Jang and Woontack Woo

GIST U-VR Lab.
Gwangju 500-712, S. Korea
{yjang,wwoo}@gist.ac.kr

Abstract. This paper presents an adaptive lip feature point detection algorithm for the proposed real-time smile training system using visual instructions. The proposed algorithm can detect a lip feature point irrespective of lip color with minimal user participation, such as drawing a line on a lip on the screen. Therefore, the proposed algorithm supports adaptive feature detection by real-time analysis for a color histogram. Moreover, we develop a supportive guide model as visual instructions for the target expression. By using the guide model, users can train their smile expression intuitively because they can easily identify the differences between their smile and target expression. We also allow users to experience the smile training system using the proposed methods and we evaluated the effectiveness of these methods through usability tests. As experimental results, the proposed algorithm for feature detection had 3.4 error pixels and we found that the proposed methods could be an effective approach for training smile expressions in real-time processing.[1]

Keywords: Lazy algorithm, lip detection, smile expression recognition, Haar-like classifier.

1 Introduction

Nonverbal information, such as facial expressions, play an important role in human communication [1] because facial expressions visually transmit feelings and intention [2-3]. In particular, smile expressions are an effective way to communicate positively with others [4]. For that reason, various smile training methods have been introduced, such as text books, magazines, and self-image making institutes, to train smile expression techniques. These methods, however, are quite restricted, as they allow for only limited interaction between the user and the training material, especially when relying on text books. Even self-image making institutes, while offering detailed advice from counselors and experts, tend to be time consuming and expensive.

[1] This research is supported by Korea Culture Content Agency(KOCCA) of Ministry of Culture, Sports and Tourism(MCST) in the Culture Technology(CT) Research & Development Program 2009.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 379–389, 2009.

As a solution to this problem, Kyoko Ito proposed a smile training system, called the 'Facial Expression Training System,' which provided a computer based process for effective facial expression training [5-7]. Ito's system involves four procedures to train a user's facial expression. First, the system registers a general image of the user's face. In the second procedure, the system selects the target facial expression and then determines the current facial expression in the third procedure. For the fourth procedure, the current and target facial expressions are compared. Several points are then marked on the currently registered facial image, representing areas where more expression or training is needed. Through Ito's four procedures, users can more accurately identify weaknesses and train more effectively.

Ito's work, however, does contain several limitations. The first problem is that the system does not support real-time processing and too many steps are required to conduct it. Moreover, the system cannot process more than one image, allowing users to use only one still image at each trial to get feedback. This inefficient procedure does not support seamless and intuitive training because a user has to consider only the marked points on the screen to understand the descriptions from the system. The descriptions, which function similar to a text book and do not easily allow the user to follow the target expression. To provide a more effective smile training system, the system needs to show both the user's facial image and target expression while running the algorithm in real-time. Then, users can intuitively compare their smile expression with the target expression and train efficiently through real-time feedback.

In this paper, we propose an adaptive lip feature detection algorithm for supporting the real-time smile training system using visual instructions. The proposed algorithm can detect lip feature points, irrespective of lip color, by a user-drawn line on a lip on the screen. Consequently, the proposed algorithm supports adaptive feature detection through a real-time analysis for a lip color histogram. In order to support intuitive comparison of a user's smile with a target expression, we develop a supportive guide model to provide visual instructions for the target expression. By using this guide model, users can train their smile expression intuitively because users can easily recognize the differences between their smile and the target expression. We also allow users to experience the smile training system using the proposed methods and we evaluated the effectiveness of the proposed methods through demonstration and usability tests.

The rest of this paper is organized as follows. Section 2 introduces the proposed real-time smile training system using the proposed algorithm and a detailed description of our proposed adaptive lip feature point detection algorithm is presented in Section 3. Section 4 describes the implementation and experimental results of the proposed system and algorithm and conclusions and future works are discussed in Section 5.

2 The Proposed Smile Training System and Algorithm

2.1 The Proposed Real-Time Smile Training System

We present the proposed real-time smile training system using the proposed algorithm, as shown in Figure 1. The proposed system consists of three parts: input devices,

computing device, and display device. A camera on the input device captures a user's facial image and the touch screen receives information through touched pixel points by a line drawn on the lip region of the image. The obtained facial image and touched pixel points are transmitted to the input source manger of the computing device.

The input source manager examines whether the input sources (image and points information) exists or not. When the input sources exist, the source manager forwards them to the feature extractor, which analyzes a color histogram of the touched pixels of the facial image and extracts feature points on the lip of the user's mouth. In the case of the feature points of the guide model, there is no color analysis process because the guide model manager delivers direct feature point coordinates as well as a guide model to the feature matcher. The guide model manager then loads and delivers the model and feature points coordinates from the guide model DB. The extracted feature point coordinates for the user's lip are transmitted only to the feature matcher, which determines whether a user smiles or not by measuring and comparing the distance between a user's lip feature points with the model. Depending on the results, the event manager then selects either visual instructions as tips or visual feedback to help produce a better match.

The visual instruction, a black line connected between the corners of a user's mouth and the guide model, represents the directions for the corners of the mouth where more training is required. The visual feedback also shows the intuitive feedback by changing the color of the supportive guide model when the user successfully trains his/her smile expression. The selected events are displayed through the display

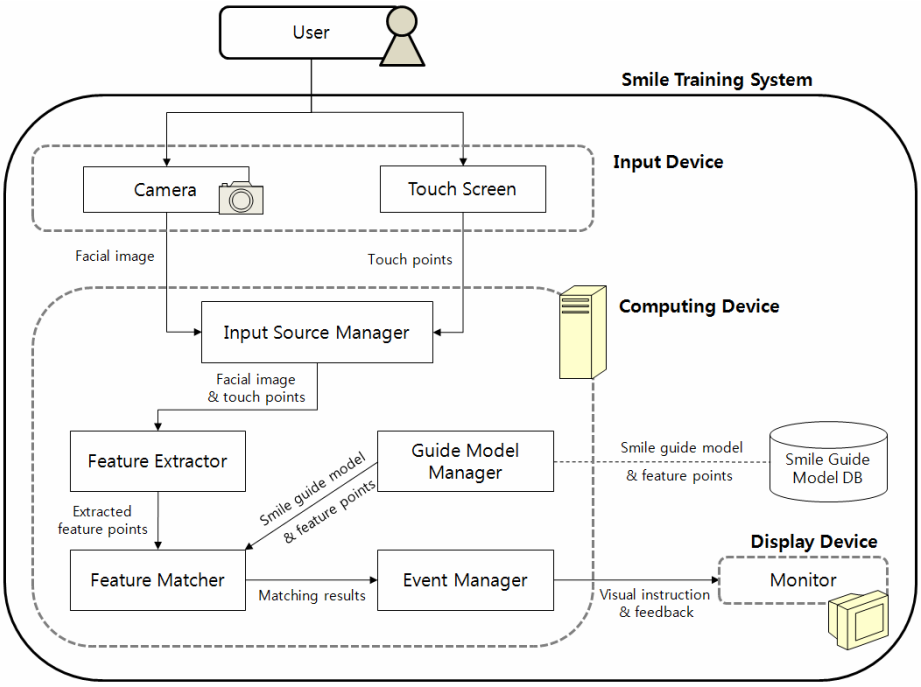


Fig. 1. Proposed the real-time smile training system diagram

device. This proposed method is more perceptive than simply following the comments from a picture as proposed in previous work [7].

2.2 The Proposed Algorithm Flow

An overview of our proposed algorithm can be seen in Figure 2. First, the proposed system captures a facial expression image, obtains touch points from the user's input, and detects mouth ROI (Region of Interests) by using the Haar-like classifiers [8-9]. Next, the corners of mouth are extracted by using the Harris Edge Detector [10]. The proposed system then detects the upper and lower feature points on the mouth by the proposed adaptive lip feature point detection algorithm, as described in section 3. The distances between the extracted feature points of the user's lip and the model are calculated to measure the differences between the user's lip shape and the target expression. When the measured value is lower than the predetermined threshold, indicating a high level of similarity, the system determines that the user's facial expression is a smile, and vice versa. If users have trained their smile expressions with the proposed system, but still want further training, another guide model shape is presented. These procedures can be repeated until users decide to stop.

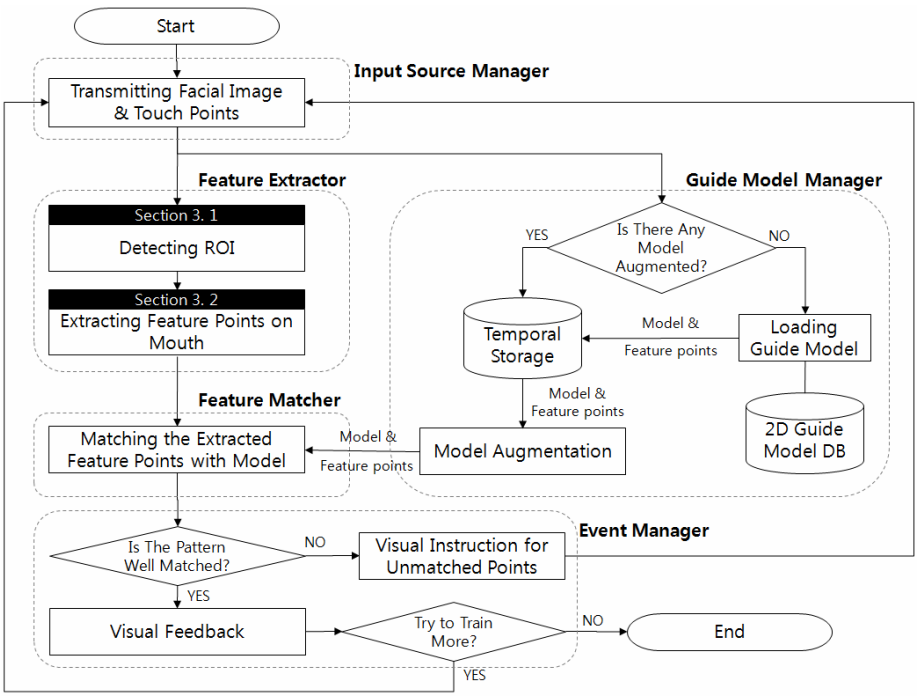


Fig. 2. Proposed algorithm for the real-time smile training system

3 The Adaptive Lip Feature Point Detection Algorithm

Because of the color variances that can occur among users, a smile training system needs to be able to detect lip features irrespective of lip color. To this end, we propose an adaptive lip feature point detection algorithm, used in the 'Feature Extractor' aspect of the system, as shown in section 2.2. Detailed explanations are provided as follows.

3.1 Detecting ROI

The proposed real-time smile training system focuses on the mouth region for training smile expressions. Therefore, before detecting the lip region, we detect the mouth ROI (Region of Interests) using a Haar-like classifier [8-9] integrated with the OpenCV library [11]. One problem with the Haar-like classifier, however, is that when the background of the captured image has a similar color or characteristics with mouth region, the classifier recommends too many candidates for the ROI, many of which are poor. To overcome this problem, we use a checking procedure for the geometric relations between the detected ROIs, as shown in Figure 3. First, we detect the frontal face ROI by using the Haar-like classifier [12-13] and then divide it into two parts, an upper half and a lower half. Using these two parts of the detected frontal face image, we can then detect the ROI for the eyes in the upper image and the mouth in the lower image. Through this procedure, we are able to determine whether or not the detected frontal face ROI is real. If there is no ROI for the eyes and mouth in the detected face ROI, the proposed method will determine that the face ROI is wrong. Therefore, we can detect the real face, eyes, and mouth ROI in more detail (see Figure 6 later in this paper), making the proposed method less affected from noise and reducing the processing time, as shown in Table 1.

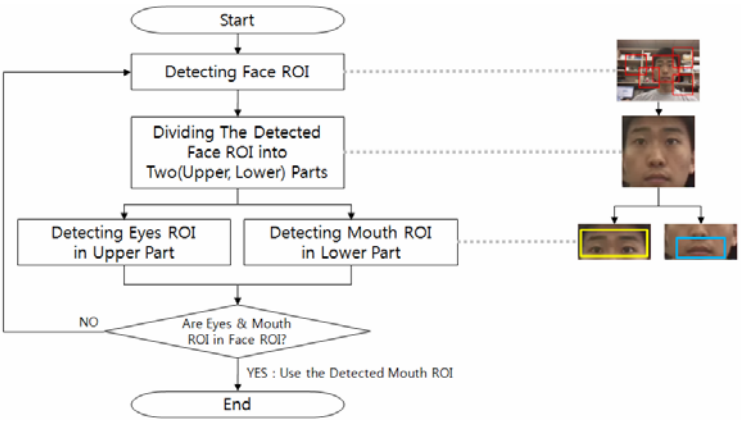


Fig. 3. The proposed procedure to check geometric relation between the detected ROIs

3.2 Extracting Feature Points on Mouth

To recognize the precise position or shape of the mouth, it is necessary to first detect more detailed feature points. Before detecting the precise feature points on an outline of the lip, though, we first detect the corners of the mouth using the Harris Edge detector [10]. We then select both the left and right-most points among the detected edges of the mouth. The predefined threshold for extracting the proper area for the edges of the mouth ROI was determined heuristically to indicate optimal performance.

Our proposed algorithm analyzes the lip color histogram information to accurately extract the lip feature points irrespective of lip color, with some user participation, as shown in Figure 4. The proposed method uses a YC_bC_r color space to analyze the lip color histogram. For each color space, the proposed method calculates the mean and standard deviation values by using all pixel values of the points on the drawn line, as shown in Eq. (1) and (2), respectively. After that, we investigate all pixels of the mouth ROI within the range between the corners of the mouth and all pixels in the range $[C_{1x}, C_{2x}]$ and $[Y_{1y}, Y_{2y}]$ in the x-axis and y-axis, respectively. As shown in Figure 4, C_{1x} and C_{2x} represent the x-axis values of the left and right corners of the mouth, respectively, while Y_{1y} and Y_{2y} represent the y-axis values of the most upper and lower points on the detected mouth ROI, respectively. If a pixel value in the mouth ROI falls in the range [(M-SD), (M+SD)], the proposed method determines that the pixel is in the lip region and vice versa, as shown in Eq. (3), allowing the lip region to be segmented, regardless of lip color.

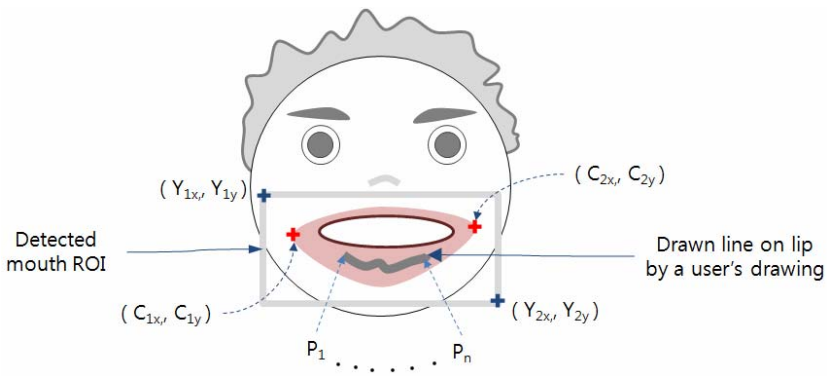


Fig. 4. User-drawn line on the lip for the adaptive feature detection algorithm

$$M = \frac{1}{n}\sum_{i=1}^{n} P_i, \tag{1}$$

$$SD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - M)^2}, \tag{2}$$

$$F(CPV) = \begin{cases} True, & (M - SD) < CPV < (M + SD) \\ False, & CPV < (M - SD), or (M + SD) < CPV \end{cases}, \tag{3}$$

where n is the number of the points on the line drawn on the lip. P represents the pixel values of a point on the drawn line, as shown in Figure 4. M and SD are mean and standard deviation values of the points on the drawn line. CPV refers to the current pixel value to be evaluated and the function F determines whether or not a pixel is in the lip region.

After segmenting the lip region, the proposed algorithm detects the candidate points in the middle region of the detected mouth ROI by selecting the outside points of the segmented lip region, as shown in Figure 5. Then, according to Eq. (4), the proposed algorithm extracts the feature points for the upper and lower lips, respectively.

$$\begin{aligned} FP_{Uy} &= \frac{1}{n}\sum_{k=1}^{n} P_U(y_k), \\ FP_{Ly} &= \frac{1}{n}\sum_{k=1}^{n} P_L(y_k), \\ FP_{Ux} &= FP_{Lx} = \frac{1}{2}(C_{1x} + C_{2x}) \end{aligned}, \tag{4}$$

where n is the number of the detected candidate points and $P_U(y_k)$ and $P_L(y_k)$ are the vertical positions of the candidate point (y_k) for the upper and lower lips, respectively. FP_{Uy} and FP_{Ly} are the y-axis values of the extracted feature points for the upper and lower lips, respectively. FP_{Ux} and FP_{Lx} are x-axis center point values of the corners of mouth and (FP_{Ux}, FP_{Uy}) and (FP_{Lx}, FP_{Ly}) respectively represent the coordinates of the extracted feature points for the upper and lower lips.

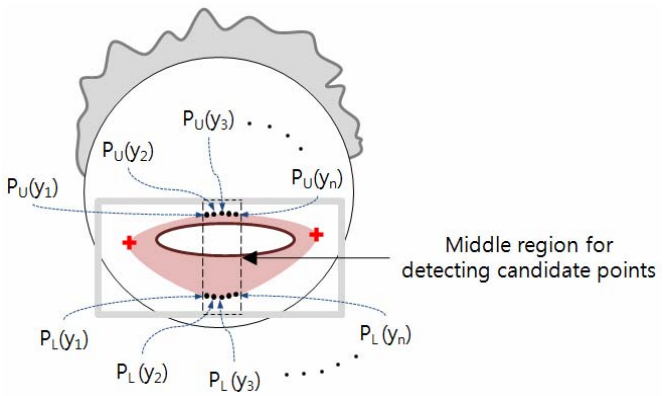


Fig. 5. Detecting candidate points on lip outline before extracting feature points

4 Implementation and Experimental Results

4.1 Implementation

In this work, we implemented a real-time smile training system using the proposed adaptive lip feature point detection algorithm which is irrespective of lip color. We used an OpenCV library [11] for capturing images from a camera and implementing basic image processing algorithms. The proposed system was implemented based on Visual C++ 2005. We used the built-in camera and display on a laptop computer for implementing the proposed algorithm. Instead of using a touch screen, we used a computer mouse for touch input, such as drawing a line on the lip.

We detected the lip feature points by using the proposed algorithm. First, in order to detect the mouth ROI, we used a Haar-like classifier integrated in the OpenCV library. Additionally, by checking the geographical relation between the detected face, eyes and mouth ROI, we were able to precisely detect ROIs, as shown in Figure 6. Moreover, we also detected four feature points on the lip by using the proposed adaptive lip feature detection algorithm irrespective of lip color, as shown in Figure 7. According to Tian's work, the lip shape can be represented by four points on the lip outline [14-15].

Because noise is always present in an image, however, the extracted feature points are shown as quivering in the real-time rendering. Therefore, we used a temporal storage to save the extracted feature points. When the current feature points on the lip were extracted, the proposed method calculated the mean position value among the currently extracted points and the previously stored points. By using the mediated position value of the feature points, the extracted points are able to be tracked more fluidly.

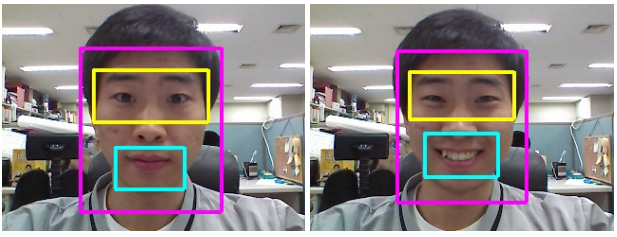


Fig. 6. Detected ROIs for frontal face, eyes and mouth

Fig. 7. Examples of the detection result of the lip feature points on lip

In order to support more intuitive training for a user's smile expression, we used the supportive guide model for the proposed system, as shown in Figure 8. By using the supportive guide model, users can intuitively recognize their target smile expression and can easily identify which direction they have to move to achieve it. By using the proposed visual instruction and feedback, users can more accurately and interactively train their smile expression simply by following the visual directional instructions, as shown in Figure 8(a). This visual instruction is shown by connecting lines from the detected corners of the user's mouth to the corners of the guide model. When a user smiles correctly, the supportive guide model changes the color of the visual feedback, as shown in Figure 8(b).

(a) (b)

Fig. 8. Examples of the visual instruction and feedback: (a) visual instruction showing the connected black line between corners of the mouth and model (b) visual feedback through the model's color change

4.2 Experimental Results

In this paper, we evaluated the performance of our proposed algorithm by using the captured frontal face image DB. The frontal face image DB is composed of 1,000 images acquired from 100 different facial expressions of 10 people using the proposed system. Among the 100 different expressions for each person, the first 50 are non-smile expression images, while the others are smile expression images. Each image in the frontal face image DB has a 24-bit color value with a pixel size of (320*240). We used a laptop computer with an Intel Core 2 Duo 2.4 GHz processor and 2GB SDRAM.

First, we measured the processing time for the proposed algorithm. As a result, our proposed system required 90.55 ms to run in our experimental environment. Specifically, ROI detection required 87.16 ms, the majority of the processing time, while our proposed algorithm required 3.35 ms to detect four feature points on a lip, as shown in Table 1. Even without optimization for the source code, the processing time was fast. With optimization, we could therefore expect even faster results during feature extraction.

In the second set of tests, we measured the detection accuracies of the corners of the mouth and feature points of the lip, shown in Table 2. The accuracies were measured based on the RMS (Root Mean Square) pixel error between the automatically detected points and those chosen manually. As can be seen in Table 2, the average

Table 1. Processing time of the proposed smile training system and algorithm

Algorithm - #1, System - #2		Processing time (ms)		
		Minimum	Maximum	Average
1	ROI detection	76.15	150.83	87.16
	Feature point detection	**1.83**	**5.37**	**3.35**
2	Entire processing time	78.82	154.79	90.55

RMS pixel error indicates a satisfactory working performance because the error pixel is less than the threshold value used for matching. Based on this, we determined a threshold of 4 pixels for detecting the corners of the mouth and 5 pixels for feature points on the lip. If the matching distances were larger than the predetermined threshold, our proposed system determined the facial expression was not a smile.

Finally, we determined the usability of the proposed system and the effectiveness of our algorithm through comments from test subjects. In terms of the proposed system, most of the users provided positive feedback, noting that mirroring the current smile expression with the guide model and direct feedback through visual instruction were intuitive and made it easy to train their smile expression. However, users also commented that the system did not support a wide variety of smile guide models and users wanted to receive a description along with the visual instructions. Users also noted that they needed more indication of success, rather than just showing the color change on the guide model. In terms of the proposed algorithm, most of users indicated that the simple procedure of drawing a line on the lip was effective and easy to use. From these results, we can conclude that, overall, the proposed system using the proposed algorithm is helpful for users to efficiently train for their target expression, despite several limitations indicated by the users.

Table 2. Detection accuracies of the corners of mouth and feature points on the lip

	Average errors for each features (pixel)		Average errors (pixel)
Corners of mouth	Left	3.65	**3.31**
	Right	2.96	
Feature points on lip	Upper	2.53	**3.52**
	Lower	4.51	

5 Conclusions and Future Works

This paper proposes an adaptive lip feature detection algorithm for a real-time smile training system with visual instructions. By using the guide model as a target smile expression, visual instructions and feedback, users can easily and intuitively train their smile expression.

For detecting the feature points of a lip irrespective of lip color, the proposed method does require some user participation, such as drawing a line on the lip. However, the proposed method is able to extract the feature points of a lip accurately. As described in the experimental results, the RMS error pixels for detecting the feature

points using our algorithm was less than 4 pixels. Therefore, we can determine that the proposed real-time smile training system using the proposed algorithm can provide positive results for smile expression training.

As future research, we plan to exchange the 2D guide model with an AR (Augmented reality) guide model. Also, we plan to consider pose tracking for the free movement of a user's head and the appropriate augmentation of the supportive AR guide model. By augmenting the supportive AR guide model to the correct position, the proposed system will provide seamless augmentation for the supportive AR guide model and no restriction of a user's head movement. We also plan to consider other components of smile expression, such as the eyes and furrow. Further, we would like to explore the possibility of running a cell-phone based algorithm to enhance convenience for the user. The user comments from this study, however, will be a primary consideration in any future undertaking in this area.

References

1. Kurokawa, T.: Nonverbal interface. Ohmsha, Ltd., Tokyo (1994) (in Japanese)
2. Yoshikawa, S.: Facial expression as a media in body and computer, pp. 376–388. Kyoritsu Shuppan Co., Ltd. (2001) (in Japanese)
3. Uchida, T.: Function of facial expression. Bungeisha, Co., Ltd. (2006) (in Japanese)
4. Mehrabian, A.: Silent messages, 2nd edn. Implicit Communication of Emotions and Attitudes. Wadsworth Pub. Co. (1981)
5. Ito, K., Kurose, H., Takami, A., Nishida, S.: Development of Facial Expression Training System. In: Smith, M.J., Salvendy, G. (eds.) HCII 2007. LNCS, vol. 4557, pp. 850–857. Springer, Heidelberg (2007)
6. Ito, K., Kurose, H., Takami, A., Nishida, S.: Development and Application of Facial Expression Training System. In: Holzinger, A. (ed.) USAB 2007. LNCS, vol. 4799, pp. 365–372. Springer, Heidelberg (2007)
7. Ito, K., Kurose, H., Takami, A., Nishida, S.: iFace: Facial Expression Training System. Affective computing, 319–328 (2008)
8. Wilson, P.I., Fernandez, J.: Facial Feature Detection Using Haar Classifiers. Journal of Computing Sciences in Colleges 21(4), 127–133 (2006)
9. Castrillón-Santana, M., Déniz-Suárez, O., Antón-Canalís, L., Lorenzo-Navarro, J.: Face and Facial Feature Detection Evaluation. In: International Conference on Computer Vision Theory and Applications (VISAPP 2008) (2008)
10. Harris, C., Stephens, M.: A Combined Corner and Edge Detector. In: Proceedings of the 4th Alvey Vision Conference, pp. 147–151 (1988)
11. Intel Open Source Computer Vision Library, `http://sourceforge.net/projects/opencvlibrary/`
12. Kruppa, H., Castrillón Santana, M., Schiele, B.: Fast and Robust Face Finding via Local Context. In: Joint IEEE International Workshop on Visual Surveillance and Performance Evaluation of Tracking and Surveillance (VS-PETS), pp. 157–164 (2003)
13. Viola, P., Jones, M.J.: Robust Real-time Face Detection. International Journal of Computer Vision 57(2), 137–154 (2004)
14. Tian, Y., Kanade, T., Cohn, J.F.: Recognizing Action Units for Facial Expression Analysis. IEEE Transactions on Pattern Analysis and Machine Intelligence 23(2), 97–115 (2001)
15. Tian, Y., Kanade, T., Cohn, J.F.: Robust Lip Tracking by Combining Shape, Color and Motion. In: ACCV 2000, pp. 1040–1045 (2000)

Fast Shape-Simplifying Image Abstraction Using Graphics Hardware

Hanli Zhao[1], Xiaogang Jin[1,*], Jianbing Shen[2], Li Shen[1], and Ruifang Pan[3]

[1] State Key Lab of CAD & CG, Zhejiang University, China
[2] School of Computer & Technology, Beijing Institute of Technology, China
[3] Zhejiang University of Media and Communications, China
http://www.cad.zju.edu.cn/home/jin

Abstract. This paper presents a new GPU-based method for creating abstracted representations of photographs. Based on the constrained mean curvature flow and the Shock filter, our approach simplifies both shapes and colors simultaneously while preserving and conveying the directionality of important features and shape boundaries. The level of abstraction can be intuitively controlled by iteratively and incrementally applying the algorithm. Note that the whole pipeline design is highly parallel, enabling a GPU-based implementation. Our GPU-based method outperforms the CPU-based one with two magnitudes of speedup. Several experimental examples are shown to demonstrate both the effectiveness and efficiency of the proposed method.

Keywords: Non-photorealistic rendering, image abstraction, flow-based filtering, GPU.

1 Introduction

Artists have learned that by making images look less photorealistic they enable audiences to feel more immersed in a story [10]. Simplified features in an image can often improve perception and facilitate comprehension, which has led researchers to investigate new non-photorealistic image processing techniques. In recent years, more and more image abstraction systems have been developed to make images easier or faster to understand [4, 6, 9, 15-17].

Recently, Kang and Lee [9] proposed a shape-simplifying abstraction technique to produce a variety of abstract images. By combining the mean curvature flow (MCF) [3], the flow tangent vector field (TVF) [8], as well as the Shock filter [12], their method simplifies both shapes and colors simultaneously while preserving important features. To selectively control the abstraction speed and to protect particular regions, they also incorporated the simple user masking into their algorithm. However, their algorithm takes about 30 seconds to complete 50 iterations for abstracting a 500*500 color image. Once the abstraction result is not satisfactory, artists must restart the time-consuming algorithm from scratch. Obviously, high computational cost

* Corresponding author.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 390–398, 2009.

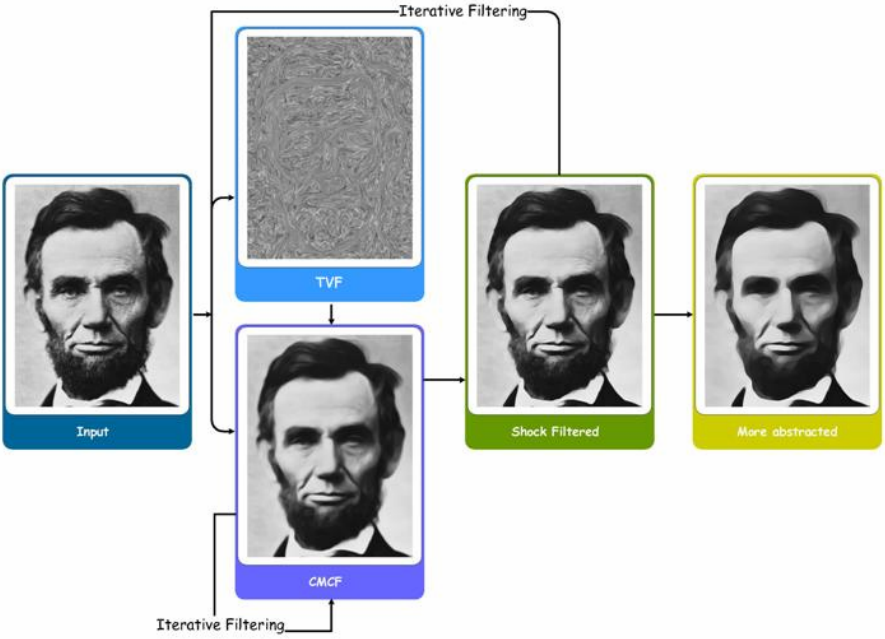


Fig. 1. Workflow overview

significantly limits their application. However, direct parallelization of Kang and Lee's algorithm is still hard to obtain real-time performance due to the high complexity of their algorithm.

In this paper, we present a new GPU-based method for creating abstracted representations of photographs. Our approach is based on Kang and Lee's shape-simplifying idea. We observe that the TVF construction is the major time-consuming component in their algorithm, which requires iterative bilateral convolution. We only construct the TVF once before performing the iterative evolution with constrained mean curvature flow (CMCF). Since the MCF is known as a useful tool for removing noise from images, we employ the standard Shock filter to enhance edges, without applying Gaussian blur before Laplacian operation. To achieve real-time performance, we then parallelize our new algorithm on the GPU by taking advantage of the locality of the algorithm. As a result, our approach simplifies both shapes and colors while preserving important features as Kang and Lee's original method.

In summary, the main contributions of this paper are as follows:

- A new shape-simplifying image abstraction framework.
- A GPU-based implementation for the whole pipeline.

The rest of the paper is organized as follows. Section 2 reviews some of related work. Section 3 describes our new algorithm, while experimental results and discussions are presented in Section 4. We conclude the paper and suggest future work in Section 5.

2 Related Work

Several image abstraction systems have been developed for creating enhanced or abstracted renderings from arbitrary photographs or videos.

Many stylization methods can only process offline images. Decarlo and Santella [6] progressively abstract images using a perception model guided with the eye tracker. However, the eye tracker is expensive and usually it is not a simple task to calibrate the eye tracker and track user's eye movements. Collomosse et al. [5] and Wang et al. [13] extended the stylization approach of Decarlo and Santella to video by treating a video sequence as a space-time 3D volume and then use the mean shift technique to segment the volume into contiguous volumes. Farbman et al. [7] abstracted a static image using an edge-preserving decomposition technique, which requires a time-consuming weighted least squares optimization over the whole image. Orzan et al. [11] performed progressive abstraction based on a control map derived from multi-scale Canny detection. Wen et al. [14] generated color sketches in a free-hand drawing style from images. Recently, Kang and Lee [9] abstracted images by simplifying both shapes and colors in an integral fashion. However, those techniques are implemented on the CPU and thus cannot achieve real-time performance. A major disadvantage is that user interactions must be prepared beforehand. Once the abstraction result is not satisfactory, the abstraction process must be restart from scratch. On the contrary, our system is implemented on the GPU and provides real-time visual feedback.

Some real-time abstraction systems have been proposed to process online images or videos. Winnemöller et al. [15] proposed an automatic real-time image and video abstraction framework. Chen et al. [4] improved the frame rates by introducing the GPU-based bilateral grid. Zhao et al. [16] extracted the coherent lines using graphics hardware to improve the abstraction effect. In order to automatically accentuate perceptually important objects, Zhao et al. [17] further proposed a real-time progressive abstraction component based on a region-of-interest function. However, these systems in general do not simplifying the region boundaries themselves, and thus may require an additional process of curve fitting and editing for further abstraction. In this paper, our approach is based on Kang and Lee's shape-simplifying idea [9] and therefore does not require any post-processing.

3 Our Approach

Our goal is to develop a real-time framework that simplifies both shapes and colors in an integral fashion. The basic workflow of our framework is shown in Figure 1. First of all, a TVF is constructed by iteratively bilateral filtering on the tangent edge curves. The smooth and coherent TVF indicates the salient feature direction of the input image. Then we iteratively simplify and shrunk the overall shape with the CMCF. Finally, the Shock filter is performed for better protection of edges. Note that the proposed pipeline is iterative and incremental, and therefore the level of abstraction is intuitively controlled.

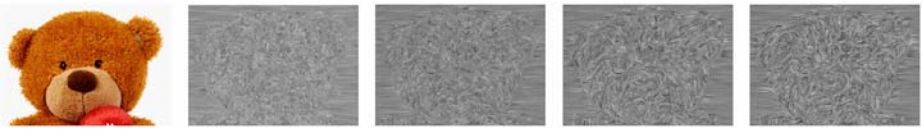


Fig. 2. Iterative TVF construction (from left to right): input teddy bear, initial field, 1st iteration, 2nd iteration, and 3rd iteration

Tangent Vector Field Construction

The construction of the TVF is originally proposed by Kang et al. [8] and accelerated by Zhao et al. [16]. We construct the TVF $v(x)$ iteratively using Zhao et al.'s GPU-based separable approximation. First of all, $v^0(x)$ is initialized as a vector perpendicular to the image gradient $g(x) = \nabla(x) = (I_x, I_y)$. After i^{th} iteration, $v^{i+1}(x)$ is obtained using the separable filter defined as follows:

$$v_h(x) = \frac{1}{v_h} \sum_{y \in \Omega_h(x)} w_m(x, y) w_d(x, y) v(y) \tag{1}$$

$$v_v(x) = \frac{1}{v_v} \sum_{y \in \Omega_v(x)} w_m(x, y) w_d(x, y) v(y) \tag{2}$$

Where $\Omega_h(x)$, $\Omega_v(x)$ denote the horizontal direction and vertical direction neighborhood of **x** respectively, and v_h, v_v are corresponding vector normalization terms.

The magnitude weight function w_m is defined as:

$$w_m(x, y) = \frac{1}{2}(1 + \tanh(\overline{g}(y) - \overline{g}(x)))$$

Where $\overline{g}(x)$ is the gradient magnitude at x. We can see that w_m ranges in [0, 1]. When a neighbor pixel's gradient magnitude is higher, this weight function value is bigger, and vice versa. This ensures the preservation of the dominant edge directions.

The direction weight function w_d is defined as:

$$w_m(x, y) = \frac{1}{2}(1 + \tanh(\overline{g}(y) - \overline{g}(x)))$$

As we can see, the value of this direction weight function increases as the angle between the two vectors decrease. If the angle is bigger than 90°, the direction of $v(y)$ is reversed before smoothing, avoiding swirling flows.

The filter actually uses a separable approximation to construct the TVF, and thus we can parallelize it with two rendering passes on modern graphics hardware. The initial gradient field $g^0(x)$ is calculated using the Sobel operator, and $v^0(x)$ can be easily obtained. Then the separable bilateral filter is iteratively applied to smooth the TVF. It is known that the texture access operation is a bottleneck of current graphics hardware. To reduce the filtering time, $\overline{g}$ and v are rendered to the same render target in each rendering pass. As a result, we only need one texture lookup for each neighbor pixel. Note that the gradient field g evolves accordingly whereas the magnitude $\overline{g}$ is unchanged. In this paper, 2 or 3 iterations are enough. In order to better illustrate the filtering effect, we visualize the TVF in Figure 2 using line integral convolution [2].

Constrained Mean Curvature Flow

If we view $I(x)$ as a height field, where height represents intensity, we should be able to draw the iso-luminance contours called isophote curves. The CMCF, when applied on the image, regularizes the geometry of each of these isophote curves. The speed of regularization is constrained with the TVF $v(x)$. Formally, after i^{th} iteration, $I^{i+1}(x)$ is obtained using the following evolution equation [9]:

$$I(x) = I(x) + a \cdot s(x) \cdot \kappa(x) \cdot \overline{g}(x) \tag{3}$$

Where $a \in [0,1]$ is a parameter controlling the overall speed of regularization. In case of a color image, RGB channels are processed separately.

The local isophote curvature κ is computed as follows [3]:

$$\kappa = \frac{I_x^2 I_{yy} - 2 I_x I_y I_{xy} + I_y^2 I_{xx}}{(I_x^2 + I_y^2)^{3/2}}$$

The intensity increases where $\kappa > 0$ (convex), and decreases where $\kappa < 0$ (concave). This results in the simultaneous abstraction of both region boundaries and colors.

The speed control function s in Eq. 3 is defined as:

$$s(x) = (1-b) + b \cdot \left| v(x) \cdot v^{0'}(x) \right| \tag{4}$$

where $b \in [0,1]$ is a control parameter and $v^{0'}$ denotes the normalized vector perpendicular to the current local gradient. If $v^{0'}$ is not aligned with v, small s will result. That is, it discourages the regularization along anything but the salient feature

Fig. 3. Various operations on Teddy bear (from left to right): (a) CMCF, (b) Shock, and (c) abstraction

directions of the input image. Therefore, Eq. 4 has the effect of protecting the directionality of features, shapes, and texture patterns. Moreover, as it directs the diffusion of colors along feature directions, it adds to the stylistic look of the output. For better illustration, we show a result of CMCF in Figure 3a.

Shock Filtering

The CMCF aggressively contracts isophote curves by blurring pixel intensities along salient edge directions. Iteration of such shrinking and blurring eventually obliterates most of the height discontinuities in the image, some of which may be of interest to the viewers. For better protection of edges, Kang and Lee [9] further performed edge enhancement by the Shock filtering.

Kang and Lee also employed a Gaussian function to reduce the sensitivity to image noise and also to help control the size of the influence zone. We observe that the CMCF is also effective for removing noise while the Gaussian convolution would be one of the time-consuming components. Thus we employ the standard Shock filter instead [12]:

$$I(x) = I(x) - c \cdot sign(\Delta I(x))\overline{g}(x) \tag{5}$$

Where $c \in [0,1]$ is a parameter like a in Eq. 3 controlling the overall speed of sharpening and $\Delta I = I_{xx} + I_{yy}$ is the Laplacian operator, the second spatial derivative of the image. As a result, the Shock filter sharpens the discontinuities between heterogeneous regions, whereas it flattens each homogeneous region. When only Shock filter is applied, the effect will be as shown in Figure 3b. We can see that the underlying edges are enhanced. We also show the abstraction result when combined with CMCF in Figure 3c.

Table 1. Performance statistics of our method

Grid size (cells)	256*256	512*256	512*512	1024*512	1024*1024
FPS	15.3	7.1	3.2	1.7	0.9

Experimental Results and Discussions

Since Direct3D 10 constitutes a large step forward from previous generations of the rendering pipeline, we implemented our GPU-based framework based on High Level Shading Language (HLSL) [1]. We have tested the tool on some scenes in order to evaluate its effectiveness and efficiency. All tests were conducted on a 2.40GHz Intel Core 2 Quad Q6600 CPU with an NVIDIA GeForce 8800 GTS (512MB) GPU.

Table 1 shows the performance statistics of our method in FPS. In all tests, we set 11 pixel-sized kernel and 2 iterations for filtering the TVF, 10 iterations for CMCF per pass, and 50 passes of Shock filtering. We can see that our method can achieve real-time performance for images with low resolutions. For images with 512*512 resolutions, we are able to obtain 3.2 FPS, while timing of 30 seconds is reported in [9]. Our GPU-based method outperforms the CPU-based one with two magnitudes of speedup. Obviously, high computational cost significantly limits the application of Kang and Lee's algorithm.

Fig. 4. Test images

For the test images in Figure 4, we show some abstraction effects using our method in Figure 5. All these images give vivid visual perception. Based on the constrained mean curvature flow and the Shock filter, our approach simplifies both shapes and colors simultaneously while preserving and conveying the directionality of important features and shape boundaries. In addition, we have also incorporated the fast feature-aware line drawing style [16] into the proposed shape-simplifying framework to improve the abstraction effect. Both the flower and the mountain images in Figure 5 demonstrate the effectiveness.

Fig. 5. Various abstraction effects using our method

Conclusions

In this paper, we present a novel GPU-based shape-simplifying abstraction system that automatically abstracts images based on TVF. The whole pipeline in this paper is

implemented automatically in real time. At last, the experimental results demonstrate both the feasibility and efficiency of our proposed algorithms.

Since the accelerated algorithm in this paper is still an iterative and incremental one, we would like to seek a better method that simplifies the image shapes while requires only one iteration.

Acknowledgments. This work was supported by the National Natural Science Foundation of China (Grant No. 60533080) and the Key Technology R&D Program (Grant No. 2007BAH11B03).

References

1. Blythe, D.: The Direct 3D 10 system. In: Proc. ACM SIGGRAPH 2006, pp. 724–734. ACM, New York (2006)
2. Cabral, B., Leedom, L.C.: Imaging vector fields using line integral convolution. In: Proc. ACM SIGGRAPH 1993, pp. 263–270 (1993)
3. Catté, F., Lions, P., Morel, J., Coll, T.: Image selective smoothing and edge detection by nonlinear diffusion. SIAM Journal on Numerical Analysis 29(1), 182–193 (1992)
4. Chen, J., Paris, S., Durand, F.: Real-time edge-aware image processing with the bilateral grid. ACM Trans. Graphics (SIGGRAPH 2007) 26(3), article 103 (2007)
5. Collomosse, J.P., Rowntree, D., Hall, P.M.: Stroke surfaces: temporally coherent artistic animations from video. IEEE Trans. Visualization and Computer Graphics 11(5), 540–549 (2005)
6. DeCarlo, D., Santella, A.: Stylization and abstraction of photographs. ACM Trans. Graphics (SIGGRAPH 2002) 21(3), 769–776 (2002)
7. Farbman, Z., Fattal, R., Lischinski, D., Szeliski, R.: Edge-preserving decompositions for multi-scale tone and detail manipulation. ACM Trans. Graphics (SIGGRAPH 2008) 27(3), article 67 (2008)
8. Kang, H., Lee, S., Chui, C.K.: Coherent line drawing. In: Proc. ACM Sym. Non-Photorealistic Animation and Rendering (NPAR 2007), pp. 43–50 (2007)
9. Kang, H., Lee, S.: Shape-simplifying image abstraction. Computer Graphics Forum (PG 2008) 27(7), 61–68 (2008)
10. McCloud, S.: UnderStanding comics. Harper Collins Publishers, New York (1993)
11. Orzan, A., Bousseau, A., Barla, P., Thollot, J.: Structure-preserving manipulation of photographs. In: Proc. ACM Sym. Non-Photorealistic Animation and Rendering (NPAR 2007), pp. 103–110 (2007)
12. Osher, S., Rudin, L.I.: Feature-oriented image enhancement using shock filters. SIAM Journal on Numerical Analysis 27(4), 919–940 (1990)
13. Wang, J., Xu, Y., Shum, H.Y., Cohen, M.F.: Video tooning. ACM Trans. Graphics (SIGGRAPH 2004) 23(3), 574–583 (2004)
14. Wen, F., Luan, Q., Liang, L., Xu, Y.Q., Shum, H.Y.: Color sketch generation. In: Proc. ACM Sym. Non-Photorealistic Animation and Rendering (NPAR 2006), pp. 47–54 (2006)
15. Winnemöller, H., Olsen, S.C., Gooch, B.: Real-time video abstraction. ACM Trans. Graphics (SIGGRAPH 2006) 25(3), 1221–1226 (2006)
16. Zhao, H., Jin, X., Shen, J., Mao, X., Feng, J.: Real-time feature-aware video abstraction. The Visual Computer (CGI 2008) 24(7-9), 727–734 (2008)
17. Zhao, H., Mao, X., Jin, X., Shen, J., Wei, F.: Real-time saliency-aware video abstraction. The Visual Computer (in press, 2009)

Music-Making and Musical Comprehension with Robotic Building Blocks

Niels Kristian Bærendsen, Carsten Jessen, and Jacob Nielsen

Center for Playware
Technical University of Denmark
The Danish School of Education, Aarhus University
Building 325, 2
2800 Lyngby
nkb@playware.dtu.dk, cje@playware.dtu.dk,
jacob_nielsen@teknologisk.dk

Abstract. Being able to express oneself musically and experiment with music composition is traditionally determined by one's ability to play an actual instrument with a certain degree of craftsmanship. Lack of skills may cause difficulties for children and young people to experience the joy of musical creativity. This paper presents a project where modular robotics is used to create a platform for creative musical expression that allows users to experiment with musical genres without any prior musical knowledge or skills. The project is an example of how to create "intelligent learning material" for educational use.

Keywords: Playware, music technology, music education, music-making, play, learning, constructivism.

1 Introduction

This paper presents a research project on creative music-making and musical comprehension and expression through the use of digital technology integrated in robotic building blocks. It is initiated as part of the continuous research at the cross-disciplinary Center for Playware, where researchers from the humanities, engineering and robotics cooperate closely to create new products for play and playful learning. The project presented here, tentatively named the RoboMusicKids project [1], aims at developing new ways for children to engage in music-making and experimentation by the use of elements from the field of modular robotics. The technology used is intelligent blocks, I-BLOCKS, which are small self-contained computer units that can communicate with each other when physically connected. In the RoboMusicKids project the user is able to create and experiment with musical composition when connecting the blocks in different ways using a multitude of pre-recorded instrumental and vocal figures. The combination of modular robotics and music in RoboMusicKids is in our view a new approach to music making that allows children to learn by doing through manipulation of physical objects and gain knowledge about music in the same natural manner as young children commonly

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 399–409, 2009.

learn to know their environment through physical interaction. In relation to learning and technology in general, RoboMusicKids is an example of how learning can be transformed by altering the behavior of the objects that we allow children to get their hands on. In the project the objects become what we term "intelligent learning material", which in use functions just as any other physical, tangible material in the hands of the user, who can manipulate and experiment freely. The pivotal difference in a learning perspective compared to other material is that advanced digital technology and robotics allow us to create physical products with behavior that can be learned through inductive thinking using observation, trial-and-error, and testing of hypothesis, which is a very natural way of learning, according to constructivist learning theory. This means that abstract concepts, models, and theory, which are difficult to explain and understand, can be made tangible and concrete to the learner. When creating intelligent learning material it is important to combine the technology and the specific subject field in such a way that the desired learning outcome will appear.

The RoboMusicKids project is based on the notion that technology, when used in a specific manner, can serve as a gateway into musical expression, experimentation and play, with the possibility of bypassing obstacles which may stand in the way of this in the more traditional musical contexts, such as the need of a certain type of craftsmanship, specific aptitudes or abilities.

In this paper we present our empirical findings from two user experiments as well as some key elements of the projects theoretical foundation. While the technology used in the project plays an important role in making this type of musical experimentation possible, our main goal is investigating new ways for children to engage in music making and the ways in which this was carried out and observed in our research. We will turn our attention mainly towards perspectives concerning musical learning and particularly musical comprehension and musical creativity.

2 Existing Music-Making Technologies and Concepts

Various research projects as well as commercial products exist that combine music making, musical play or other forms of musical engagement with new technologies. While the computer's potential in regard to music making and musical expression is a fairly well-investigated field, the projects and products we will mention in the following paragraph combine music with technologies and aggregates that we can touch, move around and interact with in a physical space. This specific field has received great attention in recent years resulting in a wide range of products and concepts that present new ways of approaching music-making and musical expression using new technologies, new approaches to design and various sensing techniques.

The amount of interesting projects and products is large and ever growing. We have chosen to point out a few important projects that we believe have had or may have a great impact on future research and our understanding of the ways in which technology and music making can be joined together with great result.

The BeatBug

The Beatbug [2] is a hand-held percussive instrument that allow the creation, manipulation and sharing of rhythmic motifs through a simple interface. Several Beatbugs can be connected in a network, thereby letting the players form large-scale collaborative compositions. The Beatbugs are the end result of a series of projects investigating new forms of musical interaction by the use of technology. Much like the RoboMusicKids project, the Beatbug project is informed by a constructivist approach to learning and a main goal in the development of the Beatbug has been to create an instrument or controller which provides both novices as well as musically adapt users the possibility of expressing themselves through musical composition.

The ReacTable

The ReacTable [3] is a table based tangible user interface with which the user is able to generate and control sound by touching or placing various objects on the tabletop interface. The project is initiated by its creators' wish to create an interface using the advantages of computer technology in regard to sound production and control of the musical output but without the necessity of using usual 'computer tools' such as the keyboard and mouse. While the interface allows for everyone to produce sound, it is a very complex system which requires skill and practice in order to get a feeling of being able to create the exact musical output that one wishes to produce. It is our impression that it is mainly created as an instrument aimed at professional musicians.

Zizzle Zoundz

Zizzle Zoundz is a musical toy with which the user can experiment with music-making by placing various objects one three hotspots on a butterfly-shaped board. Touch-sensitive buttons on the board allow for experimentation with various sound effects, and by placing the differently shaped objects on the hotspots a range of variations are available. Another feature is the possibility of recording your own samples – for instance your voice – and use for experimentation. While Zizzle Zoundz is a toy designed to create playful experiences with musical experimentation it has potential in regard to music teaching as well, offering a simple approach to electronic music-making.

Sony Block Jam

Sony Block Jam [4] is a musical interface controlled by the arrangement of 25 tangible blocks. By arranging the blocks musical phrases and sequences are created, allowing multiple users to play and collaborate. The system takes advantage of both graphical and tangible user interfaces. Much like the RoboMusicKids project, the creators of the Sony Block Jam aim at creating a musical controller which is fun and engaging for both musically trained users as well as beginners, albeit not with a pronounced purpose in regard to music education or learning as such.

While the aforementioned projects share similarities with the RoboMusicKids project, none of them aim specifically towards development of musical comprehension through music making or the integration of a multitude of genres on the same platform.

3 The RoboMusicKids Project

Part of our approach to the RoboMusicKids project was based on a desire to create an alternative way of approaching music-making and musical expression much like in the projects mentioned above. However, we took notice that the musical output the user could create in most of the recent projects in the field was characterized by sounds, melodic figures and rhythms typically found in electronic music genres. We wanted a musical scenario where the user was able to experiment with music from a wide range of genres, including e.g. 1940's jazz, 1970's reggae, 1980's thrash metal and early rock n' roll and rockabilly.

The basic idea behind the project is to separate the components of a musical piece and connect these components to the blocks giving the user the possibility of creating his or her own arrangement of a musical piece by connecting the blocks in various ways. We will get back to how the music is structured after the following, which is at short description of the technology used.

3.1 I-BLOCKS Technology

The I-BLOCKS are cubic modular robotic building blocks that can communicate with each other when physically connected. Each cube is fully self-contained with respect to power, connectors and processing. At the edges of a cube are 4 RGB LEDs, which can light up in different colors. The I-BLOCKS communicate locally via IR-transceivers. Each I-BLOCK makes use of a 3D accelerometer to detect its orientation with respect to gravity. This makes it able to detect, for instance, which side is facing down. The I-BLOCKS connect physically to each other using magnets, allowing for uni-sex connection at 90-degree angles.

The music created by the user is computed and played back on a PC, using the Ableton Live © music software as a playback unit responding to midi messages coming from the I-BLOCKS. In order to allow the blocks to “talk midi” to a PC we have made a wireless device, named “Midi Box” that converts serial wireless data coming from an XBEE-enabled ‘master I-BLOCK’ into midi signals. By using wireless technology we allow users to manipulate the blocks freely just like conventional building blocks.

Note the black master I-BLOCK in figure 1, which communicates wirelessly with the Midi Box, and therefore has to be present in every construction, in order for the PC to generate music.

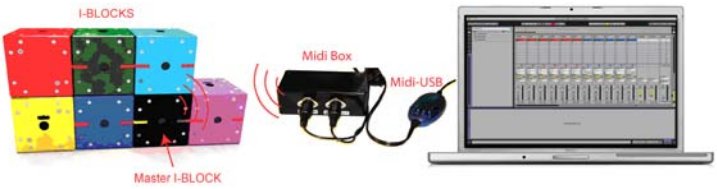


Fig. 1. Music setup with I-BLOCKS, Midi-box and PC

3.2 The Project's Musical Content

As mentioned, the music that has been produced for the project has been composed using a set of well defined genre characteristics from a selection of music genres. Also the actual recording of the music has been done in the same way or similar to the ways in which music of that particular genre was originally recorded.

The pieces of music in this project have all been constructed using these rules: There are six predefined instruments (varying according to genre) and within each piece of music there are six variations per instrument – one for each side of the block. Every variation on every instrument must fit together rhythmically and harmonically so that every possible composition of instruments will result in a well-sounding outcome. When the user grabs an I-BLOCK, representing an instrument, the block's orientation - which side is facing up - determines the variation of that specific instrument. The I-BLOCK LEDs change color depending on their orientation, in order to make it possible for the user to remember and activate specific variations. Each of the instrument I-BLOCKS has been given a color to represent a specific instrument. For instance, the color coding for a 1950's rockabilly track has been implemented as follows:

Red: Drums
Blue: Double bass
Green: Piano
Yellow: Guitar
Cyan: Lead vocals
Pink: Choir / backup vocals

The music is loop-based, meaning that when active, each variation of each instrument is playing a certain time and then repeating itself over and over until it is finally deactivated when the user removes the current instrument I-BLOCK from the structure or shifts its orientation.

A short example: A user connects a yellow guitar I-BLOCK to the black master I-BLOCK. Immediately the PC-music software starts playing one of six guitar tracks depending on how the block is rotated when connected. Another user might then add a red drum I-BLOCK to the structure, which will additionally initiate a drum track, which is synchronized with the guitar track. More instruments can be added, and others removed, and all instruments will constantly be in sync. If the user chooses to rotate the entire structure, all the instruments present will start playing a different variation.

This manipulation with musical pieces is a kind of "sampling in real time" which is known from music software on computers (e.g. Ableton Live and Garage Band). The difference between such software and RoboMusicKids is, of course, the physical building-blocks that allow for a more intuitive hands-on approach.

4 User Experiments

During the development of the music integrated in the I-BLOCKS we ran a number of tests and experiments in order to figure out how users responded to the music as well

as the way in which the blocks enabled them to navigate this. The following section focuses on two experiments carried out in an after-school centre and presents some of the observations we made in the execution of these.

4.1 After-School Experiments

The experiments at an after-school centre were of an explorative nature, as our focus was towards discovering ways to improve both the music implemented in the I-BLOCKS and ways to experiment with this as well as discovering the projects' potential regarding musical comprehension and musical creativity. The participating children, aged between 10 and 12, were divided into groups of four. Some of these groups consisted of only boys or girls and some were mixed groups. Some of the children had prior experience with formal instrumental music tuition while others had little or no experience. All group sessions were recorded on video.

The following is a description of some of the main findings as observed in the participants' use of the I-BLOCKS. In this description an overall pattern regarding the structure of events observed in each session is presented, serving also as a possible outline of the learning process among the participants.

4.2 User Sessions and Their Overall Structure

Reviewing the recorded sessions, we were able to divide each group session into three steps or phases. As hinted above, the mentioning of these steps serves as a description of the actual use of the I-BLOCKS as well as a framework for the later mentioning of perspectives in regard to music-making and musical experimentation with new technology. The three steps observed in the experimental sessions are as follows:

1. Exploratory use. Together as a group the children explored different ways of connecting the I-BLOCKS and the different musical segments and variations that resulted from this. This step was characterized by the children's fascination of the technology itself and the fact that by combining the I-BLOCKS they were able to initiate music. Everyone in the group would at this point actively connect and disconnect blocks and turn the structure around in an exploratory manner. No particular interest in the qualitative musical output and the actual combination of instruments and musical loops was apparent. The main interest among the children at this point was to activate and "check out" the different loops, and - to a certain degree - find out which colors represented which instrument or sound.

As in many other regards, exploration of something - for instance a toy that one is not familiar with - is a natural approach. Therefore the explorative way in which the participating children approached this new toy was to be expected. What we saw was children employing the basic learning principles, which leading education theoreticians like Piaget, Dewey, and Vygotsky have described as, for instance, "active learning", "hands-on learning" and "experimental learning", and which they have pointed to as fundamental for children's learning. Of particular interest is the observation of cooperation as well as turn-taking among the participants during their further exploration and music-making, as described in the following.

2. Collaborative music-making. Following the exploratory phase, the children started to pay more attention to the actual musical output of their collaborative use of the I-BLOCKS. Typically this involved discussion among the participants regarding which instruments were audible during their construction of a structure and which variation of this particular instrument they preferred. Typically one participant would start off by connecting an I-BLOCK as a starting point, choosing a loop that they were particularly fond of. Another participant would connect another block, choosing a loop which they felt accompanied the first loop. From here on the group would experiment with the different loops and the structure of the blocks. At times this involved turning the entire structure around and thereby changing the entire musical output, and at other times turning single blocks, changing only the musical output of this particular instrument. The music-making and the learning approach in this phase was still very much a collaborative effort, but did, however, at this point involve a key element of turn-taking allowing the participants to single-handedly control the blocks and the position of the structure, having the other participants suggesting changes and supplying ideas.

3. Individual music-making. In each session we encouraged the participants to create their own musical piece or "mix", having complete control over the blocks. At this stage it was particularly clear that I-BLOCKS served as a useful tool for musical expression, composition and performance. To a varying degree the participants would examine each block to choose the loop they wanted to use and be very selective in this process. Often they would leave one or two blocks out of the mix in order to receive the output or sound they wanted, avoiding the overall mix getting clustered or "muddy". Some participants would start off by creating a combination of instruments and loops that they found fit together and subsequently change the entire structure, serving as another development of the song or tune. This resulted in a series of combinations of loops compromising not just a single mix but several developments of a tune.

A striking observation made during these experiments was that every participating child was able to create a well-sounding and personal musical piece within the short time of a session (lasting approximately 15 minutes). Everybody participated in collaborative as well as individual music-making and completed the task of creating a mix of their own regardless of their prior experience with instrumental music tuition.

5 Music-Making with New Technology

Traditionally, being able to express oneself musically and engage in musical activities involving the production of sound, is somewhat determined by one's ability to play an actual instrument. In order to produce sound with an instrument one must possess a minimum of skills in regard to the actual handling of the instrument. In order to compose or in other ways carry out musical ideas a certain degree of craftsmanship and experience is needed [5] and this is a hindrance for most children, who for that reason might not experience the joy of musical performance and creation.

As technological development and research generates different possibilities in approaching music-making and musical experimentation, new paradigms of musical expression, comprehension and creativity are formed. While technology plays an important role among musicians, e.g. in regard to recording music or performing music utilizing different technological tools, the development of computer software designed for music production and creation (Steinerg Cubase, Apple Logic etc.) as well as different types of midi controllers (e.g. midi keyboards, electronic drum kits, Korg's Kaossilator and new interfaces such as The Samchillian, Monome, Beat Bugs etc.) has had an important impact in regard to musical play among children and in music teaching in general. In the following we wish to point out some of the possible advantages linked to the use of new music-making technologies, both in music education and out of school.

Norwegian professor of musicology and music education, Petter Dyndahl, has emphasized how "new" technology, for instance sequencing software or the midi standard as such, has made new ways of approaching musical creativity possible. According to Dyndahl a digital representation of music on a computer allows us to "mould directly" in the authentic, timbral substance [6], which brings to mind conceptions of music as a physical, moldable object. Like modeling-wax – flexible and manageable in the hands of the user. Sequencing software, for instance, allows us this kind of flexibility. We can record music of our own, sample existing recordings and manipulate sounds in an infinite amount of ways. Utilizing technology in the creation of music, we may experience a shortening of the distance between an idea and its actual aural representation. In fact, technology may even allow the non-musician access to a creative process involving music in ways previously unimaginable.

Professor of music education and technology Peter Webster has described creative thinking in music as a creative process in which we engage via either enabling skills or enabling conditions or both [7]. Webster's thinking can help us illustrate how music technology may help us gain access to a creative process which may reveal certain talents otherwise hidden. By using the term 'creative' we are referring to the process of creation as such and not focusing on the actual end product and any form of valuation of this. 'Creative' is not to be mistaken for 'original' or 'unique'. This view is informed by Ignacio L. Götz's definition of creativity [8] which describes creativity as the very process of making, placing it at the final stage of Graham Wallas' famous four stages describing the creative process: preparation, incubation, illumination and verification [9].

Webster uses Wallas' stages as well: in order to gain access to this creative process we need a way in. Traditionally, what we need in order to be able to be musically creative is *enabling skills*. This could be a range of aptitudes such as certain sensitivity towards rhythmic or tonal patterns and movements or the ability to express ourselves in an original manner or be very flexible in our approach to music making and our playing. Another enabling skill is craftsmanship; the ability to sing or play a musical instrument at a certain level, which is perhaps the main enabling skill in this regard, while the above mentioned aptitudes serve as further developments of our musicality alongside craftsmanship. Yet another enabling skill is a well developed aesthetic sensitivity.

Another way of gaining access to the creative process is through the *enabling conditions*. These may be certain aspects of our personality or motivational factors. The environment is a crucial element as an enabling condition as it contains a long list of outside factors that may influence us, inspire us, motivate us or in other ways enable us to be musically creative. Parents, friends, teachers, equipment and technology are parts of this category.

Looking back at some of the results we obtained from our user experiments, a key discovery was that every participant, regardless of his or her musical background, was able to engage in the creation of a musical piece and apparently feeling joy doing so. The blocks served as a piece of music technology which made it possible for the users to be musically creative – to make music, certainly within the limits of the prerecorded music we made for the blocks, but still they were able to make their personal musical pieces . An interesting aspect in regard to this is the question as to how children who normally do not engage in music making activities at home or in school may reveal certain aptitudes such as originality or flexibility in their musical expression or a well developed aesthetic sensitivity when utilizing musical toys or other kinds of music technology. When the need of a certain kind of craftsmanship in order to make music is eliminated certain aptitudes and skills otherwise hidden may reveal themselves. The music teacher may realize that pupils, who have troubles developing instrumental skills or may lack interest in taking up an instrument, actually possess skills in regard to knowledge of musical genres, having a well-developed sense of aesthetics in music or being very original in their musical expression when utilizing "untraditional" tools in their creation of music. While our user experiments hinted towards this as a possible outcome additional studies which focus on this exact issue are needed in order to draw further conclusion in relation to this.

While projects such as the aforementioned Beat Bugs or ReacTable allow the user to create rhythmic patterns or experiment with harmonic and timbral sound material, the RoboMusicKids project aims at allowing children to experiment and manipulate with pre-recorded musical sequences or elements, reminiscent of the way a DJ remixes existing tracks. The I-BLOCKS serve as a multi-track mixer giving the user complete control over the progression and overall mix and arrangement of the track. Furthermore, I-BLOCKS allow the user to isolate the separate elements of a musical piece, making it possible for him or her to understand the sound and musical role of different instruments, both in regard to musical arrangement and mix and in regard to music history, traditions of musical genres and sub-genres, technological possibilities in connection to studio equipment and the recording of music and so forth.

6 Perspectives on Learning from a Constructivist Viewpoint

In the development of the idea behind the RoboMusicKids project a main inspiration in regard to creating educative experiences for children has been Seymour Papert's writings and experiments in the field of computers as an educational tool and his LOGO programs and concept. We find his use of Jean Piaget's theories about learning and understanding to be a key element in a theoretical foundation for a constructivist approach to the development of educational learning products.

A keystone in this approach is the notion that in order to learn and gain knowledge about something children must be able to experiment with different materials and be able to construct meaningful artifacts as part of this. Papert himself showed this in his many experiments involving children's use of the well-known LOGO programs and their construction of different technological inventions and aggregates [10].

Piaget's theory on adaption as a learning principle and learning as an individual process is the point of departure in Papert's work and a theoretical base upon which educational practice can stand. What we learn and how we learn depends on what we know and what we have experienced. According to Papert, we should make room for our pupils to address problems in various ways in the classroom, making use of what they know and do in order to solve problems and gain new experiences and knowledge as part of the process. Being able to use the enormous amount of knowledge and experiences obtained in 'informal' learning situations out of school is important in this regard. Papert points to drawing as an example of a practice that often is a part of children's play which they may use to solve different kinds of problems and tasks in a school context when given the opportunity to do so, and in the LOGO program drawing is used brilliantly as an entry point to math learning [11].

The I-BLOCKS used in the RoboMusicKids project share similarities with certain kinds of toys, such as building blocks or LEGO, which children typically have had experiences playing with, hence our description of the interface as 'intuitive'. While computer software may require quite a bit of practice to get used to using, the blocks are self-explanatory, inviting the user to start building. We need not explain to the children how to use the blocks to build a structure. They already know; it is a part of their play culture. As a result of this, their attention is drawn towards the music making and the musical choices they make as part of this creative process. Not towards the technology or tool itself.

While Papert has served as an inspiration to our research, the RoboMusicKids project differs from Papert's work in (at least) one significant way: The Logo program is based on an approach which involves planning and programming as stages to be completed before achieving an actual result: write code first, watch the result afterwards [10]. When using the blocks to make music you receive an immediate result while you change the direction of the blocks or the entire structure that you have built, hence the "sampling in real-time" mention earlier. This approach is also the reason why one can talk about the music as a parallel to "modeling-wax".

7 Conclusions

I-BLOCKS make it possible for the user to rearrange and manipulate musical elements and create a musical output. In our experiments we found that the participants were aware of how they wanted their finished musical piece to sound, and were very selective in the process of "building" this.

While music technology in some cases holds the risk of allowing us to simply generate a musical product and bypass the actual creative process, our experiments showed that even when utilizing prerecorded music in a basic setup of six variations on six different instruments, the participants were still able to express themselves creatively.

Utilizing music technology in music education and out of school may give children, or adults, the opportunity to be musically creative and create understanding of musical phenomena and structures. I-BLOCKS represent an intuitive approach to music, both in regard to musical expression as well as musical comprehension and understanding. In the hands of the user, the I-BLOCKS turn music into a moldable element, allowing the user to explore its possibilities in a creative and playful way and serve as an intelligent tool that is manageable and flexible in regard to its user's approach to creativity and learning.

References

1. Nielsen, J., Bærendsen, N.K., Jessen, C.: RoboMusicKids - Music Education With Robotic Building Blocks. In: Proceedings of the 2008 Second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning, pp. 149–156 (2008)
2. Weinberg, G.: The Beatbug – Evolution of a Musical Controller. Digital Creativity 19(1), 13–18 (2008)
3. Jordà, S., Geiger, G., Alonso, M., Kaltenbrunner, M.: The reacTable: Exploring the Synergy between Live Music Performance and Tabletop Tangible Interfaces. In: Proceedings of the first international conference on Tangible and Embedded Interaction (2007)
4. Sony Computer Science Laboratories, Inc., `http://www.sonycsl.co.jp/IL/projects/blockjam/`
5. Folkestad, G.: Computer Based Creative Music Making: Young People's Music in the Digital Age. Acta Universitatis Gothoburgensis, Göteborg (1996)
6. Dyndahl, P.: Music/Technology/Education. On Digitised Music Education, its Discourse and (Self-)Irony (in Norwegian) University of Oslo, Olso (2002)
7. Webster, P.R.: Conceptual Bases for Creative Thinking in Music. In: Peery, J.C., Peery, I.W., Draper, T.W. (eds.) Music and Child Development. Springer, New York (1987)
8. Götz, I.L.: On Defining Creativity. The Journal of Aesthetics and Art Criticism 39(3), 297–301 (1981)
9. Wallas, G.: The Art of Thought. Harcourt Brace Iovanovich Inc., New York (1954)
10. Papert, S.: Mindstorms - children, computers and powerful ideas. Basic Books, New York (1980)
11. Papert, S.: The Children's Machine. Havester Wheatsheaf, Herthfordshire (1993)

AdMoVeo: A Robotic Platform for Teaching Creative Programming to Designers

Sjriek Alers and Jun Hu

Department of Industrial Design
Eindhoven University of Technology
5600MB Eindhoven, The Netherlands
{s.h.m.alers,j.hu}@tue.nl

Abstract. Designing intelligent products, systems and related services require the designers to be able to integrate technology in their designs. Among other skills, programming is the key for the designers to prototype and experiment with the intelligent behaviors. However most of the design students do not have inherent affinity towards programming and electronics. The AdMoVeo robotic platform is designed, purely for the purpose of teaching the industrial design students basic skills of programming. Moreover we aim at a platform that motivates and encourages the design students to explore their creativity with their passions in graphical and behavioral design. This paper presents the hardware and software design of the platform, and shares the experiences in using it in a programming course.

Keywords: creative programming, industrial design, robotic platform.

1 Introduction

The discipline of Industrial Design is redefined at the Department of Industrial Design at Eindhoven University of Technology, following the needs from the creative industries of lifestyle, healthcare and wellbeing, preparing students for a new type of engineering discipline: design and creation of intelligent products, systems and related services [1]. These systems, products and services are required to be adapted to the user and thereby provide a new experience. To design and create these systems, products and services, the education must cover a broad area of technology, such as computer science, electronics and mechanics, not mentioning other areas of form giving, user centered design and business process. The aim of the education is to provide the students with capabilities to break the barriers among science, design and engineering [2] and integrate these disciplines in their designs.

As Hu et al [3] point out, the industrial design of intelligent products and systems is a contemporary challenge which deserves more attention and better support by methods and tools. Things becomes more complicated when intelligence is distributed over and embedded in the networked devices [4-6]. For a long time the worlds of embedded systems and industrial design developed separately. The early examples of embedded systems included products such as telephone exchanges, plant control, and

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 410–421, 2009.

military applications. The early examples of industrial design included furniture, radios, cars, and household tools. In other words: the embedded systems where invisible and their users were not given much room for affective or spontaneous behavior. In contrast, the industrial designers had to give priority to the emotional associations, the styling, the appeal, the usability and even the fun associated with the product. Now many everyday objects contain embedded systems and the two worlds are merging, but much work regarding their integration remains to be done.

Like many other design departments, we are facing the challenge of teaching the engineering principles and practices such as computer science and mathematical modeling to design students that are neither mathematicians nor computer scientists [7]. As a general framework we use a competency based learning model [1, 8] that focuses on complex behavior and gives equal weight to knowledge, skills and attitudes. The knowledge, skills and attitudes are integrated already during learning, instead of being done afterwards, when the student has become active as a professional. The integration requires a powerful and rich learning environment. The student has to learn how to develop contexts of use, how to actively explore concepts, how to evaluate alternative solutions, how to bring new artifacts into the world, in other words, how to design. This learning model appears not only to be well-accepted for traditional industrial design, where the material form of things is the central theme, but also to be effective for the aspects of industrial design that overlap with computer science [3, 7].

To be engaged in the integration of technology and design as early as possible in their studies, the students spend more than sixty percent of their time in design projects in which working prototypes are always required. An iterative and reflective process is always encouraged [9], in which several rapid prototypes for insights and reflections need to be developed quickly when they are needed. Creating these prototypes often needs skills in basic programming and electronics. And these skills should be mastered as early as possible in their studies.

Most of the students in our department do not have an inherent affinity towards programming and electronics. But they do have passion in visual designs and product behaviors. Traditional ways of teaching programming and electronics by lectures combined with exercises had been tried in our department, but the students found that it was hard for them to build the link between the theory and the practice. Design students are often eager to put the just learned knowledge into their practice, if not immediately, as quickly as possible. In their words, they would like to see immediately their creations "dance and sing". Any longer delay in delivering the hands-on experience only builds up their frustrations and disappointments.

For this a 56 hour (over 7 weeks) course "CreaPro" (Creative programming for designers)[1] was created. In this intensive course, the programming language "Processing" is taught. "Processing is an open source programming language and environment for people who want to program images, animation, and interactions. It is used by students, artists, designers, researchers, and hobbyists for learning, prototyping, and production. It is created to teach fundamentals of computer programming within a visual context and to serve as a software sketchbook and professional production

[1] http://wiki.id.tue.nl/creapro

too"[2]. It evolved from ideas explored in the Aesthetics and Computation Group at the MIT Media Lab [10]. The language can be seen as a simplified version of Java. Actually the entire Processing environment is written in Java. Programs created in Processing are first wrapped up with referencing Java libraries and classes then translated almost directly into Java programs. Processing requires much lower entry level in understanding objects and classes than Java, hiding the complexity of Java libraries and configuration. It provides an easy-to-use but also rich graphics library without confusing the users with difficult concepts such as double-buffering. Using the graphics in the programming environment is easy and the user can easily see the visual behavior of the program. The large community of artists and designers behind Processing also gives the students the feeling of a good choice.

But our students are not only visual designers. They are educated to be industrial designers of products and systems. Processing alone is not enough to give them enough hands-on experience in designing product behavior. Additional tools are needed not only to bring their creations alive in the physical world, but also to bring their experiences into their design projects. A robotic platform, AdMoVeo[3], is designed especially for this purpose.

Next in this article, after the design requirements being explained, the detailed hardware and software design of AdMoVeo is presented, followed by examples of the student work during and after the course.

2 Requirements and Design Iterations

For several years we have been observing the design students in the need of knowledge about microcontrollers and programming in their projects. Although they have already learned Java and basic electronics, but the knowledge they had was too abstract and was not tangible enough in practice. We started exploring how we could get our design students more interested in deeper understanding the principles. Since most of the robotic platforms employ principles in both programming and embodied behavior, they seem to be ideal carriers to deliver the hands-on experience, and to be appealing enough to get the students motivated.

Taking into account the main goal of the CreaPro course, we started exploring possible candidates of robotic platforms, with clear requirements bearing in mind:

1. Easy integration with the programming language, by using the same language in programming the robots as standalone systems or by directly and easily controlling the robot from a computer, or if possible, both. This is essential because the major goal of the course is the programming language, not robotics or embedded systems. Students should not be engaged in a second language for programming the robots.
2. The main part of the platform – the microcontroller – should be detachable and should be reusable in future design projects for the students, so they can carry on the knowledge and the experience directly in their projects. This also implies that the dimension of the microcontroller should be small enough to be fit into products or prototypes of a variety of sizes.

[2] http://www.processing.org
[3] http://www.admoveo.nl

3. Intelligent products and systems require sensors and actuators to interact with the environment. The students will be facing all sorts of intelligent products and systems and will be in need of all kinds of sensors and actuators when creating their designs. Hence the platform and the microcontroller should be versatile in connecting to and interfacing with different types of sensors and actuators, and more open ports for the connections are better.
4. The success of the Processing language is largely due to the community of artists and designers sharing experiences in using it. We would also like to seek a hardware platform that has a similar large community behind it, not only for students to learn from other designers, but also for them to share their design results with the community of their own.
5. Technology see-through and transparency are preferred. The design students are often afraid of wires, switches and electronic devices. Seeing through the platform would give them the intuitive view of the hardware components, and give them the feeling of everything being in order and in control. The transparency, on the other hand, should provide the student with a simplified abstraction of the technology, such that they don't have to worry too much about voltage and current, and other fundamentals of the electronics, which are not the focus of the CreaPro course.
6. If possible, wireless communication between the platform and among the platforms is preferred, for in many cases the students need to prototype standalone or mobile products and the interaction among the products and other systems.
7. Last but not least, the cost of such a platform, including the microcontroller, should be affordable for the students.

There are several commercial robotic platforms or kits available in the market. Here we mention a few of them.

Lego Mindstorms[4] is found to be handy in robotic prototyping and in collection user requirements in designing more sophisticated robots and systems [11]. The advantages of Lego Mindstorms are large collections of mechanical parts including a variety of bricks, beams, joints and wheels, and a versatile programmable brick (RCX, and the newer NXT) that can be programmed in many different languages including C and Java. It has also a large community behind it, but people in this community are mostly children and hobbyists. As a tool to be used in a programming course, it also seems to be an expensive toy.

A lot of researchers and designers use Phidgets[5] for prototyping [12, 13]. Phidgets are mostly USB interfaces to sensors and actuators, controlled from a PC. It comes with API's for many programming languages such as C, Java, Pascal and Max/MSP. However they are simply USB interface components for PC's, which means usually a PC is required to control them and there is usually a wire tail behind them.

The Microchip PIC[6] also drew our attention due to its low cost, wide availability, large user base, extensive collection of application notes, and many low cost or free development tools. However it is hardly used by artists and designers because of its

[4] http://mindstorms.lego.com
[5] http://www.phidgets.com
[6] http://www.microchip.com

high threshold in understanding micro processors and programming embedded systems. But since it seems to be close to our requirements, our first prototype was built using a PIC, while looking for a better platform.

At the end it was our students who suggested Arduino[7]. In the same time period of our first prototype was being created, our master students discovered and started to use the Arduino platform into their projects as it turned out to be an easier platform to cope with due to the development environment and software libraries.

As stated on its homepage, "Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments". Numerous sensors and actuators can be connected to Arduino to sense and affect its environment [14]. The Arduino development environment is based on Processing, which is actually or preferable environment for teaching programming in CreaPro. Arduino applications can be both standalone or they can communicate with other Arduinos or with software running on a computer or even a mobile phone, either through a wired USB or serial connection, or through wireless connection using Bluetooth components or an XBee[8] module. The only unhandy feature for CreaPro is that the microcontroller must be programmed in so-called "Arduino programming language", which is based on Wiring[9], a simplified version of C. Wiring to C is similar to Processing to Java. Although it looks very similar to the Processing language, as we stated in the requirements, we don't want to engage the students in learning a second language in CreaPro, even if there is very little to learn. Hence additional care should be taken to hide the differences or to provide transparent access to Arduino from the Processing programs.

We went through three iterations to reach the design of AdMoVeo. The first prototype, PicBot (Fig. 1a), was built using PIC 18f4550 microcontroller, including the features such as prefab chassis, twin motor with gearbox, battery pack with integrated battery charger, motor driver circuit, and two switches as bump detection. After showing this platform to the students, the round shape was found to be appealing to them hence it was kept throughout the design process. The low-cost solution of two motors and their driving units was also found to be effective enough to be used in later iterations.

After the decision being made to switch to the Arduino platform, the second prototype, Arduinobot (Fig. 1b), was built using an Arduino Diecimila[10] board, featuring two separate geared DC motors, 4 rechargeable AA batteries, wireless xbee communication and 2 light sensors. All these features were kept for the final design of AdMoVeo. After running through numerous test runs and checking against the requirements of the CreaPro course, extra sensors were added and a professional design was made for the electronics and mechanics to improve the features of the prototype, which resulted in the final AdMoVeo design (Fig. 1c).

---

[7] http://www.arduino.cc
[8] http://www.digi.com
[9] http://wiring.org.co
[10] http://arduino.cc/en/Main/ArduinoBoardDiecimila

(a) PicBot (b) ArduinoBot (c) AdMoVeo

Fig. 1. Early prototypes of AdMoVeo

3 AdMoVeo

3.1 Hardware Design

The final design of AdMoVeo features a detachable Arduino Diecimila board and two wheels integrated within the round shape of the chassis. The size of the chassis is increased from 10cm to 12cm in diameter, exactly the size of a CD. The chassis and motor mount are made from transparent acryl glass, giving it a see-through look into everything inside. The sensors include two line readers at the bottom, three infrared distance sensors at the sides and in the front with sensibility of 0 to 20cm, two light sensors in the front, two sound sensors at the sides and two optional encoders coupled to wheels. The actuators include two motors driving two wheels, a buzzer and a RGB color LED integrated into the acryl chassis. An XBee module is optional for wireless communication. Fig. 2 shows the 3d rendering of the AdMoVeo design and an exploded view of the internal structure.

The Arduino board is designed to be detachable, so that the students can take the Arduino boards with them after the course and further make use of them in their design projects. The platform will be offered by the faculty and reused in the next run of the course.

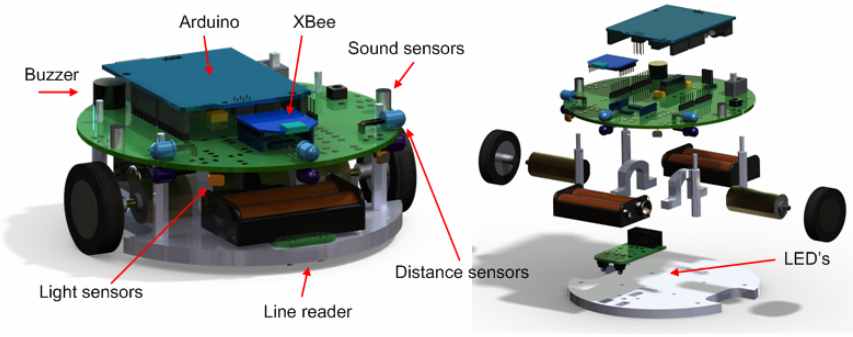


Fig. 2. 3D rendering of the design of AdMoVeo

The hardware is also designed to be easily assembled by students themselves. Experience with soldering and wiring the components together gives the student a lot of confidence in handling the electronics, although many of them do not have in depth knowledge of electronics yet.

Extra attention was also paid to the layout of the components, so that modifications and extensions can be done easily. For more experienced students, they can detach the preconfigured sensors and actuators, and connect different ones for their applications, without paying too much of efforts.

Detailed lists of components, layout of the PCB and instructions for assembly are available at www.admoveo.nl.

3.2 Software Design

Fig. 3 shows the object-oriented view of the software structure. The software design is based on a layered structure of composition and inheritance. It has mainly two major parts – the firmware *IDuino* running in the Arduino microcontroller of the AdMoVeo robot, and the Java API library for programming and controlling AdMoVeo in the Processing programming environment.

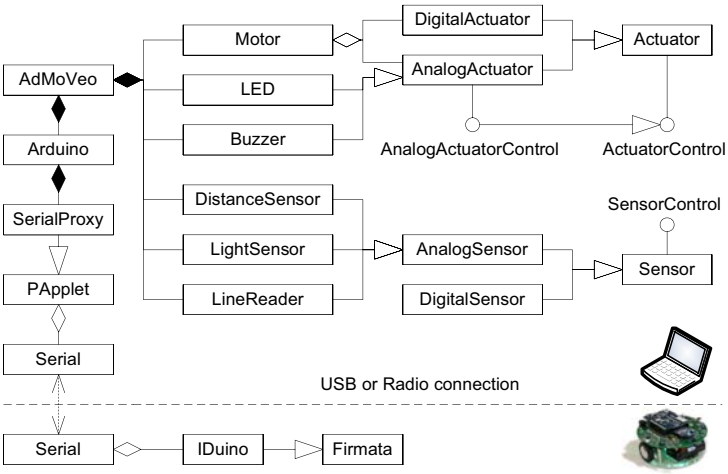


Fig. 3. AdMoVeo Software Design

The firmware *IDuino* is an implementation of Firmata[11], a generic protocol for communicating with microcontrollers from software on a host computer. At the host computer side, the *Arduino* object acts as a proxy to the *IDuino* firmware, hiding the communication details and providing transparent access to the digital and analog I/O pins of the Arduino board. The *AdMoVeo* class further wraps up the Arduino I/O details, providing transparent access to the sensors and actuators of the physical robot.

[11] http://firmata.org

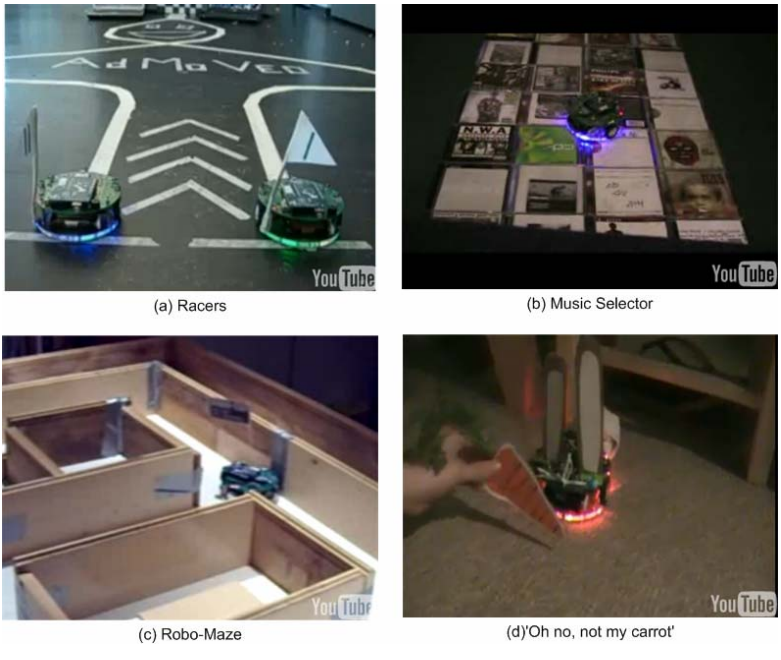
Once the *IDuino* firmware is uploaded to the robot, the students only need to program the robot from the computer using the Processing language without leaving the Processing programming environment and touching any pieces of the Wiring code inside the Arduino microcontroller.

Programming the AdMoVeo robot follows the principles of object-orientation and event-driven programming. The following code shows an example of programming a simple behavior of AdMoVeo in Processing: When the left distance sensor detects a change, the callback function *inputAvailable* receives the message and schedules a task *changeBlueLed* for being executed as soon as possible (NOW). The task *changeBlueLed* then changes the color of the blue LED of the robot according to the distance detected.

```
//import library for serial communication
import processing.serial.*;
//import the AdMoVeo library
import nl.tue.id.creapro.admoveo.*;
//declare a reference to an AdMoveo robot
AdMoVeo admoveo;

void setup(){
  //create an AdMoVeo object, setting up the serial communication
  admoveo = new AdMoVeo(this, "COM5");
  //enable the left distance sensor
  admoveo.getLeftDistanceSensor().enable();
}

//react on the input events
void inputAvailable(Sensor sensor, int oldValue, int newValue){
    if(sensor == admoveo.getLeftDistanceSensor()){
        admoveo.execute("changeBlueLed", AdMoVeo.NOW);
    }
}

//task to be executed.
void changeBlueLed(SensorStatus s){
  //left distance sensor returns a value between 0 and 1023.
  int power = s.get(admoveo.getLeftDistanceSensor())/4;
  //the color for the blue LED is set accordingly
  admoveo.getBlueLed().setPower(power);
}
```

4 Examples of Student Work

We have used the AdMoVeo robot during the CreaPro course for 140 first year industrial design students. The robot was introduced in the middle of the course, after the student were introduced to some basics of programming, such as control flows, functions, arrays and loops as well as minimal knowledge of object orientation. Before the robot was introduced the exercises were mainly focused on graphical applications but after that the exercises also included robotic assignments. No lectures were given about the Robot except some briefing about installation of the firmware and libraries, meanwhile the course went on with other topics such as algorithms and graphical user interfaces. The students were asked to read the documentation to learn the API's on their own. They were challenged to deliver a demonstration to show what they have learned from the assignment, and to show their capabilities of reading and understanding the documentations, and to show their creativities as much as they can. The strategy of combining the graphical power of the Processing language and the hands-on experience with microcontrollers in the CreaPro course turns out to be a success. The feedback from the students was in general very positive. The AdMoVeo did have positive impact on their learning experience and many found the AdMoVeo to be "a lot of fun to play with". We as teachers were also supersized and amazed by the robotic behaviors created by these first years.



(a) Racers (b) Music Selector

(c) Robo-Maze (d)'Oh no, not my carrot'

Fig. 4. AdMoVeo behaviors by first year students

In Fig. 4a are two racers created by Tom Koppenol, Marieke de Rooy and Thomas Westelaken. The robots uses two line readers to follow the line indicated using painting tapes on the floor. The tracks have curves and crossing which are quite challenging especially when the robot is running at a speed. Fig. 4b shows the music selector created by Tim Ebbers and Chris Gruijters which uses the line reader for a different purpose – to find which CD box is underneath the robot. Once found, the message is send to the computer and the computer plays back the corresponding album. The AdMoVeo in Robo-Maze (Fig. 4c) by E C Vos, J L Adriaanse and S Wouw can escape from the maze by using its distance and light sensors to detect the walls. Jaap van der Schaaf, Julie Hornix and Diane Bouten transformed the AdMoVeo ino a rabbit that is sensitive to the distance of the carrot, always trying hard to follow it. The still pictures in Fig. 4 can hardly show the dynamic behavior of these robots and the happy faces of the students. To see these robots, as well as many others, visit YouTube and search for "AdMoVeo" and "CreaPro".

The creativity of the students goes further with the experiences with the Arduino platform. The strategy of a detachable microcontroller encourages the students further explore the possibilities and the opportunities brought forward by the integration of technology and design. The arduino platform is now widely used in student projects, many of which have resulted in impressive designs. Limited by the space in this paper it is impossible to show all of them, instead we include only two examples shown in Fig. 5. The TV remote in Joris van Gelder's hands turns into a magic interaction device instead of a boring one, giving the interaction a aesthetic touch with dynamic movements and lighting (Fig. 5a). Ennea (Fig. 5b), which is Greek for nine and symbolizes a turning motion, is the result of our six-week design project by five stuents. Ennea records real-life data by looking at social contact and interaction between pupils within a school environment. This is done with mobile-networked objects, which can be carried around by the pupils. These interactive objects provide a platform to reflect upon real-life social data through exercises and to create a new way of interaction between pupils to stimulate social contact.

(a) Magic Interaction by Joris van Gelder (b) Ennea by Doesborgh et al

Fig. 5. More designs created using the Arduino platform

5 Concluding Remarks

The AdMoVeo robotic platform is designed purely for the purpose of teaching the industrial design students basic skills of programming. Moreover we aim at a platform that motivates and encourages the design students to explore their creativity with their passions in graphical and behavioral design, which in turn gives them spontaneous and intrinsic drive in learning programming. In the design of AdMoVeo, the transparency provided by the software structure enables the student focusing on the programming aspects, and at the same time quickly being engaged in hands-on experience with embedded behaviors; the separation of the Arduino board from the robotic platform invites the students further apply and further develop the learned knowledge in their design projects.

We would also like to mention that the AdMoVeo platform and the software mentioned in this article are all open source, available for sharing and further development at www.admoveo.nl and wiki.id.tue.nl/creapro.

Acknowledgements

The authors would like to thank Chet Bangaru for his support on mechanics and 3D modeling, Geert van den Boomen and Peter Peters for their help on electronic devices, Caroline Hummels for her understanding and support, the CreaPro team for working out this fantastic course together, and the /d.search labs for prototyping facilities.

References

1. Feijs, L., Kyffin, S.: The new Industrial Design Program and Faculty in Eindhoven-Competence based learning and designed intelligence. In: Proceedings of the Designing Designers (2003)
2. Bartneck, C., Rauterberg, M.: HCI reality-an 'Unreal Tournament'? Int. J. Hum.-Comput. Stud. 65, 737–743 (2007)
3. Hu, J., Ross, P., Feijs, L., Qian, Y.: UML in Action: Integrating Formal Methods in Industrial Design Education. In: Hui, K.-c., Pan, Z., Chung, R.C.-k., Wang, C.C.L., Jin, X., Göbel, S., Li, E.C.-L. (eds.) EDUTAINMENT 2007. LNCS, vol. 4469, pp. 489–498. Springer, Heidelberg (2007)
4. Hu, J.: Design of a Distributed Architecture for Enriching Media Experience in Home Theaters (PhD Thesis). Department of Industrial Design, Eindhoven University of Technology, Eindhoven (2006)
5. Hu, J., Feijs, L.: IPML: Structuring distributed multimedia presentations in Ambient Intelligent Environments. International Journal of Cognitive Informatics & Natural Intelligence (IJCiNi) 3, 37–60 (2009)
6. Hu, J., Feijs, L.M.G.: An Agent-based Architecture for Distributed Interfaces and Timed Media in a Storytelling Application. In: The 2nd International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2003), pp. 1012–1013 (2003)

7. van der Vlist, B., van de Westelaken, R., Bartneck, C., Hu, J., Ahn, R., Barakova, E., Delbressine, F., Feijs, L.: Teaching Machine Learning to Design Students. Technologies for E-Learning and Digital Entertainment, 206–217 (2008)
8. Voorhees, R.: Measuring what matters: Competency-based learning models in higher education. Jossey-Bass (2001)
9. Hummels, C., Frens, J.: Designing for the unknown: A design process for the future generation of highly interactive systems and products. In: International Conference on Engineering and Product Design Education, Universitat Politecnica de Catalunya, Barcelona, Spain, pp. 1–6 (2008)
10. Reas, C., Fry, B.: Processing: a programming handbook for visual designers and artists. Mit Press, Cambridge (2007)
11. Bartneck, C., Hu, J.: Rapid prototyping for interactive robots. In: Groen, F., Amato, N., Bonarini, A. (eds.) Intelligent Autonomous Systems 8, pp. 136–145. IOS Press, Amsterdam (2004)
12. Greenberg, S., Fitchett, C.: Phidgets: easy development of physical interfaces through physical widgets, pp. 209–218. ACM, New York (2001)
13. Peters, P., Feijs, L., Oei, G.: Plug and Play Architectures for Rapid Development of Medical Simulation manikins. In: The 12th World Multi-Conference on Systemics, Cybernetics and Informatics: WMSCI 2008, Orlando, Florida, USA, vol. II, pp. 214–219 (2008)
14. Igoe, T.: Making things talk: Practical methods for connecting physical objects. Make Books (2007)

Edutainment Robotics as Learning Tool

Eleonora Bilotta, Lorella Gabriele, Rocco Servidio, and Assunta Tavernise

Linguistics Department, University of Calabria,
via P. Bucci, Cube 17/B, 87036 Arcavacata di Rende, Cosenza, Italy
{bilotta,lgabriele,servidio,tavernise}@unical.it

Extended summary. Many constructivist technologies, such as Lego® MindStorms™ robotic kit, allow students to improve problem solving strategies in educational settings, encouraging teamwork and creativeness. This latter Edutainment robotic kit has been built in accordance with learning principles derived from Piaget and Vygotskij theories of cognitive development, as revised by Papert, which portray learning as the acquisition or 'construction' of knowledge through observation of the effects of one's actions on the world.

In this work we focused on cognitive strategies adopted by University students attending a Robotics laboratory program, working in an Edutainment setting with the Lego MindStorms kit. We analyzed the students' reports on the teamwork during laboratory activities, and we gathered information on the subjects' working modalities during the activities of building and programming basic robots. First of all, we detected three different typologies of work subdivision: each member adopted a role in the building work and all programmed the robot; members did not adopt a fixed rule in building and programming the robot; each member adopted a role in building and programming the robot and a leader supervised the work. We then found that the use of robots stimulated students to explore their own knowledge in a critical way and to share it within the group, and that the activity of realizing an artefact took place through precise phases. These phases were:

1) Planning and building of the artefact, related to problem identification and objective definition, collection and production of ideas, problem conceptualization. During the building and manipulation phases, a fundamental role was exercised by the perceptive and behavioral functions and by the affordance that the elements of the kit suggested to the subjects. As they progressed with the work, students advanced in the learning process and became able to explore, arrange and recombine, in different ways, the material structures and the creative ideas in order to realize the final artefact.

2) Behavioral programming, in which students detected problems, hypothesized and applied solution strategies. In this way, they were able to enrich their work through new details, looking at different thinking modalities; in particular, in planning strategies students divided the problem into many parts and elaborated each part from the particular to arrive at a general solution. This phase was strictly related to the check phase.

3) Check, in which subjects evaluated the realization of the artefact and decided on the need to go back to the building phase, to the programming phase, to both, or rather to search for new ideas.

Thanks to the results of this analysis we can affirm that the Robotics laboratory stimulated students with regard to problem finding (the subject identifies and formulates the initial idea or the problem to solve), problem solving (the subject elaborates and explores some possible solutions in order to reach the objective) and checking procedures (the subject evaluates the artefact's properties from functional, planning and behavioral points of view). The repetition of each of these phases allowed the subjects to modify and improve the structure and this reflected their mental model of the artefact in relation to the assignment. Edutainment Robotics creates a cognitive bridge between educational aims and concrete experience, encouraging in the students, at different levels, the acquisition of new skills in an engaging setting.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, p. 422, 2009.

Designing a DSL Solution for the Domain of Augmented Reality Software Applications Specification

André Rosa, Vasco Amaral,* and Bruno Barroca*

Research Center for Informatics and Information Technologies,
Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa,
Quinta da Torre, 2829-516 Caparica, Portugal
adr13041@fct.unl.pt, vasco.amaral@di.fct.unl.pt,
mailbrunob@gmail.com

Abstract. Code repetition, lack of reuse and basic errors are typical problems in the industry that decrease the productivity during the software development process, and this is no exception in the domain of interactive applications with focus on Augmented Reality (AR). In this paper, we describe a new Domain-Specific Language (DSL), based on an existing AR software framework that tackles this problem by adding a new abstraction layer for product specification. The proposed language's abstract syntax covers the definition of application logic's organization, its configuration, objects construction and behaviour definition. The language's concrete syntax was implemented using a metamodeling language workbench. A real case study within the context of an AR software house was used for validation purposes.

Keywords: Domain-Specific Language, Modeling Language, Model Driven Development, Interactive Applications, Augmented Reality.

1 Introduction

Code repetition, lack of reuse, and basic errors are some of the typical problems that occur in today's software computer industry while developing complex systems. This impacts negativity the development time and with the inappropriate solution of building a bigger team provides a negative blow to a company efficiency. In fact, in the software industry most applications are built upon frameworks and/or using application programming interface (API) calls to a reusable set of libraries.

This is also true in regard to interactive applications such as video games and augmented reality applications. In these, game engines and middleware solutions are used in different products. What software houses spend most of the time is creating new contents. For that, they need reliable tools that allow the creation of new visual and gameplay elements. Also important is the ability of those tools to extract the maximum performance and functionality from the lower abstraction implementation level. In what concerns to the learning curve, it should be smooth. One important concept

*The results are partially supported by FCT- MCTES project PTDC/EIA/65798/2006.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 423–434, 2009.

about the creation on new contents is that it involves two types of professionals. On the creative end is the designer that composes the content. On the other hand is the programmer that sets up the necessary code to emulate the designer's intentions. This creates a possible troublesome gap between the content's creation and its implementation. The usual approach to this problem is the use of game editors that facilitate content creation. But they normally also require detailed implementation knowledge. All of these problems need to be tackled. By use of a thoughtful approach so that the resulting solution can solve today's problems.

The objective of this work was to provide and promote reusability, simplify the design process, enable prototype based development in Software Engineering, and to add another abstraction layer in the specific domain of Augmented Reality Software applications Specification. This is achieved by designing and implementing a new Domain-Specific Language (DSL). By reaching these goals, a reduction on the development time is accomplished, that leads to an increase of efficiency and originates a better productivity on the software house.

Our DSL was designed and implemented over a real C# framework (YVision) from YDreams[1], as proof of concept. In spite of this particularization, the language was designed in a generalist way so that it can be used in other frameworks. YVision is aimed at producing interactive applications, but its focus is Augmented Reality applications. It supports a Software Product Line that integrates: Computer Vision, Graphics 3D/2D audio and behaviour.

On section 2 the background of this project is presented. Section 3 describes the DSL development. A case study for validation is shown on section 4 and on section 5 the language evaluation is detailed. Finally, on section 6 conclusions and future work are presented.

2 Background

2.1 Augmented Reality

The target domain of this project is that of interactive applications with focus on Augmented Reality (AR). AR is the name given to the technology that uses computer generated elements to complement reality in real time 3D interactivity. The computer generated information (effects and content) is overlapped to the user's real world natural view, enhancing and augmenting the set of information given to the user. Augmented Reality is similar to the concept of Virtual Reality in the way that the user interacts with virtual elements. However, it is different since AR uses the real world information as a base for the presentation and characterization of the virtual elements.

An example of AR that we focus our attention is the concept of Reality Computing [1] that uses techniques from ubiquitous interactivity and mobile computing. In Reality Computing the computer is everywhere, cameras are scattered all around and capture the user's input without them needing to use any interface devices. The focus is on providing a better immersion.

[1] This project is a collaboration between the Departamento de Informática, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa (DI/FCT/UNL) with the Portuguese software house YDreams [1].

2.2 Domain-Specific Language

A DSL is a language that sacrifices generality for proximity to the problem domain. It is focused only on expressing problems from a specific domain, using concepts from that domain to express problems at a higher level of abstraction. This way, the domain expert can ignore solution details, and that will reduce the development time. In some cases, DSL are considered end-user languages because it exists the intention of them being used by non programmers. DSLs allow validation and optimization at the domain level, conservation and reuse of domain knowledge [2].

A DSL is normally declarative and provides a smaller set of notations and abstractions when compared to a general purpose language (GPL). Some well known examples of DSLs are SQL, HTML, BNF or GraphViz.

The DSL development methodology consists on doing a domain analysis to collect important domain knowledge [3]. It is followed by a modelling phase where the language is built. To design a DSL, we start by defining the abstract concepts and specific terms (language's abstract syntax) that are used according to the domain expert's profile and its specific context of use. Also we can map the representation of each abstract concept in a particular editor (language's concrete syntax). But most important, we need to be able to map each abstract concept with its meaning (language's semantics) on a computational framework.

The concrete syntax of a language represents the way of how the abstract concepts of the language are to be symbolically presented to the domain experts. Generally, the concrete syntax of a language is categorized into textual or visual/diagrammatic according to presentation paradigms present on today's modelling frameworks.

On the implementation phase it is built a custom editor for the DSL users to work with and an automatic artefact generator. This enables a DSL to be portable to other languages since it is possible to define a code generator to transform the DSL solution into various programming languages.

Regarding the Augmented Reality Software applications Specification domain no published work was found that contained a DSL definition. Nothing was found that was able to fulfill and cover the complete specification of an AR application with the specific requirements of the YDreams domain experts. This project sets to fill this void by providing a solution that enables AR applications to be constructed using a higher abstraction level, where irrelevant details are suppressed.

2.3 Implementing DSLs with Model Driven Development

On this project the approach consists on the use of metamodeling theory. Models are the main development entities. A model is used to construct abstractions that define the properties and features of a system [4]. It acts as a simpler representation of reality. A metamodel describes the properties, constructions and rules necessary to build a model. In a metamodel, the abstract syntax description of all the concepts used on the language and the relations between them, is expressed. A metamodeling language is used to define the abstract syntax of a modelling language [5].

The usage of models as development entities, bring some powerful advantages like: a cleaner architecture presentation, conceptual simplicity, efficient implementations, scalability and flexibility [4]. It is also possible to execute operations and

transformations over the models. Allowing the creation of new models, generation of development artefacts such as code and documentation from models, mapping and synchronization of models from the same or different abstraction layer. Models allow a better comprehension of the problem domain concepts because they are first class entities and an abstraction of the domain architecture. To harvest the full power of Model Driven Development it is necessary that the modelling concepts refer to domain concepts instead of the usual technological concepts [6].

This is where DSLs come in to play. They allow the use of domain concepts on the specification of the models. To the modelling and development of systems using DSL is given the name of Domain-Specific Modelling (DSM). In DSM, the modelling language is specific to the problem domain as is the code generator. This way the errors between the domain, models and code mappings are minimized. Because the modelling language includes domain rules, it is harder or impossible to create wrong specifications and the development errors are detected and avoided earlier on the development process. There is also a levelling of experience that comes from the fact that the creator of the DSM solution is normally the most experienced person on the problem domain and he determines and controls the way the users will use the solution. The users will only need to create models on the DSL and then the application code will be automatically generated. Using a metamodeling tool simplifies the development process of a DSL [7]. It provides the necessary functionalities to develop the language metamodel, set up rules and validations to be run on the models during the design, create the graphic editor to be used by the DSL users, and present methods to help on the automatic code generation.

3 DSL Development

The language formal semantics is not the focus of this paper, it will be described elsewhere. The focus is the definition of the language abstract and concrete syntax and we will also provide meaning in an informal description of each of the language's terms and its relations. Another reason why we are only giving informal description of the language's meaning is that to be able to implement the DSL based solution it was necessary to do an analysis to the target framework. That analysis is not presented on this paper as the implementation process is unique to each framework.

3.1 Domain Analysis

First we analyzed the main characteristics (profile) of the designer of Augmented Reality applications. The DSL target audience mainly consists of designers with experience in programming. From the domain analysis, a recommended set of features had been identified. The first one is the definition of the application logic flow. Basically, while designing AR applications, it is necessary to express the application following a workflow presentation and provide means to configure it. After that, the content needs to be defined using some kind of entity abstractions. Finally, it is necessary to define the behaviour of those entities. Therefore, the designed DSL composes four different interdependent views over the system: application graph model and configuration, world objects and behaviour.

Application's Graph and Configuration Model View
The definition of an application logic flow uses a system of nodes and connections. The connections represent relations between the nodes and enforce constrains upon the execution model of the application. The configuration is expressed using elements that represent configurable properties of each node. This way, the configuration is dependent on the application's graph.

World Objects Model View
A component oriented approach is used to represent the world objects [8]. By using standalone components, the objects by themselves do not possess any properties except their name, and methods to add, remove or get a component. The components provide the objects with features and functionalities.

Behavior Model View
The complete description of such a complex task such as the definition of an world object behaviour is hard endeavour to solve. The most valid plan of attack is to divide the behaviour as a set of sub behaviours in a form of a behaviour tree [9] with particular composition operators. This approach promotes reuse and modularity. The total definition of the behaviour using only a DSL is a exhausting task and to be complete it would have to support the definition of sub behaviours using code defined blocks. In a behaviour tree, the behaviour is organized using special composite nodes that have children behaviours, special decorator nodes that control their child behaviour and atomic nodes, where code defined behaviours run.

All of these elements were already present in YDreams's framework.

3.2 Language Design

Resulting from the domain analysis some new valuable requirements emerged. In spite of the existence of several different and configurable parts, the DSL as a whole should be consistent and unify both the presentation and organization aspects of an AR solution. The use of these mechanisms promotes modularity and occultation of selected elements preventing the visual clustering of elements. Still, the most important aspect that arose was the possibility of adding new elements to the language without having to change the DSL.

Generic Elements
The main characteristic of this DSL lies in the fact that some language elements act as generic elements where concrete elements are loaded. For instance, the behaviour code blocks. Each generic element defines an interface and those interfaces correspond to the main building blocks of the language. This allows new building blocks to be created and used on the DSL according to their interface. For example, regarding the vast range of video capture devices, their nature and functionality can be different but they all fulfill the same purpose and provide similar communication interfaces. By using this technique, it is possible to create an expandable DSL, by defining special generic elements in the DSL, where selected building blocks are placed based on their interfaces. We will now describe for each modelling view its abstract and concrete syntax. Since this DSL is a modelling language its abstract syntax is defined by a

metamodel that we present on Fig.1. The attributes are omitted to improve the visibility of the concepts.

Application's Graph and Configuration Model View

It is possible to observe that a graph model (top part of Fig.1) has nodes and each node can be a block, entry, exit, setting or setting dictionary. The pin hierarchy is displayed together with the connections and bindings. The application logic flow is defined using *blocks* that represent and operation or functionality. They have *input*, *output* and *property pins*. A block is essentially a black box that interacts with the other elements using the pins as its only communication interface and executes when data is available. Though the input pins the block receives data and by the output pins it emits data. The property pins are used to configure the block properties. A block is the building block unit of the graph model and also a generic element.

Type definitions are tied to implementation technologies and programming languages, therefore we do not have a syntax structure to express them. We could have provided type definitions however, that could lead to the destruction of the abstraction layer that was achieved by the language. Nevertheless, the only thing that is provided is a simple *type representation*. These type representations are used almost everywhere on the application graph model, namely on pins that come into play when a connection is being made. A *connection* is made between a connection input and an output connection. When the pins are from the same type, it is called a direct connection. A filtered connection can be created when the pins have different types, and only if it is possible to apply a conversion between the types.

An *execution context* represents a thread of execution. In a valid application specification every block needs to be assigned to a execution context. Therefore it is possible for the DSL user to express the application's multi-threading organization. For example, it is possible to specify a rendering block and a physics block and assign them to different threads. An application graph model also has the self describing *Entry* and an *Exit* that are essential to tackle the reuse of graph models.

The configuration is expressed using three elements, *settings*, *bindings* and a *setting dictionary*. A setting represents a configuration flow and is linked to the setting dictionary. The need to associate a setting to other settings arises from situations where two or more blocks share the some configuration value. An example of this is the screen rendering resolution parameter. It can be used to configure both the camera block and the rendering block. A binding is an association between a binding input and a binding output.

World Objects Model View

A *world object* (bottom left part of Fig.1) is represented by a name and its components. Each *component* has a family identification attribute that refers to its component family and a set of properties which can be defined. An object can only host a component from each family. A component is the building block unit of the world objects and a generic element. *Managers* are special entities that provide synchronization and reference mechanisms essential to running an interactive application. A manager needs a provider and act as a service that other language elements subscribe.

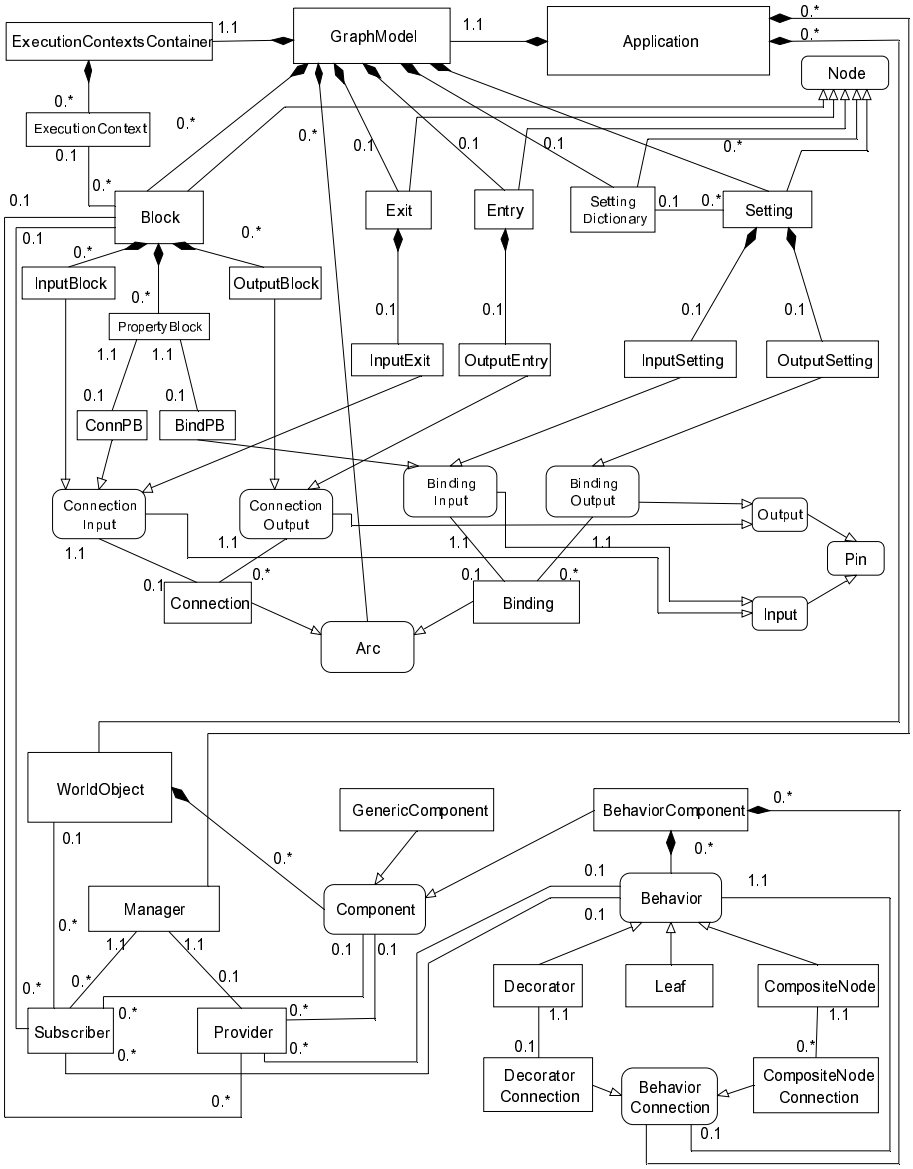


Fig. 1. Language abstract syntax metamodel (UML 2.0 class diagram compliant)

Behavior Definition

A World object's behaviour is defined in a *behaviour component* (bottom right part of Fig.1) using concepts from the Behaviour Tree specification [9] that was introduced in the domain analysis section. A behaviour tree is an acyclic connected graph where a node, depending on its type, can have zero, one or more children nodes and has one parent node. The root of the tree is the only node that has no parent node.

A behaviour tree has three different types of nodes *composite nodes*, *decorators* and *leaf* nodes. Any of these types of nodes can have configuration parameters and act as the tree root node. The composite nodes can have a finite set of children nodes. The decorator nodes have a mandatory child node. The leaf nodes do not have any child. Given the fact that these three types of nodes act as the building blocks of the behaviour definition all of them are generic elements in the DSL.

In a behaviour tree every node has a state. Those states are success, failure and running. This state data is the only information that nodes share. A child node executes and sends its state data to his parent. The behaviour tree execution flow is then defined statically by the way nodes are arranged and dynamically by the state data that is propagated between children and parents.

3.3 Language Implementation

The DSL was implemented using Microsoft DSL Tools [7] as the metamodelling language workbench. The language diagrammatic editor was prototyped and designed using DSL Tools, and the language's visual representation was based on the Human-Computer Interaction facilities that this workbench already possess. The complete description of the concrete syntax would occupy too much space. Therefore, we simply present a textual description and a small example in Fig.2.

The visual representation of the DSL concepts follows the logic of nodes and connections and the placing of elements inside others elements. Some elements can contain other elements inside their boundaries. Inside the application graph model element blocks, settings, setting dictionary, entry and exit points are placed. In the world object element components are inserted. And on the interior of the behaviour component, the behaviour tree elements are added. Any of these three container elements can be resized or collapsed hiding their inner elements.

This way, visual modularity is achieved and the clustering on the canvas is minimized. The user interaction approach to the problem of building objects using components is based on drag and drop. Components will be dragged to the inner boundaries

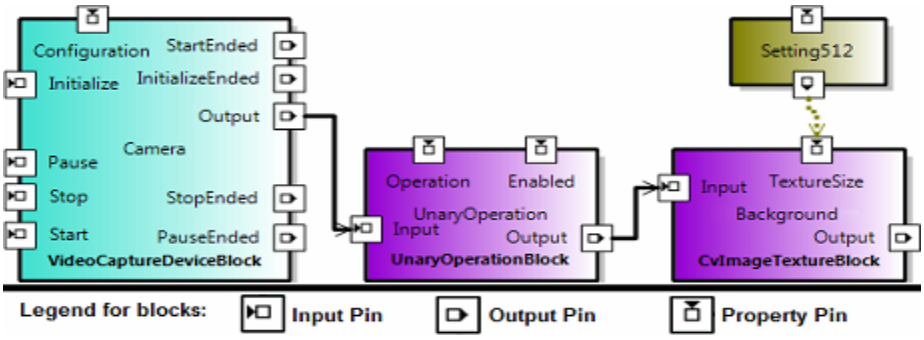


Fig.2. Graph model with three blocks and a setting

of an object representation. This was found to be the best solution since using nodes and connections use too much visual space on the edition canvas. About the DSL elements properties they appear on a separated area and not on top of corresponding element. This solution is the best one because it does not corrupt the clarity of the visual models created.

The DSL editor uses the layout given by the metamodeling tool. There is a toolbox where the language elements reside that the user can drag to the drawing area, and an area where the parameters of each language construct are shown, and a special grid where messages are displayed.

Furthermore, we also used DSL Tools to specify code generation templates which can convert any XML model built on that editor into C# classes and XML files that have a direct link with the target framework implementation classes and services.

4 Case Study

The case study goal was to take a previously developed application called "Bubbles" and model it using our DSL. This application was chosen because it represents well the complexity of augmented reality applications. The main objective of the "Bubbles" application is to have bubbles falling down from the top of the screen and have its trajectory altered when they interact with the user(s) and with other bubbles. Depending on certain conditions, for instance when the user touch them with too much strength, they pop and then disappear [10].

4.1 The "Bubbles" Application Model

To model this application it was necessary to define the application graph model and to create two world objects. The application graph model already using our language Concrete Syntax is presented on Fig. 3. On the application graph model is described, using the DSL, the logic flow of the "Bubbles" application. The problem presented is defined by having a camera that records the environment and collects data necessary to generate the interactions between the bubbles themselves and the users. Furthermore, it is necessary to create the world and define the game loop.

This problem is what the application graph model details. The video capture device represents the camera that records the environment. After that, some image processing is done to extract contour information that together with tracking data is used to generate the collisions. The *WorldObjectLoaderBlock* creates the world object that represents the Bubble's scene and the *BehaviorExecutionBlock* provides the manager that the bubbles will subscribe. The game loop is defined by four blocks each with a different task, processing the world physics, getting user input, executing the objects behaviors and then rendering the scene.

Half of the graph, the brighter lines, is dedicated to the initialization process, while the other half deals with image processing challenges. The association between execution context and block is shown by having the block take the color of the associated

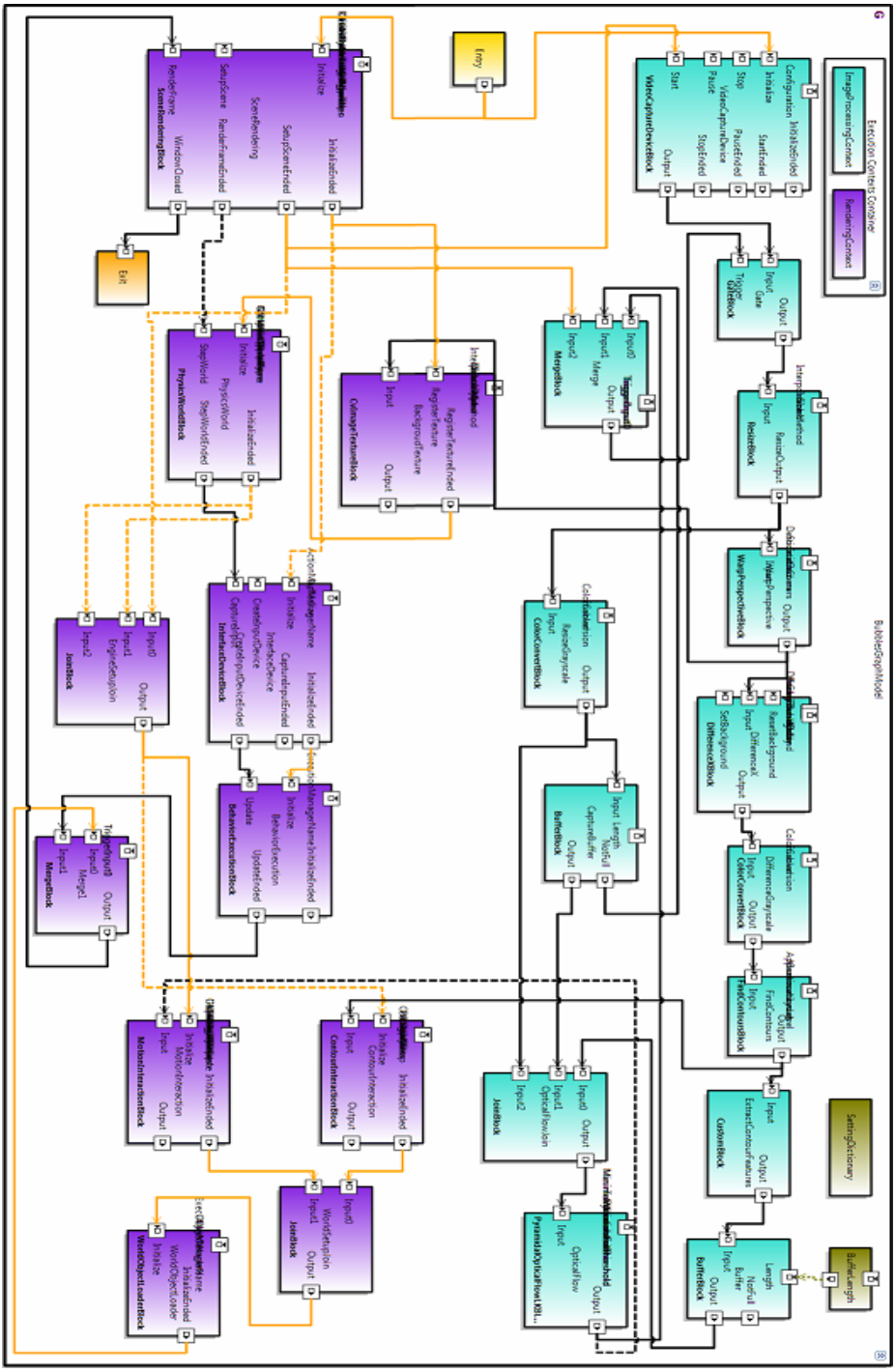


Fig. 3. “Bubbles” Application's Graph and Configuration Model View

execution context. The blocks display the input pins at their left side and the output pins at the right side. This way the application graph model is read from left to right. Connections are represented as solid lines between the pins and connections where a conversion occurs are represented by dashed lines.

The object representing the world has a visual component, a physics component, and a behaviour component. Each one of these components are implicitly connected to their respective implementation classes on the target framework, however the AR application designer do not have deal with them directly. Its behaviour is creating bubbles until the application is terminated.

The bubble's world object definition has the same components as the world. The bubble behaviour tree has a top node which refers to the three sub behaviours. The first one is the Inflate behaviour, where controlled by a sensor (given a particular maximum allowed grow time and a maximum bubble size) the bubble grows. The second one defines the life of a bubble. It is also necessary to create the physics representation of a bubble from its visual representation.

After that, the bubble is active on the screen, updating its visual from the physics, until certain conditions are met. Finally, the Pop sequence deals with the destruction of the bubble, playing an animation for a certain period of time.

5 Evaluation

The results of the experiment with "Bubbles" shows that the design process took less time, had less errors, and in general was more satisfying while regarding to the old approach using the framework directly.

Furthermore we did an assessment of the language usability in comparison with the old approach (using the framework directly) using a series of tests and a questionnaire that were made to YDreams's domain experts[11]. These tests evaluated the user interpretation and construction capacities while using the DSL approach and the framework. They were centered on specific activities that are representative of real life ones. Domain experts were classified accordingly to their expertise level in different profiles: beginner, advanced and expert.

The DSL approach had a considerable smaller error rate for the beginner and advanced profiles and slightly smaller for the expert profile.

Beginners and advanced domain experts registered a shorter development time when they used the DSL. In regards to the expert domain experts, given their experience working with the framework, the development time using both approaches was similar in total time. In fact, they were faster using the DSL to model the application logic flow and slightly faster using the framework to model the application world objects and behaviour.

The questionnaire goal was to assess the domain experts opinions on key questions. They considered that the concepts used on the DSL are adequate and intuitive as they correspond to the ones they have present in their mental models. The interaction method, learning curve, ease of use and overall user satisfaction were classified as good. The domain experts of the beginner and advanced profiles also preferred to use the DSL instead of programming directly on the framework. The expert profile users also shared this opinion but at a lower rate.

6 Conclusion and Future Work

One of the main contribution of this work, was to design and develop a graphic DSL that targets AR solutions in a particular AR platform. The other main contribution is the increased efficiency of the YDreams software company that uses our DSL in its application's development processes to develop real applications with less errors, shorter development times and more reusable. No expressiveness is lost, and both the development and maintenance time decrease, resulting in better productivity. Therefore, we believe that this work is another contribution to the use of the metamodelling language approach to tackle problems in the industry.

This project will continue exploring modelling and engineering techniques from Model Driven Development to guide the AR designers through all the phases of the software development cycle. The next goals will bring traceability techniques to track changes in the models, visualization techniques to provide different visualization modes, and the definition of new components types using our DSL. Also, we are aiming to reuse the models used in our DSL in order to be able to explore all the possible configurations, and predict problems in early stages of the design.

Acknowledgments. A note of appreciation goes for the YDreams company for allowing the use of their framework as the target of this project.

References

1. YDreams, `http://www.ydreams.com/`
2. Deursen, A., Klint, P., Visser, J.: Domain-Specific Languages: An Annotated Bibliography. SIGPLAN Notices 35(6), 26–36 (2000)
3. Thibault, S.: DomainSpecific Languages: Conception, Implementation and Application. Phd. Thesis. University of Rennes. France (1998)
4. Bezivin, J.: On the Unification Power of Models. Software and System Modeling (SoSym) 4(2), 171–188 (2005)
5. Kelly, S., Tolvanen, J.: Domain-Specific Modeling. Wiley, Chichester (2008)
6. Booch, G., Brown, A., Iyengar, S., Rumbaugh, J., Selic, B.: An MDA Manifesto. MDA Journal (2004)
7. Cook, S., Jones, G., Kent, S., Wills, A.C.: Domain-Specific Development with Visual Studio DSL Tools. Addison-Wesley, Reading (2007)
8. Stoy, C.: Game Programming Gems 6, pp. 393–403. Charles River Media (2006)
9. Champandard, A.J.: Behavior Tree, `http://aigamedev.com/tag/behavior_tree`
10. Bubbles video, `http://www.youtube.com/watch?v=SJLTskfbY8s`
11. Rosa, A.: Designing a DSL solution for the domain of Augmented Reality Software applications Specification. Msc. Thesis. Universidade Nova de Lisboa, Portugal (2009)

A Study of Virtual Product Presentation with Whiteboard and Its Effect on Users Perception

Wu-Yuin Hwang[1], Siao-Han Syu[1], Jung-Lung Hsu[2], and Chio-Tan Kuo[3]

[1] Graduate School of Network Learning Technology, NCU, Taiwan
[2] Department of Information Management, Kainan University, Taiwan
[3] Management & Information Dept. National Open University, Taiwan
wyhwang@cc.ncu.edu.tw, han8584@yahoo.com.tw, srl666@gmail.com, tony@mail.nou.edu.tw

Abstract. In this paper, one innovative VPPW (Virtual Product Presentation with Whiteboard) system is proposed. The system provides multi-presentation virtual products and high level of interactivity on products to let users explore products online. In addition, semi-translucent multimedia whiteboards were provided in which users could study products information and explore 3D product simultaneously. By investigating the effect of consumers' attitude toward product, shopping enjoyment and purchase intention, this paper contributes to better understand how different level of interactivity influence consumer online shopping behavior.

Keywords: virtual product**;** semi-translucent multimedia whiteboards; purchase intention; Web3D.

1 Introduction

As the information technology continues advancing, many online retailers begin shifting their focus from demonstrating merchandises in a 2D way to presenting the products with 3D technology, which, they believe, can afford customers more positive online shopping experience. Objectives of this research are to provide some interactive function on products and to investigate the influence of potential factors that are supposed to motivate consumer's desires and curiosities to interact with products, in this way; they will know more about information of products. It will provide more chances for customers to interact with 3D products than traditional online shopping websites can do. We hope this way will help users get more real feeling and understandings about the products afterwards.

Currently, some visualization system can be used to view 3D data easily, but most of them usually encounter two problems. First, users lack a useful tool to express their ideas or explain the meanings of 3D data. Similarly, in the Internet, shopping websites usually just present 3D products, but lose detail illustrations about them. And as we

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 435–443, 2009.

know, people usually use 2D symbols to represent 3D real objects in daily life, but it's hard to express in 3D space. Another disadvantage of shopping websites is that web pages about product always be fixed, so consumers probably do not really clearly understand the descriptions and specifications of products. Thus, we solve those problems by incorporated semi-translucent multimedia whiteboards into a 3D virtual space combined with virtual 3D products; we called it as Virtual Products Presentation and Whiteboard System, or VPPW. In this system, it not only allows users viewing virtual 3D products but also interacting with products and understanding information of products from translucent multimedia whiteboards.

2 Related Work

2.1 Use 3D Technology to Present Virtual Product

In traditional online shops, the way of presenting product usually conducted through the texts or 2D images. In fact, both ways can't clearly present real shapes of products. Thus, there is a gap between market place to market space, making consumers hesitate to purchase the products of interest. And users also have the probability of buying a product that is not exactly what they really wanted. According to Li's [1] study, online 3D virtual products can provide a stimulated experience because of the visualization information and perceptions of mind. The process of trying garments on a 3D virtual model may provide affective experience dimensions, creating attractive, novel, or complex ensembles to one's likes and may generate arousal and pleasure [3]. And Liet[2] found that a positive experience on presenting 3D virtual products which can provide more abundant information about the products with involvements and enjoyments while users controlling the 3D products. According to the research, we considered it important to present products online by 3D technology.

2.2 The Interactivity of Virtual 3D Products

Although some virtual product presentation systems have begun to use virtual reality to support multi-angles viewing of products, exploring the functions embedded within the virtual products is so far not available. Thus, users hardly have experiences to virtually operate the products' functions and receive real-time feedbacks from the online products. However, Abend[3] showed that the ability of trying products may be an important interactive feature for apparel Web sites because consumers frequently state the inability to try on the product which leads to hesitation to purchase apparel online. And the interactive nature of Web sites also has been acknowledged to be positively affect users' responses, including enhancing their desires to browse and purchase online. In addition, Goose and Dou [4] used Internet special interactivity and appealing level toward web site for further analysis. Results showed that while the higher interactivity web site was provided, the higher appealing toward online shop by users. Another advantage of interactivity, Hoffman and Novak [6] showed that the navigational process facilitated by interactivity dramatically increased the freedom of choice and the level of control experiences of customers. Based on those findings,

researchers have emphasized on supporting high level of interactivity on virtual 3D products and facilitate users to manipulate essential functions of 3D products to simulate real shopping situations. Eckman[3] stated that consumers think garment products is intricate and requires more in-depth examination before purchase, thus, interaction with products may provide detailed indirect but vivid experiences. Another study concentrated on the effects of level of interactive technology in the online retailing environment using the technology acceptance model and found a significant positive effect of interactive technology on user perceptions of online shopping enjoyment [3]. And Li [7] found that 3D product presentations outperformed 2D pictorial presentations in enhancing perception of virtual product experience online.

2.3 The Virtual Whiteboard

For convenience and ease of use, people usually use 2D symbols to represent 3D physical objects in daily life, using tools such as paper and whiteboard. Hwang [7] have proposed a system which integrated with virtual whiteboard to support mathematical problem solving with multiple representations. This research is extended from the system. And Hus[5] pointed out three key factors that a website should possess, namely timeliness, readability and information richness. Of the three factors, the last one means the web site must provide sufficient information for users to choose the right products; this is another reason why we would like to use whiteboard in 3D product presentations. Kalakota[8] found that before users make a purchase decision, especially when they buy the unfamiliar or high value products, they hope to obtain complete information to make a correct choice. Thus, this research would like to use virtual semi-translucent whiteboards to help users understand products by posting product descriptions they want to know or making annotations on it and whiteboards can be seamlessly integrated with the back 3D products and be put in any space in the 3D environment.

2.4 Consumer Attitude toward Product and Purchase Intentions in E- Commerce

Holbrook and Corfman noted that product attitude is especially useful in expressing the feeling of an ongoing relationship with the product or product category [9]. Attitude toward product is related to a more general conception of a product, and it incorporates affective and behavioral components [10]. Oliver and Churchill stated that product attitude can be assessed as the sum of satisfactions with the various attributes of the product or the service [11]. Thus, when we increase level of interactivity on products, we would like to investigate users' attitude toward product as well. We considered it important and thus hypothesize it has direct and positive effect on users' purchase intention. On the other hand, reflecting on the seminal work of shopping enjoyment, Kim founded that consumer shopping enjoyment culminates from pleasure and excitement triggered by the store environment [3]. And Koufaris pointed that shopping enjoyment and perceived usefulness of a site are important predictors of revisiting a site in the future [8]. Another study found that interactive technology has a significant positive effect of on user perceptions of online shopping enjoyment [3].

In addition, we considered that shopping enjoyment should also influence consumers' attitudes. Similarly, in Terry L. Childers studies, enjoyment is a consistent and strong predictor of attitude toward interactive shopping [14]. Furthermore, pleasing sensory qualities of store design positively affected shoppers' behavioral intentions (e.g., willingness to stay longer, purchase intentions) [13]. Li et al. showed that consumers had more positive approach responses when they were exposed to 3D visualizations as compared to 2D graphics of the product [12].

3 System Implementation

Web3D open standards allow the delivery of interactive 3D virtual learning environments through the Internet, reaching potentially large numbers of learners worldwide, at any time [1]. We implemented the 3D models in VPPM system, and the open XML-enabled 3D standard is employed, which proposed by the Web3D consortium, and we integrate multimedia whiteboard into our system. In this system, users can explore products easily without other assistive tools through Internet. With multimedia whiteboard, users could use different representations like graphics, texts and annotations to show their ideas and share with others by whiteboard contents transferring. And high level of interactivity on the 3D virtual product is available to consumers; they can explore the essential functions of products, further know about products sufficiently and enhance their perception experiences and shopping enjoyment. Furthermore, 3D product presentation system usually just show one product, but our system can put several different 3D products in a 3D space to help consumers to make a contrast about different products conveniently. And another feature in our system is virtual whiteboard which can be put in right position and seamlessly integrated with 3D product. Whiteboard could be pulled down to read product information and pulled up to manipulate the products behind so that users can easily compare the characteristics and functions of products, thereby bringing more convenience and usefulness than the traditional advertisements. Different from popup spec sheets in web pages, virtual whiteboard is designed for 3D theme which is a 2D object and can be created or deleted flexibility in anywhere in 3D space as user would like.

4 Research Design

4.1 Experiment Design

We used a one-factorial between-subjects design comprised of three experimental conditions to examine the effect virtual whiteboard and interactivity on products on user intention to purchase and attitude toward products. The factors manipulated between subjects were the availability of interactivity on 3D products and the textual product description provided by whiteboard. Each experiment conditions consisted of two scenarios, the first one was to let users only view 3D products appearance included Product A and Product B shown in Figure 2 and 3 respectively. After that, in the second scenario, subjects had to explore two 3D products again with investigated features, including virtual whiteboard (see Figures 4 and 5.) or/and interactivity of

products (see Figures 6 and 7). Each condition took about 40 minutes. After each experimental scenario was done, one brief questionnaire was given. Subjects were 31 undergraduate students in which divided into three groups: one group with interactivity, the other group with virtual whiteboard and the other group with interactivity and virtual whiteboard.

4.2 Research Architecture

Under the proposed framework, we hypothesized that interactivity on product and whiteboard would have a positive effect on attitude toward product and shopping enjoyment of users. And we investigated whether shopping enjoyment would bring positive effect on attitude toward product or not. Finally, we considered that attitude toward product and shopping enjoyment would have positive effect on purchase intention.

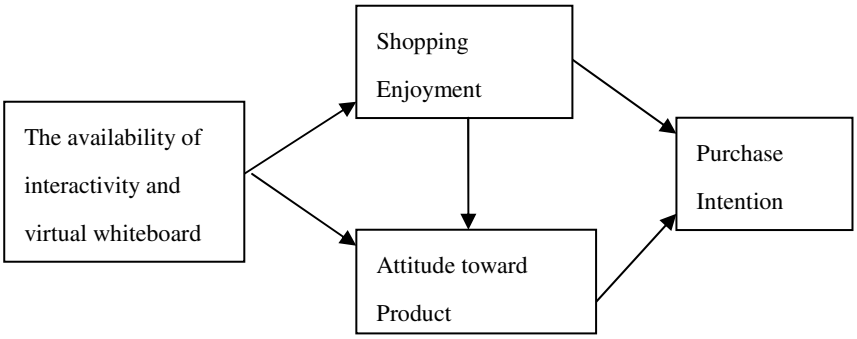


Fig. 1. One figure is given to show research architecture

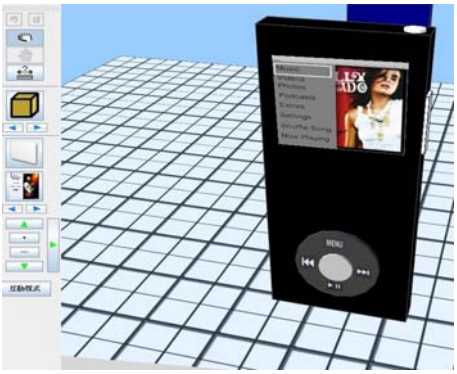


Fig. 2. 3D virtual presentation of product A

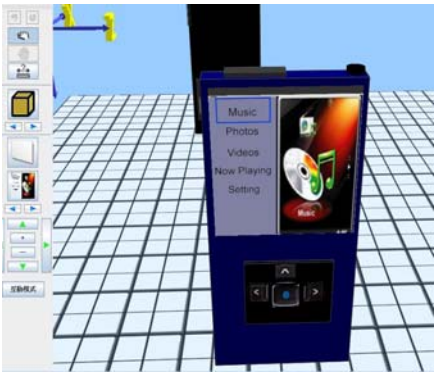


Fig. 3. 3D virtual presentation of product A

Fig. 4. Information about product A on whiteboard

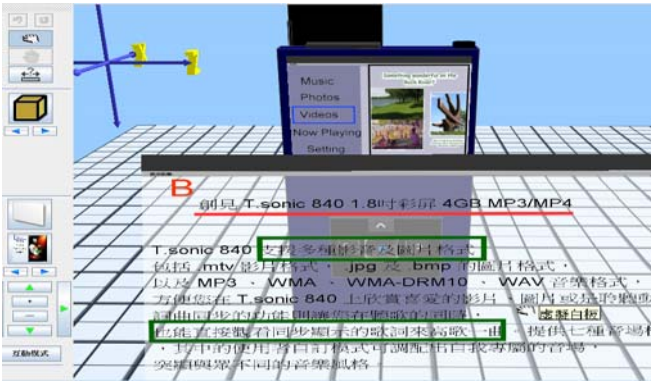


Fig. 5. Information about product B on whiteboard

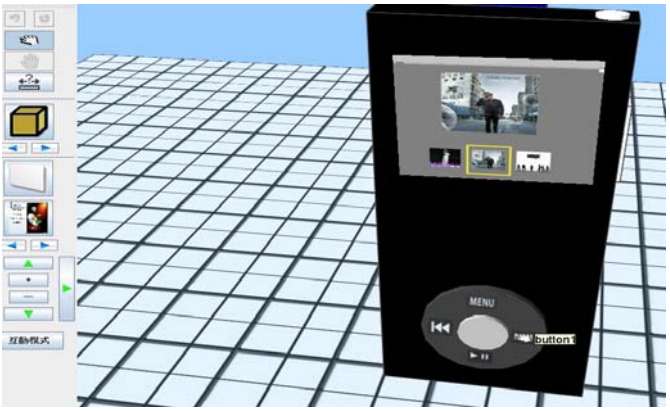


Fig. 6. One interactive function of product A

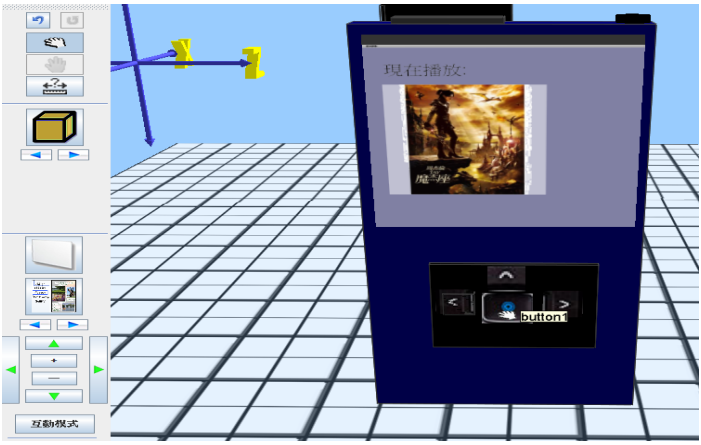


Fig. 7. One interactive function of product B

Fig. 8. Virtual whiteboard is pulled down To show the product information

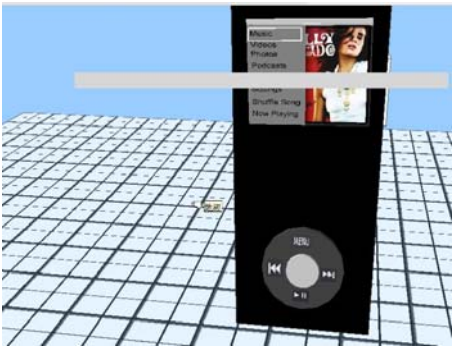


Fig. 9. Virtual whiteboard is pulled up And manipulate the product is allowed

5 Results and Discussion

The results of questionnaires were shown in Table1, 2 and 3. Results showed that availability of interactivity of products had a positive effect on purchase intention about product A ($p<.007$) and product B ($p<.010$). Therefore, interactivity on products could enhance users' purchase intention. However, the availability of virtual whiteboard had a little promotion on purchase intention about product A, but it is little decreasing on product B. And about attitude on products and shopping enjoyment of users, the group of whiteboard did not receive positive evaluations, the reason maybe is when we provide more information, consumers not necessarily have more affection feeling about products and enjoyment feeling. As for the availability both of interactivity of products and whiteboard stand for our system had a positive effect on purchase intention ($P<.047$). On the other hand, it had a positive effect on attitude about A ($p<.003$) and B ($p<.005$) product and this effect was stronger than the groups of

interactivity and the group of whiteboard and users also give positive evaluations on shopping enjoyment higher than only 3D products presentation (P<.046), meaning that the VPPW system can provide them more shopping enjoyment. Importantly, according to these observations, the subjects were highly motivated by the availability both of interactivity of products and virtual whiteboard; such the effect may have caused users to produce more purchase intention.

Table 1. The values of mean score and standard error in group of interactivity and whiteboard

No. Group of interactivity and whiteboard	Pre		Post		p
	Mean	SD	Mean	SD	
Purchase intention of A product	2.85	.929	3.26	1.22	.047
Purchase intention of B product	2.62	.734	3.00	.849	.073
Attitude of A product	2.77	.955	3.38	1.15	.003
Attitude of B product	2.49	.637	3.30	1.24	.005
Shopping enjoyment	2.96	.916	3.31	1.14	.046

Table 2. The values of mean score and standard error in group of interactivity

No. Group of interactivity	Pre		Post		p
	Mean	SD	Mean	SD	
Purchase intention of A product	3.02	.858	3.36	.881	.007
Purchase intention of B product	2.58	.653	2.86	.772	.010
Attitude of A product	3.18	.833	3.37	.261	.157
Attitude of B product	3.03	.669	3.14	.578	.275
Shopping enjoyment	3.39	.701	3.50	.714	.078

Table 3. The values of mean score and standard error in group of whiteboard

No. Group of whiteboard	Pre		post		p
	Mean	SD	Mean	SD	
Purchase intention of A product	3.30	.785	3.56	.386	.226
Purchase intention of B product	3.80	.624	3.73	.307	.758
Attitude of A product	3.60	.377	3.52	.150	.638
Attitude of B product	3.65	.502	3.67	.540	.414
Shopping enjoyment	4.16	.436	3.53	.531	.004

6 Conclusion

In this paper, the Virtual Product Presentation and Whiteboard system was proposed a multi-representative products environment to let users explore products online. Researchers employed computer 3D graphics and simulations to create the system, offering users a flexible way to know products. And it incorporated semi-translucent multimedia whiteboard which can seamlessly integrate with 3D products and be post specifications of products, through whiteboard; users can more understand features of product. Another feature in the system is higher level of interactivity on products;

users can manipulate essential functions of products to enhance their shopping experience and understanding about products. The proposed system was evaluated with a questionnaire on purchase intention; attitude about products and shopping enjoyment, and the results showed that most of subjects have positive perception about the WPPW system. But the group of whiteboard shown that virtual whiteboard did not have positive effect on attitude about products and shopping enjoyment. In future, the researchers will try to enhance more powerful whiteboard to facilitate users to compare, understand products and share information.

References

1. McBreen, H., Jack, M.: Empirical Evaluation of Animated Agents. In a Multi-Modal E-Retail Application (2000)
2. Häubl, G., Figueroa, P.: Interactive 3D Presentations and Buyer Behavior. Short Talk: User Studies –Lessons for HCI (1998)
3. Kim, J., Fiore, A.M., Lee, H.H.: Influences of online store perception shopping enjoyment, and shopping involvement on consumer patronage behavior towards an online retailer. Journal of Retailing and Consumer Services (2006)
4. Xiong, H., Surong Sun, A.: Distributed Collaborative Product Customization System Based on Web3D. In: Proceedings of the 2007 11th International Conference on Computer Supported Cooperative Work in Design (2007)
5. Durstewitz, M., Kiefner, B., Kueke, R., Putkonen, H., Repo, P., Tuikka, T.: Virtual Collaboration Environment for Aircraft Design. In: Proceedings of the Sixth International Conference on Information Visualisation (2002)
6. Srini, S., Srinivasana, Andersona, R., Ponnavolub, K.: Customer loyalty in e-commerce: an exploration of its antecedents and consequences. Journal of Retailing (2002)
7. Wu Yuin, H.: A Study of Multi-Representation of Geometry Problem Solving with Virtual Manipulatives and Whiteboard System
8. Ahmed, Y., Mahfouz: Interactive Experiential Ecommerce: An Experiential Study. In: Proceedings of the 7th Annual Conference of the Southern Association for Information Systems
9. Holbrook, M.B., Corfman, K.P.: Quality and value in the consumption experience: Phaedrus rides again. Perceived Quality: How Consumers View Stores and Merchandise, Lexington Books, Lexington, MA, pp. 31–57 (1985)
10. Bolton, R.N., Drew, J.H.: A longitudinal analysis of the impact of service changes on customer attitudes. Journal of Marketing 55, 1–9 (1991)
11. Churchill, G.A., Surprenant, C.: An investigation into the determinants of customer satisfaction. Journal of Marketing Research 19, 491–504 (1982)
12. Li, H., Daugherty, T., Biocca, F.: Characteristics of virtual experiences in electronic commerce: a protocol analysis. Journal of Interactive Marketing 15, 13–30 (2001)
13. Mattila, A.S., Wirtz, J.: Congruency of scent and music as a driver of in-store evaluations and behavior. Journal of Retailing 77, 273–289 (2001)
14. Terry, L.C., Christopher, L.C., Peckc, J., Carson, S.: Hedonic and utilitarian motivations for online retail shopping behavior. Journal of Retailing 77, 524–526 (2001)

Survey on Collaborative AR for Multi-user in Urban Studies and Planning

Ajune Wanis Ismail and Mohd Shahrizal Sunar

Faculty of Computer Science and Information System
Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
ajunewanis@ymail.com, shah@fsksm.utm.my

Abstract. This paper describes an augmented reality (AR) environment that allows multiple participants or multi-user to interact with 2D and 3D data. AR simply can provide a collaborative interactive AR environment for urban planning, where users can interact naturally and intuitively. In addition, the collaborative AR makes multi-user in urban planning to share simultaneously a real world and virtual world. The fusion between real and virtual world, existed in AR environment by see-through HMDs, achieves higher interactivity as a key features of collaborative AR. In real-time, precise registration between both worlds and multi-user are crucial for the collaborations. Collaborative AR allow multi-user to simultaneously share a real world surrounding them and a virtual world. Common problems in AR environment will be discussed and major issues in collaborative AR will be explained details in this survey. The features of collaboration in AR environment are will be identified and the requirements of collaborative AR will be defined. This paper will give an overview on collaborative AR environment for multi-user in urban studies and planning. The work will also cover numerous systems of collaborative AR environments for multi-user.

Keywords: Augmented Reality, Multi-User, Collaborative, Urban Planning.

1 Introduction

In 1965, Ivan Sutherland developed a technology that made it possible to overlay virtual images on the real world [1]. Attaching two head worn miniature Cathode Ray Tubes (CRT) to a mechanical tracker he created the first display known as Head-Mounted Display (HMD). The term AR is often used to refer to interfaces in which two and three-dimensional computer graphics are superimposed over real objects, typically viewed through head-mounted or handheld displays [2]. In 1994, the context of AR, often the term "Mixed Reality" (MR) is used. It is a superset of AR and covers the reality-virtuality continuum between completely real environments and completely virtual environments, a concept introduced by Milgram and Kishino [3], which encompasses both AR and Augmented Virtuality (AV). The degree of how much both elements between virtual and real objects, are within an MR application, define its classification as either AR or AV.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 444–455, 2009.

Azuma and friends [4] provide an in-depth review of current and past AR technology and applications in their research. Although single user AR applications show great promise, possibly the greatest possible use for AR is for growing new types of collaborative interfaces. AR enables us to enhance real world with virtual world. In addition, the collaborative AR makes multi-user to simultaneously share a real space surrounding and virtual space, registered visually with the real one.

Based on review related literature on urban planning, the *Digital Urban Planning* was first come up with the development of Digital City in later 2000. Professor Lai Ming, who is one of the officials of the Ministry of China Construction, pointed out that Digital City supplied totally new way to solve the issues of urban planning, managing, constructing, and controlling. At the same time, Professor Ding Lie Yun said that the concept and method of urban planning require to be changed along with the development of digital city. Two months later, Professor Jian Fengmin [5] stated that the digital urban planning means to illustrate the past, current, and future spatial shape of city by combination of city economical, social, and population information based on digital map.

In 2001, Professor Wu Shuxia [6] claims that digital urban planning was the combination of theory and method of traditional urban planning with new technology in the new digital city period. The concept of digital urban planning is not only the technology, but also the quantitative theory and method of urban planning [7]. Later, technologies AR are expanding for urban planning. An *Augmented Reality Workbench* called "Luminous Table" that attempts to deal with this issue by integrating multiple forms of physical and digital representations. In order to support the urban design process, 2D drawings, 3D physical models, and digital simulation are overlaid into a single information space [8]. Schmalstieg et. al. [9] describes how AR technology is applied in the urban reconstruction process and can be used to share the sense of place and presence.

This survey describes collaborative AR for multi-user in urban planning that employs collaborative AR as a medium of collaboration. Section 2 will describe AR environment for urban planning and common problems encountered in order to propose AR environment. The next section will explain about collaborative AR environment including their features of collaborative AR, and requirements of collaborative AR environments. In this paper will summarize the previous collaborative AR environments that have already developed and proposed by group of AR researcher that focusing on AR collaboration for multi-user. Finally, this paper will discuss the comparative studies on previous works of AR projects, focusing on collaborative AR environment for multi-user in urban planning. Conclusion and future directions are discussed in Section 6.

2 AR Environment for Urban Studies and Planning

Traditionally urban design is perceived, communicated and created using physical and digital media. However, these realms are handled as separate entities, which hinder

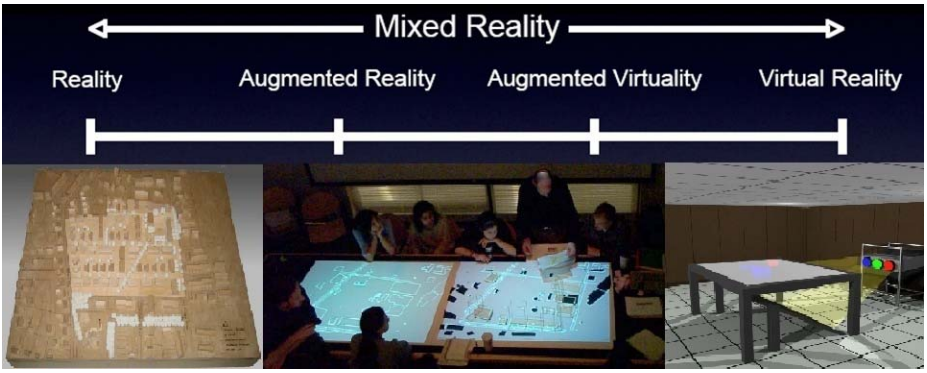


Fig. 1. A concept of Mixed Reality introduced by Milgram and Kishino with illustrated the new appearance of urban planning from traditional view of blocks to virtual reality

collaboration, understanding and communication. Collaborative AR systems can integrate these tasks into one media type and allow a different conversation with complex issues. Human Computer Interfaces (HCI) and Tangible User Interfaces play a key role in AR. They allow the combination with both the real and virtual component of an urban design project.

AR environments are defined by Milgram and Kishino [3] as those in which real world and virtual world objects are presented together on a single display. The AR applications have shown that AR interfaces can enable a person to interact with the real world in ways never before possible [2]. These AR researches, however, have been made mainly on single-user applications so far. New application fields will appear if multi-user able to share a physical space and if we can seamlessly offer a virtual space into the shared physical space [10]. For example, it becomes possible for multiple people to collaborate to design something while exchanging their ideas through virtual objects [11].

Common to all roundtable meetings is that the multi-user are sitting together, facing each other, and communicating verbally and through hand gestures and facial expressions. Multi-user is often starting with simple sketches by their hand drawings, improving over several stages of 2D plans and 3D models, gradually getting more complex and finally leading to very complex CAD models and highly real 3D models [12]. It is a highly iterative process, which is often very slow. Architects consider the possibility of interactively varying and touching the sketches, plans, and models as an essential part of motivation during design review meetings.

AR collaboration and multi-user for urban planning are reflected by the use of intuitive interaction mechanisms, which allow even untrained users to benefit from the enhancements provided by the AR environment. However, in this paper we discussed two problems in collaborative AR; there are registrations and user collaboration.

3 Collaborative AR Environment

AR has two unique features [13]. One is that the virtual space is seamlessly merged with the physical one. The second is that the virtual space as well as the physical one reacts to the physical actions of physical participants.

Based on the requirements of these registration accuracy and response time to physical actions, multi-user collaboration systems with AR are categorized into four groups. First is the type where both requirements are not strict [14]. Secondly, there is a type that requires the accurate positional registration though it does not need high speed response [15]. On the contrary, there is a type that requires the real-time response and needs not the accurate spatial registration. Finally, there exist applications in which both requirements are strict. There is another factor, mutual exclusion, which characterizes the collaborative operations.

A seam is a spatial, temporal or functional constraint that forces the user to shift among a variety of spaces or modes of operation [16]. People looking at a projection screen or crowded around a desktop monitor are less able to refer to real objects or use natural communication behaviors [17]. Tangible interfaces are extremely intuitive to use because physical object manipulations are mapped one-to-one to virtual object operations.

For co-located collaboration AR can blend the physical and virtual worlds so that real objects can be used to interact with 3D digital content and increase shared understanding. Tangible interaction techniques can be combined with AR display techniques to develop interfaces in which physical objects and interactions are equally as important as the virtual imagery and provide a very intuitive interaction metaphor, defined as Tangible Augmented Reality (Tangible AR).

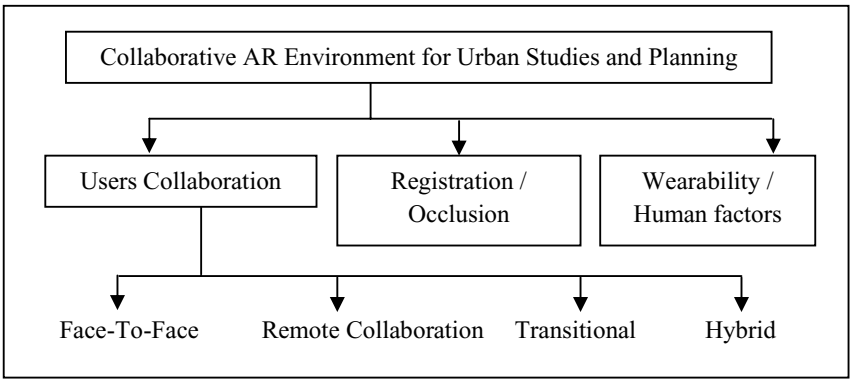


Fig. 2. Collaboration consists of four subdivisions. There are consists of collaboration interfaces which attempts to support current collaborative technologies.

Table 1. Comparison of collaborative AR interfaces and example has given for each collaborative interfaces and technologies

Collaboration AR	AR Condition	Example
Face-To-Face	Conversation, speech, gesture, body language and other non-verbal cues combine to show attention and interest. [7]	**Studierstube**
Remote Collaboration	The roles of audio and visual cues in teleconferencing have produced mixed results. [18]	**WearCom**
Transitional Interfaces	Physicality, AR and immersive VR are traditionally separate realms that people cannot seamlessly move between. [19]	**MagicBook**
Hybrid Interfaces	Integrate AR technology with other collaborative technologies. [20]	**AR PRISM, EMMIE**

Audio interfaces remove the visual cues vital for conversational turn taking, leading to enlarged interruptions and overlap, difficulty in disambiguating between speakers, and in determining other's willingness to interact [19]. With conventional video conferencing subtle user movements or gestures cannot be captured, there are no spatial cues between multi-users, the number of multi-user is limited by monitor resolution and multi-user cannot easily make eye contact. Speakers cannot know when people are paying attention to them or are able to hold side conversations. The main effect on communication is the presence of mediating technology rather than the type of technology used [21].

Desktop and immersive collaborative virtual environments (CVEs) can provide spatial cues to support group interactions. These interfaces restore some of the spatial cues common in face-to-face conversation, but they require the user to enter a virtual world separate from their physical environment. According to Raskar et. al. [22], in case multiple cameras are used to capture and reconstruct a virtual geometric model and live video avatar of a remote user.

3.1 Major Issues with AR Collaboration

AR is ideal for collaborative interfaces because it addresses two major issues in CSCW: *seamlessness* and *enhancing reality* [19].

Seamlessness. According to [16], seams can be of two types: Firstly, Functional Seams: Discontinuities between different functional workspaces, user is forcing to change modes of operation. Secondly is Cognitive Seams: Discontinuities between existing and new work practices, user is forcing to be taught new ways of working.

Enhancing reality. Removing the seams in a collaborative interface is not enough. Considering face-to-face interaction as a specific type of communications medium, it becomes apparent that this approach requires one medium to adapt to another, pitting the strengths of face-to-face collaboration against other interfaces. They must enable users to go "beyond being there" and enhance the collaborative experience [23] [24]. In fact, because of the nature of the medium, it may be impossible for mediated collaborations to provide the same experience as face-to-face collaboration [25].

3.2 Features of Collaborative AR Environment

Virtuality. The potential of objects can be viewed and examined, either are not reachable or do not exist in the physical spaces can be carried out in AR environment.

Augmentation. Real objects that do exist in real world can be augmented by virtual annotations. As a result, it allows a smooth fusion between real objects and virtual properties in propose processes [26].

Multi-user. The situations where multi-user gather together to perform other types of cooperative work or collaboration. Higher interactivity among multi-user effectively interacts with themselves using normal sense of human interactions, like verbal and gestures are now simply possible in an augmented reality setup [27].

Independence. Each user has the option to move freely and independently of the other users. Each user may freely control his own independent viewpoint. However, not only is observation independent, interaction can also be performed independently without interrupting any action that performed by other users [28].

Individuality. In general models and objects are shared among users means all users can observe the same coherent model, consistent in sense of visibility. The displayed objects can also be different for each observer, as required by the application's needs and the individual's option [28].

4 Collaborative AR Environment for Multi-users

AR can create an augmented workspace which multi-user may access a shared space populated by virtual objects, while remaining grounded in the real world. One of the most important purposes of collaborative AR environment is to promote social interaction among multi-user located in the same physical space.

Another form of collaborative AR is efficient to be applied in entertainment applications. Interactive in gaming becomes one of the dominant application areas especially for computer graphics. Handheld computers, mobile phones and personal

Table 2. AR systems that support collaboration for multi-user in collaborative AR

AR System	System Overview
Studierstube: *An Environment for Collaboration AR.*	Developed at the Technical University of Vienna uses light-weight HMD displays to project artificial 3D objects into the real world. [7]
MARE: *Multiuser AR Environment on table setup.*	Decomposed the table surroundings in two parts: first, the personal area where the user put his private real and virtual objects. The second part is the shared area, communication and common interactive space. [29]
Virtual Round Table: *A Collaborative Augmented Multi-User Environment.*	Designed to support location-independent mixed reality applications, overcome the limitations for collaboration and interaction of existing approaches. It extends preserving verbal and non-verbal communication and cooperation mechanisms. [30]
Construct3D: *Collaborative AR in Education.*	Designed for mathematics and geometry education. It describes efforts in developing a system for the nhancement of spatial abilities and maximization of transfer of learning. [31]

digital assistants have the potential to commence AR. As a result, AR can be widely applied for games. AR^2Hockey (Augmented Reality AiR Hockey) is a game where players can share a physical game field, mallets, and a virtual puck to play an air-hockey game [13]. In ARQuake game, the player runs around a virtual world, shooting at monsters, collecting objects, and completing objectives [32]. Virtual Roulette is famous casino game shows the table with multi-user is playing [33] and the latest collaborative multi-user AR game, virtual trains on a real wooden tiny rail track, The Invisible Train [34] [35].

5 Collaborative AR Environment for Multi-user in Urban Studies and Planning

Previous section before we have discussed on requirements of collaborative AR and their features that have a force on overcoming major issues with collaborative AR. This section summarizes collaborative AR systems for multi-user in design and planning, as well as for urban planning. Finally we look at the comparative study on several projects that employs collaborative AR systems in urban studies and planning.

Table 3. Collaborative AR systems for design and planning

AR System	Exhibit contents
MagicMeeting *A Collaborative Tangible Augmented Reality System.*	Supports product review meetings by augmenting a real meeting location. Instead of real mock-ups, virtual 3D models are used, which may be loaded into the environment from usual desktop applications or from PDAs. [36]
AR-Planning Tool *Designing Flexible Manufacturing Systems with Augmented Reality*	Supports the collaborative planning of production lines. Machines are modeled as virtual building blocks and can be positioned by the user with a visually tracked paddle. [37]
The Urban Sketcher *Mixed Reality on site for urban planning and architecture*	Instrumental for developing urban spaces by augmenting the real environment with sketches, facades, buildings, green spaces or skylines. [38]

Table 4. Collaborative AR for multi-user in Urban Studies and Planning

AR System	Comparative Studies
ARTHUR *A Collaborative Augmented Environment for Architectural Design and Urban Planning.* 	Arthur is system for collaborative urban design using AR for presentation. It allows designers a direct access to geometrical data and provides a tabletop immersive environment. By using optical augmentation and wireless computer–vision based trackers to allow for a natural 3D collaboration. Virtual objects are displayed using stereoscopic visualization to seamlessly mix them into the real world. However, it attempts to integrate manipulation techniques of CAD directly through spatial 2D menus and does not provide an estimate of this approach. [12]
The *Luminous Table* *Augmented Urban Planning Workbench: Overlaying Drawings, Physical Models and Digital Simulation.* 	"Luminous Table" that attempts to tackle this issue by integrating multiple forms of physical and digital representations. 2D drawings, 3D physical models, and digital simulation are overlaid into a single information space in order to support the urban design process. The physical objects are tracked with cameras. It was conceived as a platform for multi-layered physical and digital representations. [27]

Table 4. *(Continued)*

AR System	Comparative Studies
The Augmented Round Table *A new Interface to Urban Planning and Architectural Design* 	Augmented Round Table is providing a new interface for collaborative design and review for architecture and urban planning. The interface relies on unobtrusive input mechanisms and natural and intuitive user interactions. Focus on providing an intuitive environment, which supports natural interaction with virtual objects while sustaining accessible collaboration and interaction mechanisms. [11]

6 Conclusion

In this paper we performed our survey on collaborative AR for multi-user in urban studies and planning. On the first section of this paper, we have described about AR environment and AR for urban planning. Next section we identified the collaborative AR environment. We found several common problems that can be encountered by AR collaborative environment. In this paper we described the major issues in AR collaboration system. We also have identified the features of AR collaborative and the requirements needed for collaboration AR environment. Users experience with these interfaces have shown that they facilitate collaboration in a natural manner, enabling people to use normal gestures and non-verbal behavior in face-to-face collaboration, and to have access to their conventional tools and workplace by both face-to-face and remote collaboration.

AR techniques can be effectively used to develop fundamentally different interfaces for face-to-face and remote collaboration. This is because AR provides seamless interaction between real and virtual environments, the ability to enhance reality, the presence of spatial cues for face-to-face and remote collaboration, support of a tangible interface metaphor, the ability to transition smoothly between reality and virtuality. In this paper we have provided several examples of collaborative AR environment in gaming and also comparative studies on previous works of collaborative AR environment for urban studies and planning. Finally we have focused the highlighted issue on multi-user in collaborative AR for urban studies and planning. The challenge of this survey is to bring collaborative AR for multi-user into the urban studies and planning in order to provide new effective approach in urban studies and to enhance collaboration shared physical urban workspace. As conclusion, we hope that this research is useful for AR urban planning education and also brings benefit to the computer graphics community especially in AR emerging technologies.

Acknowledgement

We would like express our appreciation to Universiti Teknologi Malaysia (UTM) and Malaysian Ministry of Science, Technology and Innovation (MOSTI) for providing financial support of this research through *eScienceFund (79282)* grant scheme.

References

1. Sutherland, I.: A Head-Mounted Three-Dimensional Display. FJCC AFIPS 33 (1968)
2. Lee, Y., Oh, S.j., Suh, Y., Woo, W.: The ARTable: An AR-Based Tangible User Interface System. In: KHCI 2005, pp. 507–512 (2005)
3. Milgram, P., Kishino, F.: A taxonomy of Mixed Reality visual displays. IEICE Transactions on Information Systems E77-D 12 (1994)
4. Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., Blair, M.: Recent advances in augmented reality. IEEE Computer Graphics and Applications, 20–38 (2001)
5. Jian, F.: From Digital Earth to Digital City Shanghai Urban Planning. In: Information System. Engineering Design CAD and Intelligent Architecture, pp. 10–17 (2000)
6. Shuxia, W., Ai, J., Guo, P.: Digital Urban Planning-Concept and Support Technology. In: Ming, L., Menhui, W. (eds.) Theory and Practice of Digital City, vol. 2001(9), pp. 234–241. World Book Press, Guangzhou (2001)
7. Schmalstieg, D., Fuhrmann, A., Szalavari, Z., Gervautz, M.: Studierstube - An Environment for Collaboration in Augmented Reality. In: CVE 1996 Workshop Proceedings, Nottingham, Great Britain, September 19-20 (1996)
8. Ishii, H., Ullmer, B.: Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In: Proceedings of CHI 1997, Atlanta, Georgia, USA, pp. 234–241 (1997)
9. Wang, X.: State-of-the-art review of augmented reality in architecture and construction. In: Proceedings of the 4th International Structural Engineering and Construction Conference (ISEC-4), Melbourne, Australia, September 26-28 (2007) (in press)
10. Carlson, C., Hagsand, O.: DIVE - A Platform for Multi-User Virtual Environments. Computers and Graphics 17(6), 663–669 (1993)
11. Broll, W., Stoerring, M., Mottram, C.: The Augmented Round Table – a new Interface to Urban Planning and Architectural Design. In: Rauterberg, et al. (eds.) INTERACT 2003, pp. 1103–1104. IOS Press (c) IFIP, Amsterdam (2003)
12. Broll, W., Lindt, I., Ohlenburg, J., Wittk, M., Yuan, C., Novotny, T.F., Schiecky, M.C., Strothmann, A.: ARTHUR: A Collaborative Augmented Environment for Architectural Design and Urban Planning. Journal of Virtual Reality and Broadcasting 1(1), 1 (2004)
13. Ohshima, T., Sato, K., Yamamoto, H., Tamura, H.: AR^2Hockey: A case study of collaborative augmented reality. In: Proceedings of VRAIS 1998, pp. 268–295. IEEE Press, Los Alamitos (1998)
14. Billinghurst, M., Baldis, S., Miller, E., Weghorst, S.: Shared space: Collaborative information spaces. In: Proceeding HCI International 1997, pp. 7–10 (1997)
15. Fuhrmann, A., Loffelmann, H., Schmalstieg, D.: Collaborative Augmented Reality: Exploring Dynamical Systems. In: Proceeding Visualization 1997, pp. 459–462 (1997)
16. Ishii, H., Kobayashi, M., Arita, K.: Iterative Design of Seamless Collaboration Media. Communications of the ACM 37(8), 83–97 (1994)

17. Pedersen, E.R., McCall, K., Moran, T., Halasz, F.: Tivoli: An Electronic Whiteboard for Informal Workgroup Meetings. In: Proceedings of Human Factors in Computing Systems, InterCHI 1993, pp. 391–398. ACM Press, New York (1993)
18. Billinghurst, M., Kato, H., Kiyokawa, K., Belcher, D., Poupyrev, I.: Experiments with Face to Face Collaborative AR Interfaces. Virtual Reality Journal 4(2) (2002)
19. Billinghurst, M., Kato, H., Poupyrev, I.: The Magic-Book – Moving Seamlessly between Reality and Virtuality. IEEE Computer Graphics and Applications 21(3), 6–8 (2001)
20. Butz, A., Höllerer, T., Feiner, S., MacIntyre, B., Beshers, C.: Enveloping Computers and Users in a Collaborative 3D Augmented Reality. In: Proceeding IWAR 1999 (1999)
21. Sellen, A.: Remote Conversations: The effects of mediating talk with technology. Human Computer Interaction 1995 10(4), 401–444 (1995)
22. Raskar, R., Welch, G., Cutts, M., Lake, A., Stesin, L., Fuchs, H.: The Office of the Future: A unified approach to image based modeling and spatially immersive displays. In: Proceedings of SIGGRAPH 1998, pp. 179–188 (1998)
23. Hollan, J., Stornetta, S.: Beyond Being There. In: Proceedings of CHI 1992, pp. 119–125. ACM Press, New York (1992)
24. Gaver, W.: The Affordances of Media Spaces for Collaboration. In: Proceeding CSCW 1992, Toronto, Canada, October 31-November 4, pp. 17–24. ACM Press, New York (1992)
25. Agrawala, M., Beers, A.C., Fröhlich, B., McDowall, I., Hanrahan, P., Bolas, M.: The two-user responsive workbench: Support for collaboration through individual views of a shared space. In: Proceeding SIGGRAPH 1997, pp. 327–332 (1997)
26. Azuma, R.: A Survey of Augmented Reality. PRESENCE: Teleoperators and Virtual Environments 6(4), 355–385 (1997)
27. Ishii, H., Ben-Joseph, E., Underkoffler, J., Yeung, L., Chak, D., Kanji, Z., Piper, B.: Augmented Urban Planning Workbench: Overlaying Drawings, Physical Models and Digital Simulation. In: Proceedings of International Symposium on Mixed and Augmented Reality ISMAR 2002, pp. 203–211. IEEE Computer Society, Los Alamitos (2002)
28. Cheok, A.D., Yang, X., Zhou, Z.Y., Billinghurst, M., Kato, H.: Touch-Space: Mixed Reality Game Space Based on Ubiquitous, Tangible, and Social Computing. Personal and Ubiquitous Computing 6(2), 430–442 (2002)
29. Grasset, R., Gascuel, J.: MARE: Multiuser Augmented Reality Environment on table setup. In: SIGGRAPH, Conference Abstracts and Applications, Computer Graphics Annual Conference Series (2002)
30. Broll, W., Meier, E., Schardt, T.: The Virtual Round Table, a Collaborative Augmented Multi-User Environment. ACM, San Francisco (2000) 1-58113-303
31. Kaufmann, H., Schmalstieg, D., Wagner, M.: Construct3D: A Virtual Reality Application for Mathematics and Geometry Education. In: Education and Information Technologies 5-4, pp. 263–276 (2000)
32. Thomas, H., Close, B., Donoghue, J., Bondi, P., Morris, M., Wayne, P.: ARQuake: An Outdoor/Indoor Augmented Reality First Person Application. In: Proceedings of the Fourth International Symposium on Wearable Computers (ISWC 2000), Atlanta USA (October 2000)
33. Szalavári, Z., Gervautz, M.: The Personal Interaction Panel – A Two-Handed Interface for Augmented Reality. In: Proceedings EUROGRAPHICS 1997, pp. 335–346 (1997)
34. Wagner, D., Pintaric, T., Ledermann, F., Schmalstieg, D.: Towards Massively Multi-User Augmented Reality on Handheld Devices, Vienna University of Technology (2005)

35. Ajune, W., Zakiah, N.: Augmented Reality and application. In: Shahrizal, M., Najib, M. (eds.) Advances in Computer Graphic & Virtual Environment 2008, vol. 2, pp. 87–105. Universiti Teknologi Malaysia (2008)
36. Regenbrecht, H., Wagner, M., Baratoff, G.: MagicMeeting: A Collaborative Tangible Augmented Reality System. Virtual Reality 6(3), 151–166 (2004)
37. Gausemeier, J., Jurgen, F., Carsten, M.: AR-Planning Tool - Designing Flexible Manufacturing Systems with Augmented Reality. In: Proceedings of the Eighth Eurographics Workshop on Virtual Environments 2002, pp. 19–25 (2002)
38. Schmalstieg, D., Sareika, M.: Urban Sketcher: Mixing Realities in the Urban Planning and Design Process. In: Proceedings of 6th IEEE and ACM International Symposium on Mixed and Augmented Reality, pp. 27–30 (2007)

The Learning Effectiveness of Blended and Embodied Interactive Video Game on Kindergarten Students

Chih-Min Tsai, Jon-Chao Hong, and Ya-Jiuan Ho

National Taiwan Normal University, 162 Hoping E., Rd., sec. 1, Taipei 106, Taiwan
tcm@tp.edu.tw, hong506@gmail.com, jho@tp.edu.tw

Abstract. We developed an embodied interactive video game (EIVG) that is both educational and entertaining in the hope of using such system to explore the differences that exist in learning effectiveness between blended and pure digital learning. Apart from conducting experiments by having the children learned using the EIVG, we also involved teachers as part of the study helping us observe the emotional aspect of the children. The results of the study can be summarized into the following: 1 The effectiveness of blended learning is much better comparing to that of pure digital learning. 2 The effectiveness of EIVG learning of boys is better than girls. However there is no significant difference between them. 3 The EIVG is highly entertaining which results in learning objects remain highly interested and focused throughout the study. Both types of learning can effectively improve the learning outcomes of the objects.

Keywords: blended learning, embodied interactive video game, game-based learning.

1 Introduction

There is plenty of movement-based video interactive technologies exist in the current market such as Dance Dance Revoluion, Xavis, Nintendo Wii, etc. The utilization of such technology can effectively motivate the users. Nevertheless, due to the expensive nature of such equipments, it is rarely seen in a typical school environment. What has become its feasible alternative is a computer equipped with a webcam that can be utilized as video interactive environment in a school network, based on which the development of video interactive learning can be realized [1].

Our research group has developed a web-based interactive video educational game system utilizing webcams, image recognition, networking technologies, with which a learner can input information using gestures and body movements. The learning history of a particular learner is to be recorded on a server, which can then be retrieved for the purpose of analysis and diagnoses. Our study also used this system to develop the interactive video learning materials for kindergarten children and at the same time conducted various experiments on kindergarten children.

2 Theoretical Framework

There have been many interpretations to the meaning of blended learning due to the evolution of its terminology [2]. Many researchers hold that blended learning should

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 456–463, 2009.

be a learning method that incorporates several instructional modes; or several instructional methods; or that of several educational environments such as that of online and face-to-face instruction. The most common interpretation is that of online as in e-learning and face-to-face activities [3].

Many researchers [2], after comparing the students involved in blended learning, hold that the relationship between the cognitive state of a student and his/her community awareness can serve as good indicators for the design of blended learning environment. Blended learning could increase the learning outcomes of a student and enhance his/her sense of community.

Piaget believes that human minds can be illuminated while involved in game playing [4]. It effectively stimulates intellectual activities and induces the application of reasoning, logic and various intellectual faculties of the brain. There have been many studies in the past that confirmed the great importance of game playing to the learning ability of children, especially to various aspects of a child such as his/her cognitive, social, psychological, physiological and ethical development.

Squire believes that through the repetitive practice of game playing, a learner can learn to master certain obtainable techniques, which then gives the learner a sense of instant reward thereby further motivates the learner and at the same time save work and time from the instructors. The EIVG learning software developed by our research lab possesses both the strengths described above; namely repetitive practice and instant reward.

Interaction video learning realizes a new form of visual education. It enables the learners to observe physical and realistic images of the learning subjects using their sight and touch. The learning outcome engendered by this form of learning is similar to that of face-face education [5]. This characteristic can be applied to any learning locations, effectively and synchronously enhance the learning results of students and at the same time improves the memory, understanding, application and responsiveness of each individual [1]. Therefore it enables students to obtain a better processing ability on the given learning content [6]. A student, by playing games, obtains an understanding of the meaning of an object or the ability to make rational judgments on the basis of the relationship between learning content and learning objects [7].

3 Method

3.1 Research Questions

The research questions proposed by this study include:

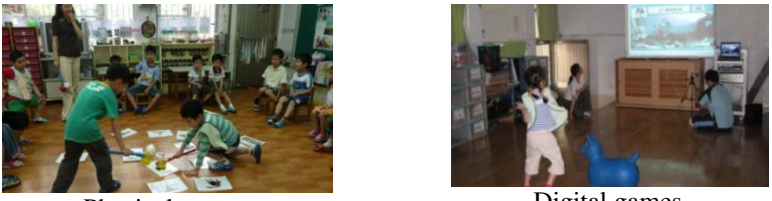
1. Which of the two learning methods, blended learning or pure digital interactive video learning, gives better learning results?
2. Could gender and age differences contribute to the difference in learning outcomes in the case of blended learning?
3. Is there a difference in the learning trend of a child who has repetitively learned using the interactive video learning system?

3.2 Participants

The participants consisted of 255 kindergarten children, out of which 144 were male and 111 were female. All of them were aged between 4 and 5 and enrolled at local kindergartens in Taipei. There were 4 kindergartens selected, one per three administrative areas and 12 areas in total. Out of each selected kindergarten, two classes were selected making the total of 8 classes of kindergarten children.

3.3 Instruments

The primary research tool we developed was named Embodied Interactive Video Game (EIVG) shown as Fig.1. EIVG is a web-based digital learning system. The mode of interaction can be described thus: A kindergarten child is to face a computer monitor (or projector screen) equipped with a webcam observing the participants and questions appeared in the monitor. At anytime, there will be a few objects falling down from above and the player will pick a matching object using body movements, based on the question appeared on the top left hand corner. Every time when the game is over, the system will halt and announce the score gained by the player therefore the player can instantly see his personal score. There will also be encouraging words displayed at the end of the game play to motivate the player for self-challenge.



Physical games Digital games

Fig. 1. The Instrument and the process of experiment

There is also a physical type of game play. It has the exact same rules as EIVG except that it requires the image files of various items found in EIVG to be printed out, which then can be used as learning material. The physical game play has the same timing and scoring system as that of EIVG.

The learning material of the game was organized and designed by kindergarten child experts and kindergarten teachers. The experiment includes two major categories each contains two game play modules. The first category contains the same game play module but different learning topics (Mode A) while the second category contains the same learning topic but different game play modules (Mode B). During the learning phase, the system can record the learning history of each child. The data obtained can then be used for analysis.

3.4 Experimental Design and Implementation

Among the kindergartens, two classes were selected from each kindergarten for experiment. One class would undergo pure digital learning while the other would undergo blended learning. For each blended learning class, a child would go through IVEG

three times and its physical counterpart three times therefore making a total of 6 times. As for the pure digital learning class, each child would go through IVEG six times and there would be no physical-learning taking place. Therefore it does not matter if pure digital learning or blended learning were to take place, there should only be 6 times of learning for each learning unit. A one-minute learning session is conducted each time learning is taken placing for both digital and physical type of learning. Every time when a question was correctly answered, a score of 10 would be given. At the end of each learning session, the total scores would be summed up, which would then be referred to as the learning outcome of this session.

4 Data Analysis

1. The comparisons of learning outcomes among children who partook in blended learning who are of different genders and ages.

An independent-samples analysis of T test was adopted for the analyses. The F value of the learning statistics was 4.37 ($p = .038 < .05$), which is an indication of the obvious difference in learning effectiveness comparing kindergarten boys with girls. It shows that kindergarten boys demonstrate better learning outcomes. As for the learning method, the F value was 12.32 ($p = .001 < 0.1$), which also indicates that blended learning has superior learning effectiveness comparing to pure digital learning.

As for the age difference study, we have included children who are taken from senior level (age 5) and intermediate level (age 4). It can be observed from Table 1 that there wasn't significant correlation between age differences and learning methods as can be seen from F value ($F = .04$, $p = .84 > .05$). Therefore the individual factor that contributes to significant difference in learning effectiveness was learning method. Age difference of kindergarten children did not play a significant role in this study. The F value of age factor was 1.59 ($p = .21 > .05$). Even though, the means of learning outcomes of senior level children were shown to be better the difference shown still did not reach a level of significance. On the other hand, the F value of learning method factor was 14.10 ($p = .0 < .001$), and it was a valid indicator showing that there is a significant difference in learning effectiveness according to different learning methods. Blended learning in this case demonstrated better learning effectiveness comparing to pure digital learning.

For the blended learning group, the F value of the correlation between the gender and game mode (digital and physical mode) did not reach a level of significance ($F = .037$). However both individual factors (gender and game mode) reached a level of significance ($F = 6.588$). There was a remarkable difference exhibited by the male children comparing to the female children of the blended learning group. The F value of game mode factor was 8.93, which shows that within blended learning, children learned better during physical sessions comparing to digital sessions. The difference was also significant.

For the blended learning group, the correlation between the age and game mode did not reach a level of significance ($F = 1.97$). As for the contributions by individual factors, despite the fact that game mode reached a level of significance, age factor did not. The F value pertaining to age factor was 0.62, which shows that there was not a direct link between the age of children and the game modes (digital or physical

mode). As for the game mode factor, the F value was 7.76 and it indicates that within the blended learning group, children learned better during physical sessions comparing to digital sessions and the difference was significant.

Table 1. The descriptive statistics of the digital and blended learning group

Groups	Digital learning			Blended learning		
	N	M	SD	N	M	SD
Boys	69	132.62	33.19	75	156.87	48.30
Girls	58	129.11	24.63	53	139.65	44.63
Age5	57	135.04	33.23	54	152.81	45.60
Age4	70	127.74	25.91	74	147.50	48.86
Total	127	131.02	29.53	128	149.74	47.41

2. The comparison of learning outcomes of physical learning and pure digital EIVG learning

An independent-samples T test was adopted for the analyses; t value was 3.38. Therefore we can conclude that physical learning was shown to be much more effective when compared with digital learning.

Table 2. The descriptive statistics of the blended learning group

Groups	Digital learning			Physical learning	
	N	M	SD	M	SD
Boys	75	146.20	55.15	167.53	51.53
Girls	53	130.28	55.66	149.03	48.28
Age5	74	133.38	54.08	161.62	55.00
Age4	54	148.15	57.26	157.47	44.93
Total	128	139.61	55.70	159.87	50.85

3. The study of learning trends of children when repeated learning sessions were given in interactive video learning mode.

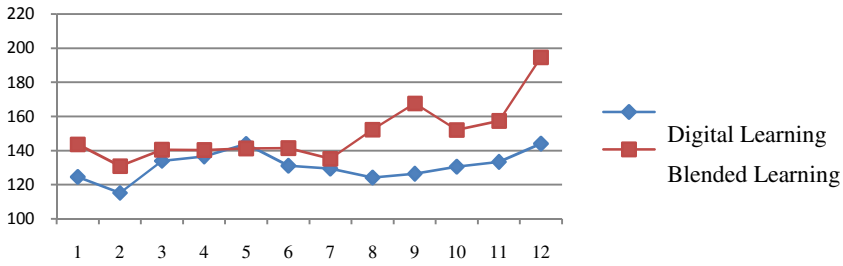


Fig. 2. Learning trends over the number of learning attempts for blended and digital group

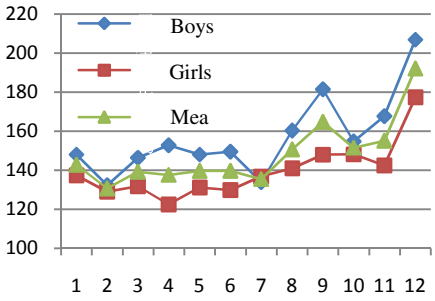


Fig. 3. Learning trends for different genders over the number of learning attempts

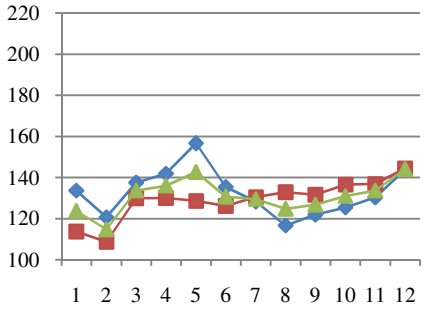


Fig. 4. Learning trends for different genders over the number of learning attempts

A repeated measures one-way ANOVA analysis was adopted for the analyses. Fig. 2 shows that, comparing to the pure digital learning, the scores of children in blended learning demonstrated an upward trend. Fig. 3 is a trend chart of children with different genders within the blended learning group scoring over repeated attempts of learning specified in a given order. It can be observed that the male children of the blended group demonstrated bigger fluctuations comparing to that of female children of the same group. It shows that the impact on learning results due to getting bored with IVEG was more prevalent in the case of the kindergarten boys comparing to the kindergarten girls. We can identify two major drops in the scoring of male children, one in 2nd attempt, one in 7th attempt, from Fig. 4. There were three turning points and on the 7th attempt, there were signs of getting tired of learning. On the female side, since the 3rd attempt, there was a steady improving trend on the scoring. This was an indication that there were more fluctuations on the kindergarten boys than the kindergarten girls. It was probably due to the fact that the kindergarten boys tend to be affected by the learning tools as compared to the kindergarten girls.

5 Discussion and Conclusion

1. Blended learning provides better learning outcomes than pure EIVG learning.

Blended learning, which combines the traditional learning and digital learning, has both the strengths of digital technology and the strengths of traditional learning in which students and the teachers both take part interactively. The fun elements of digital learning are combined with the effectiveness of traditional face-to-face learning. Blended learning can also be considered as learner-centered since a learner is provided with greater freedom of customization on how he/she could best utilize the digital technology to enforce his/her learning experience while being instructed in a traditional face-to-face manner [8].

An effective learning method should incorporate media, delivery methods and technology in a holistic manner such that the highest learning outcomes can be achieved. Since EIVG learning system belongs to the type in which more intense body movements are expected, it tends to incur fatigue under prolonged period of

usage. Therefore the appropriate insertion of both learning types, namely, traditional and digital learning, is important in striking a balance between interesting learning and effective learning. According to the observation from the instructors, both types of games (digital or physical) can successfully capture the attentions from kindergarten children. However only when blended learning is applied, through the appropriate use of physical and digital games, children tend to develop more self-confidence, more successful rate in drawing connections between various pictures therefore better learning results are achieved.

2. The outcomes achieved by boys after trying EIVG are shown to be better than that of the girls. The outcomes of children from senior level and that of intermediate level do not differ significantly.

In our study, we discover that regardless of pure digital learning or interactive video learning, boys achieve better learning results than girls. The EIVG is of action type and the content of the game belongs to creative type, and boys prefer more actions while girls prefer more creation. Our study combines both elements into the learning system and concludes that the delivery method, which is of action type, plays a more important role than the delivery content, which is of creative type, in affecting the learning of boys and girls.

As for the age difference, according to Piaget's proposed four-phase theory of Cognitive- Development, children of age 4 to 7 belong to the Intuitive stage of Pre-Operational Period. Children in this stage rely on their intuition for problem solving and have not yet developed a sense of Conservation. Generally speaking, as age grows, the types of children games show gradual changes accordingly. Parten holds that the games children play according to age is progressive in nature; from play alone (age 2 to 2.5) to parallel play (age 2.5 to 3.5); from play together (age 3.5 to 4) to play collaboratively (after 4.5).

Our study demonstrates that there is no significant difference existing in learning outcomes caused by the age difference of the kindergarten children in either blended learning or pure digital learning. One possible cause is that the ages of the participants are too close and both belong to the same phase in Piaget's theory, Intuitive stage of Pre-Operational Period. In the future, when research can incorporate a bigger age group, this can become one of the main topics for further research.

3. The children who make repetitive attempts on the EIVG demonstrate better learning trend in the case of blended learning.

Through playing games, children learn to take control on things. Games are also children's main tool for emotional adjustments, through which it is possible to observe the development of children's emotional life [9]. Through the sharing of personal experiences, children can obtain valuable lessons such as respecting others, emphasizing with others, etc. The next phase of EIVS will concentrate on the networking learning approach. This will provide a better picture of how a group of children and teachers can learn through interactions with each other.

It is also important to focus on the game design by including new and interesting features in order to increase both the entertainment and educational value. Furthermore, we could also do specialized research on the impact that EIVG has on the learning effectiveness of students suffered from mental retardation. This study has

primarily targeted kindergarten children in Taipei as research objects. In the future, the EIVG can be expanded to accommodate various levels of education. This will enable us to do research on the learning of students across the entire spectrum of educational system and gain a better understanding on the design approach that should be taken for the future EIVGs.

References

1. Hong, J.C., Ho, Y.C., Wu, C.J.: Dynamic Interactive Visual Media Design and Learning Effectiveness. In: Educational Research Association of Singapore International Conference 2007, Singapore (2007)
2. Graff, M.: Individual Difference in Sense of Classroom Community in a Blended Learning Environment. Journal of Educational Media 28, 203–210 (2003)
3. Driscoll, M.: Blended Learning: Let's get beyond the hype. E-learning (2002)
4. Piaget, J.: Play, dreams and imitation in childhood. W. W. Norton, NY (1962)
5. Zhang, D., Zhou, L., Briggs, R.O., Nunamaker Jr., J.F.: Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness. Information & Management 43, 15–27 (2006)
6. Schwan, S., Riempp, R.: The cognitive benefits of interactive videos: learning to tie nautical knots. Learning and Instruction 14, 293–305 (2004)
7. Fernaeus, Y., Tholander, J.: Designing for programming as joint performances among groups of children. Interacting with Computers 18, 1012–1031 (2006)
8. Ward, J., LaBranche, G.A.: Blended learning: The convergence of e-learning and meetings. Franchising World 35, 22–23 (2003)
9. Trevarthen, C., Aitken, K.: Infant intersubjectivity: Research theory and clinical implications. Journal of Child Psychology & Psychiatry 42, 2–48 (2001)

From Fingers to Embodiment: A Study on the Relations of the Usability, Dependability of the Embodied Interactive Video Games and the Elders' Flow Experience

Ming-Yueh Hwang, Jon-Chao Hong, Jyh-Tsorng Jong, Chia-Kun Lee, and Hsing-Yun Chang

National Taiwan Normal University 162, Sec.1 Hoping E. Rd.
10610 Taipei Taiwan
t06013@ntnu.edu.tw, hong506@gmail.com, t10020@ntnu.edu.tw, chiakunlee@hotmail.com, hsing_yun_chang@hotmail.com

Abstract. The elders feel better and healthier when participating in activities and recognizing their ability to move and creating something. Implementing technology can benefit their lives and improve social interaction. This study develops the embodied interactive video games (EIVG) relying on embodied interactions, which are free from the fine motor skills like pointing, grasping etc. Four research objectives include (1) To evaluate the usability of the EIVG; (2) To evaluate the dependability of the EIVG; (3) To understand the flow experiences of the elders during game play; (4) To explore the relations between the usability, dependability, and the elders' flow experiences. The results were discussed in three aspects. In terms of the usability and dependability of the game system, the elders were satisfied with the EIVG games due to the familiarity of the content and the ease of interaction. In terms of the flow experiences, the challenge of the games played an important role to the elders with high SES. In terms of the relations between usability, dependability, and flow experience, the usability and dependability were identified as critical factors for the elders to use computer technology due to the cognitive ageing.

Keywords: embodied interactive video game, flow experience, usability, dependability.

1 Background and Purpose

Participation in an activity helps older people feel better and healthier as they recognize their ability to move and create something [1]. Also, according to a recent report, moderate, regular exercise may be just as helpful in combating serious depression in older people as antidepressant medication [2]. Due to the development of techniques and functions, the technology helps elderly keep in touch with families and friends, ensures more safety at home, assisting and facilitating them in health care [3], bringing new stimuli into their lives and providing more access to information [4]. Other studies confirm the role of technology in increasing social interaction and pride [5], self-esteem [6], life satisfaction [7], and perceived autonomy [8]. Therefore, it is

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 464–472, 2009.

worthwhile to investigate how we could use digital technology to improve the well-being of older people through social interaction, physical activity, and entertainment.

According to the Entertainment Software Association (ESA) 2007 annual report, the average American gamer age is 33 and only 24.2% of the gamers are above the age of 50. It is a positive sign that more older people are participating in the digital games arena [9]. Findings from scientific research studies show that playing video games can lead to changes in an individual's pleasure, arousal, dominance, and/or affiliate behaviors [10] [11] [12]. Lifespan changes in interactions between sensory motor and cognitive aspects of behavior, even though, it has been shown that older people enjoy computer gaming experiences [13]. However, the impacts of aging on human –machine interactions are still lack of investigations. And the development of more friendly human –machine interface to break through the elders' literacy and psychomotor hindrance to technology is necessary.

Fortunately, commercial arcades have seen a growing trend in games that require human physical movement as part of the interaction. For example, dancing games such as Dance Dance Revolution (DDR) and parara Pararadise by Konami are based on players dancing in time with a musical dance tune and moving graphical objects. Some game systems have offered Exergames [14], which use the electronic game format to promote exercise, but these are often lack bringing the ability to motivate the players. These systems still force the person to stand, more or less in the same spot, and focus on a computer screen in front of them. Recently, the Brain Age games on Nintendo DS have gained huge popularity among older Japanese people [15]. The older players believe that such games can sharpen their thinking and they enjoy playing the games very much. On the other hand, Nintendo wii has gained tremendous popularity and has sold over 6 million consoles since its launch in late 2006 (Wii). To play the games on the console, for example in Wii sports, the player physically swings and moves the Wii remote, which goes beyond the micro movements of just pressing buttons. In addition, iGameFloor [16]. A recent research project that uses an interactive floor platform for social games and entertainment has shown that children are generally motivated by the use of bodily interaction. Thus, we believe that there is a growing need and trend for video games which promote physical activity and mental stimulation for children, adult, and older people as well.

So far, the contents of Wii are sport-oriented and the different extra devices are required for different reaction patterns. From the perspective of learning as well as cognitive aging prevention, knowledge learning contents are worth being developed. Moreover, the human-machine interfaces based on devices-free for the elders should be produced in the future. According to Fisk et al. [17], who conducted several focus groups with elderly people, found that more than 50% of problems reported by participants in using technological tools related to usability, and could be solved by improving the design (25%) or by providing training (28%). Input and output devices are particularly delicate, because they involve an interaction with the sensory or perceptual system of the user, which undergoes several changes with age that can hamper usability.

Fisk et al. [17] consider "usability" as the possibility to have access to a product, and define "utility" as the capability to provide the functionality the product possesses. They also identify five characteristics related to usability, which are particularly important when speaking about older adults:

(1) Learnability: how difficult it is to learn to use a device, to understand and to integrate functioning instruction. Time needed to complete a task correctly and results obtained in a certain amount of time are possible measures of learnability.

(2) Efficiency: the extent to which technological applications satisfy users' needs, avoiding loss of time, frustration and dissatisfaction. It can be measured by an experienced user's performance on a specific task.

(3) Memorability: elderly users' memorability of a device's functioning is very important in order to avoid frustration and loss of time. A simple measure of this characteristic can be obtained by considering the time needed to perform a previously experienced task.

(4) Errors: how easily a product can induce errors for elderly users and how easily it recovers from them.

(5) Satisfaction: users' attitude and adoption of technological applications could be influenced by the pleasure derived from their usage.

Furthermore, age-related neuromuscular changes result in older adults having muscles that do not respond as well as those of younger adults [18]. These muscular issues affect the performance of older adults in fine motor tasks [19]. Therefore, it is very important to ensure the dependability of interactive system, which reflects the extent that a system can be trusted to operate perfectly in a particular environment [20]. The attributes of dependability include availability, reliability, safety, confidentiality, integrity and maintainability [21]. This study was interested in exploring the relationship between the usability and dependability of the computer system environment and the elders' flow experience.

Flow is the mental state of operation in which the person is fully immersed in what he or she is doing by a feeling of energized focus, full involvement, and success in the process of the activity. Csikszentmihalyi [22] identifies the following nine factors as accompanying an experience of flow:

(1) Clear goals (expectations and rules are discernible and goals are attainable and align appropriately with one's skill set and abilities).

(2) Concentrating and focusing, a high degree of concentration on a limited field of attention (a person engaged in the activity will have the opportunity to focus and to delve deeply into it).

(3) A loss of the feeling of self-consciousness, the merging of action and awareness.

(4) Distorted sense of time, one's subjective experience of time is altered.

(5) Direct and immediate feedback (successes and failures in the course of the activity are apparent, so that behavior can be adjusted as needed).

(6) Balance between ability level and challenge (the activity is neither too easy nor too difficult).

(7) A sense of personal control over the situation or activity.

(8) The activity is intrinsically rewarding, so there is an effortlessness of action.

(9) People become absorbed in their activity, and focus of awareness is narrowed down to the activity itself, action awareness merging.

Not all are needed for flow to be experienced.

Csikszentmihalyi [22] emphasized the balance between an individual's skills and difficulties of tasks. He theorised that the occurrence of flow experiences depends on this balance. In order to facilitate flow experiences, computer games should have

some characteristics. Sweetser and Wyeth [23] stated that players' perceived skills are very important and they should match the challenge supported by the game. Both of them should be in balance in order to facilitate and maintain flow during gameplay. they also stated that challenge is a very important aspect of good games; Besides, games should be usable and provide clear goals and appropriate feedback to the players in order to facilitate flow experience [24]. Pilke [25] emphasizes the user interface of computer games and states that user interface should not require more cognitive processing in order to facilitate flow experience properly.

Theories of psychological aging emphasize three aspects of this process: the speed of information processing shows an aging-related decline that negatively affects cognitive abilities [26]; lack of resources and the reduced capacity of working memory [27]; poor capacity of inhibiting irrelevant information [28]. Aging determines problems affecting the manipulation of objects and the perception of sensorial feedback in terms of pressure, vibration, spatial acuity, perception of roughness, length and orientation [29]. Also, older adults have the problem of divided attention. Divided attention is the distribution of processing resources among multiple simultaneous tasks or rapidly switching from one task to another [30]. Age-related deficits increase with the increase of the stimulus complexity [31] and decrease with the increase of the amount of practice in the task [30].

Learning is affected by interacting factors. For instance, older people's lack of confidence in their abilities can create obstacles to the efforts to approach new technologies [32]. Therefore, the design of technology device should consider relying on familiar aspects of the activity, reducing the amount of learning efforts; minimizing the number of interface elements; and so on. Meanwhile, older adults are less experienced with ICTs and could lack some basic knowledge. Thus, the information required to correctly perform a task should be immediately visible in the interface.

According to aging biophysiology, the muscular system begins to change noticeably during the mid-30s [33]. The degree of loss differs widely among various muscle groups, and the rate and degree of loss is influenced by one's level of physical activity. If one exercises regularly, age-related muscle atrophy can be minimized. More evidence proves the relationships between the plasticity of brain development and motor. Motor executions required a set of motor abilities. There are difference in motor abilities in terms of age [34], sex, intelligence and expertise. It takes more time for elders to respond in the multiple choice situations [35]. Female are superior in color distinguishment, typing and fine target pointing. Complex motor tasks are particularly suited to reveal the crucial link between action and action and cognition and the generic brain areas at the interface between these domains [36]. Based on these literatures, this study developed the interactive video games relying on embodied interactions, which are free from the fine motor skills such as pointing, grasping etc. Moreover, for the elder players, it was free from literacy requirements. Based on the above perspectives, the purposes of this study were as follows:

(1) To evaluate the usability of the EIVG

(2) To evaluate the dependability of the EIVG

(3) To understand the flow experiences of the elders during game play.

(4) To explore the relations between the usability, dependability, and the elders' flow experiences..

2 Research Design

2.1 Participants

There were 30 elders (above 60 years old) as participants, 14 male and 16 female, in this study. They were from three different settings: rural community, elementary school volunteer groups and the nursing home for elderly. The elders from nursing home had higher SES whereas those who were from the rural community had lower SES. Moreover, the elders from the nursing home had more computer experiences than those from rural community had.

2.2 Study Materials

Older people hesitate to engage in computer related activities. The EIVG system supports the interaction by not intimidating them with traditional interfaces, such as keyboard, mouse, and others extra devices. The player's body becomes the interface in this study. That is, the players could move their bodies, wave their hands, or shake their heads, etc. to manipulate the digital elements in the system. In other words, this game system relied on the physical interactions of the players' movements without any burden of game equipments.

The major interaction modules of the games were categorizations and selections. The first game was about food for health. The second kind was about identifying the symbols of the Asia or European countries. The cognitive process involving in this game at least three steps. First of all, the elders identified the pictures on the left top corner, then, distinguished the figures falling down in the middle of screen, and finally, selected a figure with proper costume to stand for the country. The interaction process was more complex. The elders switched their attentions between the pictures on the left top corner and the figures falling down in the middle of screen. There was sound effect with score increase once the elders had correct response.

In addition, the third game was a kind of race competition. The elders used their hands or feet to compete to each other only based on the speed of movements.

2.3 Data Collection Methods

The major method to collect data was interview. Observation was used for triangulation. The guidelines of interview were: (1) the difficulty to learn to play the game; (2) the time needed to perform a previously experienced task; (3) the tendency to induce errors; (4) safety, confidentiality; (5) the extent to satisfy the users; (6) the pleasure derived from usage; (7) the integrity and maintainability.

As far as the measurement of flow experience could be done by observing the expressions and gestures of the subjects in playing, also, by interview (self-report) the feelings of the subjects in playing such as clear goals, degree of concentration, loss of the feeling of self-consciousness, immediate feedback, balance between ability level and challenge, sense of personal control, intrinsically rewarding, and action awareness merging.

2.4 Procedure

This study proceeded as follows:
(1) to explain the purpose of the study
(2) to demonstrate the method to play the games
(3) to practice one by one
(4) to play the game individually or cooperatively
(5)to interview the users individually and in groups
(6) to analyze the data by theme, then by concepts, and construct the concepts.

3 Results

3.1 The Usability and Dependability of the EIVG System

In the first game which was healthy food categorizations. The elders answered **"***It is very easy to learn to play the game."* Especially for the elders who had fewer experiences in using computer. *"You just look at the screen like you are looking at the mirror and move your hands to the objects you want to select, and then, shake your hands. It is similar with the real world situations. So, you won't forget and make errors. Moreover, it is safe."* The researcher could feel their confidence and pleasures in playing from their expressions and gestures.

In contrast, the elders with higher SES and more computer experiences were confused with the methods to interact with computer. The prior experiences made them touch the screen directly and felt frustrated. Finally, they got used to the different interactive approach by practices and said "*It is easier. You don't have to worry about the coordination between the hand on the mouse and the eyes on the screen"*.

Due to the familiarity of the content and the ease of interaction, the elders were satisfied with the EIVGs. However, in the game about country symbol identification, the elders felt nervous due to no enough prior knowledge and complex interaction. Generally, female elderly were more active in exploring activity, while male elderly were more passive as observers. However, when being unfamiliar with the contents, they discussed the strategies and shared the experiences to enhance pleasures. Based on the findings, this study would conclude the usability and dependability of this interactive video system were high.

3.2 The Flow Experiences of the Elders during Game Play

In the EIVG system, people are free from extra devices, so that they could concentrate on achieving goals and controlling the situations**,** which increased the possibility of the occurrence of flow experiences.

In the race competition game, the elder players with lower SES just moved their hands or feet to compete with others or oneself. No prior knowledge required decreased the demanding on cognitive loads. The elders felt "*My mind isn't wandering. I am not thinking of something else. I am totally involved in what I am doing.", "My concentration is like breathing. I never think of it I am really quite oblivious to my*

surroundings after I really get going.", "I am involved in what I am doing.", and *"I don't see myself as separate from what I am doing."*

In contrast, to the elders with high SES, the challenge of the games had an important role in terms of their flow experience. The challenge came from the contents and the modules of the games. They felt bored in playing race competition game. It was very interesting that the male elders indulged in the game of food categorization with the sense of their favorite food selections. There was a kind of flow experience occurred during this process. Moreover, the elders with high SES prefer playing the games of country symbol identification. The complexity of cognitive process and the requirements of prior knowledge and cultural experience increased the challenge to them that enhanced the occurrence of flow experiences. The elders said:" *I enjoy the challenge." "I loss of the feeling of self-consciousness during the process of recalling."*

3.3 The Relations between the Usability, Dependability, and the Elders' Flow Experiences

The usability and dependability are found as the important factors for the elders to use computer technology due to the cognitive ageing. The EIVG system was developed with these characteristics, which decreased the demanding of cognitive loads and made it possible the occurrence of flow experience for the elders in playing the computer games.

In addition, there was difference in the occurrence of flow experience in terms of gender, SES, prior knowledge, computer experiences etc. The female preferred having company, and the flow experience came from the process of sharing. In contrast, the male preferred playing alone, and the flow experience came from indulging in personal preference. For the elders with high SES and prior knowledge, the flow experiences came from the challenge of cognitive loads and prior knowledge on game modules and game contents. However, the computer experiences interfered with their interactive behaviors in playing the games. In contrast, the usability and dependability of the system were in favor of elders with less computer experience and prior knowledge in experiencing the flow.

References

1. Matsuo, M., Nagasawa, J., Yoshino, A., Hiramatsu, K., Kurashiki, K.: Effects of activity participation of elderly on quality of life. Yonago Acta Medica 17(46), 17–24 (2003)
2. Babyak, M., Blumenthal, J., Herman, S., Khatri, P., Doraiswany, M., Moore, K., Craighead, W., Baldewicz, T., Krishnan, K.: Exercise treatment for major depression: maintenance of therapeutic benefit at 10 months. Psychosomatic Medicine 62(5), 633–638 (2000)
3. Czaja, S.J.: Interface design for older adults. In: Ozok, A.F. (ed.) Advances in a lied ergonomics. USA Publishing, Istanbul-West Lafayette (1996)
4. Lehto, M., Tekniikkaa, I.: Kayttajan kasitys asumisen automaatiosta. Ymparistoministerio, Helsinki (1998)
5. Kautzamann, L.N.: Introducing computers to the elderly. Physical and Occupational Therapy in Geriatrics 9(1), 27–36 (1990)

6. Lustbader, W.: On bringing older people into the computer age. Generations 21(3), 30–32 (1997)
7. Sherer, M.: The impact of using personal computers of the lives of nursing residents. Physical and Occupational Therapy in Geriatrics 14, 13–31 (1996)
8. McConatha, D., McConatha, J.T., Dermigny, R.: The use of interactive computer services to enhance the quality of life for long-term care residents. The Gerontologist 34, 553–556 (1994)
9. Khoo, E.T., Lee, S.P., Cheok, A.D., Kodagoda, S., Zhou, Y., Toh, G.S.: Age invaders: Social and physical inter-generational family entertainment. In: CHI 2006 extended abstracts on human factors in computing systems, pp. 243–246 (2006)
10. Christian, H.: An activity analysis of electronic game simulators. Therapeutic Recreation Journal 12, 21–25 (1978)
11. McGuire, F.: Improving the quality of life for residents of long term care facilities through Videogames. Activities, Adaptation and Aging 6, 1–7 (1984)
12. Weisman, S.: Computer games and the frail elderly. Gerontologist 23, 361–363 (1983)
13. Whitcomb, G.R.: Computer games for the elderly. In: The conference on computers and the quality of life, Washington, D. C, USA, pp. 112–115 (1990)
14. Bogost, L.: The rhetoric of exergaming. In: The Digital Arts and Cultures(DAC) Conference (2006)
15. Fuyuno, I.: Brain craze. Nature 447, 18–20 (2007)
16. Gronbaek, K., Iversen, O.S., Kortbek, K.J., Nielsen, K.R., Aagaard, L.: Igamefloor: a platform for co-located collaborative games. In: ACE 2007: In the international conference on advances in computer entertainment technology, pp. 64–71. ACM, New York (2007)
17. Fisk, A.D., Rogers, W.A., Chamess, N., Czaja, S.J., Sharti, J.: Designing for older adults: Principles and creative human factors a roaches. CRC Press, Boca Raton (2004)
18. Patten, C.: Reeducating muscle force control in older persons through strength training. Geriatric Rehabilitation 15(3), 47–59 (2000)
19. Chaparro, A., Rogers, M., Fernandez, J., Bohan, M., Choi, S.D., Stumpfhauser, L.: Range of motion of the wrist: Implications for designing computer input devices for the elderly. Disability & Rehabilitation 22(13), 633–637 (2000)
20. Sommerville, I., Dewsbury, G.: Dependable domestic systems design: A socio-technical approach. Interacting with Computers 19(4), 438–456 (2007)
21. Laprie, J.C.: Dependable computing and fault tolerance: Concepts and terminology, `http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=532603&isnumber=11214`
22. Csikszentmihalvi, M.: Flow and education. NAMTA Journal 22(2), 2–35 (1997)
23. Sweetser, P., Wyeth, P.: Game flow: A model for evaluating player enjoyment in games. Computers in Entertainment 3(3) (2005)
24. Killi, K.: Digital game-based learning: Towards an experiential gaming model. Internet and Higher Education 8, 13–24 (2005)
25. Pilke, E.M.: Flow experiences in information technology use. International Journal of Human-Computer Technology 61, 347–357 (2004)
26. Salthouse, T.A.: The processing-speed theory of adult age differences in cognition. Psychological Review 103, 403–428 (1992)
27. Craik, F.I.M.: Age related changes in human memory. In: Park, D., Schwarz, N. (eds.) Cognitive Aging. Psychology Press, Hove (2000)
28. Zacks, R.T., Hasher, L.: Cognitive gerontology and attentional inhibition: a reply to Burke and McDowd. Journal of Gerontology: Psychological Sciences 52(B), 273–283 (1997)

29. Scialfa, C., Ho, G., Laberge, J.: Perceptual aspects of gerotechnology. In: Kwon, S., Burdick, D. (eds.) Gerotechnology: Research and practice in technology and aging. Springer, Heidelberg (2004)
30. Rogers, W.A.: Attention and aging. In: Park, D.C., Schwarz, N. (eds.) Cognitive aging: a primer. Psychology Press, Hove (2000)
31. McDowd, J.M., Craik, F.: Effects of aging and task difficulty on divided attention performance. Journal of Experimental Psychology: Human Perception and Performance 14(2), 267–280 (1988)
32. Marquie, J.C., Jourdan-Boddaert, L., Huet, N.: Do older adults underestimate their actual computer knowledge? Behavior and Information Technology 21(4), 273–280 (2002)
33. Panek, P.E.: The older worker. In: Fisk, A., Rodgers, W. (eds.) The handbook of human factors and the older adult. Academic Press, San Diego (1997)
34. Spirduso, W.W.: Physical dimension of aging. Human Kinetics, Champaign (1995)
35. Fozard, J.E., Vercruyssen, M., Reynolds, S.L., Hancock, P.A., Quilter, R.E.: Age differences and age changes in reaction time: the Baltimore longitudinal study of aging. Journal of Gerontology: Psychological Science 49, 179–189 (1994)
36. Serrien, D., Ivry, R., Swinnen, S.P.: The missing link between action and cognition. Progress in Neurobiology 82(2), 95–107 (2007)

Kindergartners' Color Preference and Temperament in Embodied Interactive Video Game

Jyh-Tsorng Jong, Yin-Wen Lee, Jon-Chao Hong, Ming-Yueh Hwang, and Yung-Wei Hao

National Taiwan Normal University; 162, Sec.1 Hoping E. Rd.
10610 Taipei, Taiwan
t10020@ntnu.edu.tw, dada1913@hotmail.com, hong506@gmail.com, t06013@ntnu.edu.tw, hao@ntnu.edu.tw

Abstract. The purposes of this study were to explore what's kind of the color kindergartners chose in embodied interactive video game and what's the relation between kindergartners' color preference and their characteristic of temperament in embodied interactive video game. The 230 kindergartners, 4 to 5-years-old, participated in the game play, "Matching the shapes,○, □, and Δ" at school. Each child's father or mother completed the Revised Behavioral Style Questionnaire. By using SPSS17.0, the results showed that the color preferences of kindergartners were yellow, red, purple, blue, and green in order. Sex difference was found in color preference. Kindergartners who liked red or purple colors represented higher distractibility than those liked yellow. Kindergartners who preferred the purple color would be more sensitive than others who liked red, yellow, green, or blue respectively.

Keywords: color preference, temperament, kindergartners, embodied interactive video game.

1 Introduction

"*Embodied interactive video game*" is a modern technological design, which is the application of wii game for students going through the physical motion to learn something. It has not only promoted the development of computer software, but also opened a new vision in the student learning. With this new, educators are now focused on how to adapt the concept and technology used in the classroom, to provide students with a more enjoyable learning environment. Young children (aged 2–6 years old) are the youngest students whose learning begins in daily living. If "embodied interactive video game" can be developed to incorporate into young children's life, then this new technology can be used well for them. Therefore, it's important to think how to use this new way to match the young children's developmental needs. Also, researcher can explore the characteristics of young children during the play of embodied interactive video game.

Educators often have to remind themselves that mainstream education does not fit every kind of students. In order to be successful in teaching, one must be able to make learning materials suitable for student's specific needs. In developmental psychology,

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 473–478, 2009.

"temperament" was defined as the characteristic that makes one individual unique, it is one component of the individual's personality, and also the way the individual behaves. In Taiwan, most scholars use the nine dimensional models by Thomas and Chess [1] when studying temperament, such as "activity level", which means the speed and the level of activity an individual exhibits during a day. "Rhythmicity" means the daily living pattern of a child, which also means the predictability of a child's timing spend on resting, or acting. "Approach or withdrawal", was defined as children's first responses when they encounter a new situation, they either approach it, or they withdrawal from the situation. "Adaptability" was defined as an individual's ability to fit into a new environment, in other words, if an individual only needs a short amount of time to fit into the new environment when compared to others, then he/she is said to be more adaptive than others. "Quality of mood" means when the child expresses positive mood (e.g., friendly, happy etc.), or negative mood (e.g., unfriendly, angry etc.). "Intensity of reaction" means that children with a high intensity of reaction often react more strongly when they are stimulated, as children with a low intensity of reaction react more mildly when they are stimulated. A child is said to have "Persistence" when he/she persists on solving a problem, even when faced with obstacles. "Distractibility" means whether or not the child is easily distracted when he/she is doing a task. "Sensory threshold" was defined as the amount of sensory stimulus needed in order for the child to respond to it, such as auditory, visual, olfactory, tactile, taste, and social senses (the ability to read people's faces). Children with high threshold need larger amount of stimulus in order for them to sense it, on the other hand, children with a low sensory threshold only need a small amount of sensory stimulus. From all of the above dimensions, we can see that every child is different in so many ways, and therefore, every child is different when he/she comes to learning.

In the preschool, we can see children use different colors in their painting. Moreover, children show their preference of color use. Some of them prefer red, and some of them like others, e.g., yellow, green, blue, or purple. Is this individual difference related to children's temperament? The answer of this question has been proved by Hwu [2]. Research showed that there were some relation between infant's color preference and their temperament. 12 to 24 month-old infants who liked green were inclined to show the temperament of good adaptability. Infants who liked purple got higher scores on the temperament scales of activity level and intensity of reaction. Other literature also released that females with high anxiety preferred yellow, and males with low anxiety preferred blue [3]. People who appreciate purple represent little maturity in personality, especially in emotion [4].

The relation between color preference and temperament seems variably. According to Hwu [2], if 12 to 24 month-old infants can be examined, 4 to 5 year-old kindergartners should be done well. This study based on an embodied interactive video game, was to investigate the association between kindergartners' color preference and their temperament. The purposes of this study were as follows:

(1) Understand the kindergartners' color preference when they play the embodied interactive video game.

(2) Investigate the association between kindergartners' color preference and their temperament through the embodied interactive video game.

2 Method

2.1 Participants

A total of 230 kindergartners (112boys, 118girls) and their parents (mother or father) participated in this study. The kindergarten children (M= 70.73months) were recruited from 12 public elementary schools located in 12 districts in Taipei. The majority of these kindergarten parents were mothers (80%), while 20% of them were fathers. About 62.5% of the mothers and 55.6% of the fathers had associate degree, bachelor's degree, or graduate degree. According to Hollingshead's Two Factor Index, 14.4% of the participants' SES (socioeconomic status) came from social class I, 35.9% from social class II, 16.6% from social class III, 26.2% from social class IV, and 6.9% from social class V.

2.2 Instruments

Color preference measure. Color preference measure went through the game "Matching the shapes ○, □, and Δ" in this study. At the beginning of the game, kindergartners were asked "What 's color you like best on this board? There were five colors (red, yellow, green, blue, purple) shown on the board. Then, researcher asked the second question, "There are five color games here. What 's the color you would like best to choose in your play game?" The game "Matching the shapes ○, □, and Δ" was designed by different colors (i.e., red, yellow, green, blue, and purple). On the left corner of screen, there was showed one kind of object (e.g., clock, book, paper money, hamburger, etc.). Then, ○, □, and Δ with same color in different sizes were falling to be touched by kindergartners. These games were presented with different speed (12/sec, 16/sec) for one minute, respectively. The score indicated the efficacy of the embodied interactive video game. If the kindergartner matched for the shapes correctly, he/she would get 10points/one time. The face validity of these games were discussed and examined by the study group. The inter-observer reliability for two investigators was .96 (p<.001).

Temperament measure. Kindergartners' temperament was measured using .a revised Behavioral Style Questionnaire [5] [6]. It is a 6-point rating scale (i.e., 1=never, 2=rarely, 3=usually does not, 4= usually does, 5=frequently, 6=always) including 52 items which were divided into nine subscales (i.e., activity level, rhythmicity, approach or withdrawal, adaptability, intensity of reaction, quality of mood, persistence, distractibility, and sensory threshold). High scores indicated that parents reported their children showing high activity, arrhythmicity, withdrawal, non-adaptability, high intensity, negative mood, non-persistence, non-distractibility, and low sensory threshold. The face validity of this scale was examined by subject matter experts. The test-retest reliability for each subscale ranged from .67 to .94 in original scale, and .82 for the whole revised scale. The internal consistency reliability (Cronbach's alpha) for each subscale ranged from .62 to .81, and .83 for all items in the revised one

2.3 Procedure

Following approval by 12 elementary schools, parent consent letter and scales were sent to all kindergarten parents. After completing permission form and scales, parents were instructed to return them to kindergarten teacher in an enclosed addressed envelope. Their kindergartner was interviewed to play games individually in a quiet

location at school. The total interview time was 10 minutes per child. Data collection occurred between May and June 2008.

3 Results

The online version of the volume will be available in LNCS Online. Members of institutes subscribing to the Lecture Notes in Computer Science series have access to all the pdfs of all the online publications. Non-subscribers can only read as far as the abstracts. If they try to go beyond this point, they are automatically asked, whether they would like to order the pdf, and are given instructions as to how to do so.

Please note that, if your email address is given in your paper, it will also be included in the meta data of the online version.

3.1 The Distribution of Kindergartners' Color Preference in Embodied Interactive Video Game

The primary analyses focused on the distribution of kindergartners' color preference in embodied interactive video game. To make sure the color preference, this study examined the results of kindergartners' answers of the question "What's color you like best?" Among 230 kindergartners, there were 93 children with same answers in two replies. That is, those children showed consistent in color preference. Then, their data were used into further analyses. The total number in a sample, the number in a subsample, and percentage of kindergartners' color preference were showed as Table1. The color preferences of kindergartners were yellow, red, purple, blue, and green in order.

Table 1. Kindergartners' color preference (N=93)

ITEMS	Red	Yellow	Green	Blue	Purple
n	21	30	10	14	18
%	22.58%	32.26%	10.75%	15.05%	19.36%

3.2 Kindergartners' Sex, SES and Color Preference in Embodied Interactive Video Game

By chi-square test, this study found that there was no difference among kindergartner's SES in embodied interactive video game, $\chi^2(4, N=93) = 5.10$, $p=.747$. However, sex was a significant factor because girls liked red and purple colors more than boys did. Also, boys preferred blue and green colors more than girls, $\chi^2(4, N=93) = 11.92$, $p=.018$. See Table2.

3.3 The Relation between Kindergartners' Color Preference and Temperament in Embodied Interactive Video Game

The relation between kindergartners' color preference and temperament in embodied interactive video game was examined by one-way analysis of variance. The means, standard deviations, and F-value were showed as Table3. It indicated the significant association between kindergartner's color preference and the temperament of distractibility,

Table 2. Crosstabulation of boys' and girls' color preference (N=93)

Color	Boys		Girls		χ^2	*df*	*p*
	n	%	*n*	%			
Red	5	11.9%	17	32.7%			
Yellow	14	33.3%	16	30.8%			
Green	7	16.7%	3	5.8%	11.92*	4	.018
Blue	10	23.8%	4	7.7%			
Purple	6	14.3%	12	23.1%			

*$p < .05$.

Table 3. Analysis of variance of kindergartners' color preference among the variables of temperament in embodied interactive video game (N=93)

Temperament	Color preference	*n*	*M*	*SD*	*F*	*p*	LSD
Activity level	Red	21	3.20	.86			
	Yellow	30	3.50	.76			
	Green	10	3.72	.85	1.07	.377	
	Blue	14	3.19	.82			
	Purple	18	3.51	.92			
rhythmicity,	Red	21	2.79	.67			
	Yellow	30	2.66	.86			
	Green	10	2.36	.88	1.12	.351	
	Blue	14	2.99	.77			
	Purple	18	2.57	.80			
approach or withdrawal	Red	21	3.19	.66			
	Yellow	30	3.21	.74			
	Green	10	3.08	.90	.74	.566	
	Blue	14	3.54	.82			
	Purple	18	3.16	.82			
adaptability	Red	21	2.85	.66			
	Yellow	30	2.97	.81			
	Green	10	3.18	.92	.64	.636	
	Blue	14	3.11	.83			
	Purple	18	2.78	.86			
intensity of reaction	Red	21	4.97	1.75			
	Yellow	30	4.81	.59			
	Green	10	5.06	.71	.203	.936	
	Blue	14	4.78	.72			
	Purple	18	4.94	.54			
quality of mood	Red	21	3.80	.68			
	Yellow	30	3.87	.73			
	Green	10	4.02	.92	.219	.927	
	Blue	14	4.00	.71			
	Purple	18	3.87	.89			
persistence	Red	21	3.36	.63			
	Yellow	30	3.15	.77			
	Green	10	2.88	.65	.943	.443	
	Blue	14	3.10	.62			
	Purple	18	3.06	.81			
distractibility	Red	21	3.00	.84			R<Y*
	Yellow	30	3.50	.93			P<Y*
	Green	10	2.96	.80	2.367+	.059	P<B*
	Blue	14	3.53	1.04			
	Purple	18	2.88	.80			
Sensory threshold	Red	21	4.57	.77			R<P+
	Yellow	30	4.47	.94			Y<P*
	Green	10	4.42	.47	2.307+	.064	B<P*
	Blue	14	4.34	.48			G<P*
	Purple	18	5.03	.59			

+$p < .07$. * $p < .05$.

$F(4, 88) = 2.367$, $p=.059$. In addition, the threshold of responsiveness in temperament was significantly related to kindergartners' color preference, $F(4, 88) = 2.307$, $p=.064$. The further LSD analysis showed that children who liked red or purple colors represented higher distractibility than those liked yellow. Children who preferred the purple color would be more sensitive than others who liked red, yellow, green, or blue respectively.

After comparing with the means, it was interesting to find that kindergartners who preferred green were inclined to be higher activity level and higher intensity of reaction, more regularity, and more approach to new things. However, they would show lower adaptability and negative quality of mood easily.

References

1. Thomas, A., Chess, S.: Temperament and development. Brunner /Mazel, New York (1977)
2. Hwu, Y.F.: The relation between infant's color preference and their temperament. Unpublished master's thesis. National Taiwan Normal University, Taipei, Taiwan (2007)
3. Spiegel, D., Keith-Spiegel, P.: Manifest anxiety, color preferences and sensory minimizing in college men and women. In: California State Psychological Association, Monterey, California, pp. 318–321 (1970)
4. Cernovsky, Z.Z., Fernando, M.L.D., Hussein, F., Fernando, M.C.K.: Color preferences of borderline patients and of normal controls. Perceptual and Motor Skills 84, 1347–1353 (1997)
5. McDevitt, S.C., Carey, W.B.: The measurement of temperament in 3-7 year old children. Journal of Child Psychology and Psychiatry 19, 245–253 (1978)
6. Infant, child and adult temperament, `http://www.temperament.com/index.html`

Researches on Using Robots in Education

Liang-Yi Li, Chih-Wei Chang, and Gwo-Dong Chen

Department of Computer Science and Information Engineering, National Central University, Taiwan, R.O.C.
{liang,gogo,chen}@db.csie.ncu.edu.tw

Introduction

Since Seymour Papert (1993) [1] who was the first man to apply robots in education, using robots to support teaching and learning, from secondary school to undergraduate courses to graduate education, has become a popular research topic in recent years [2] [3] [4]. He proposed an approach to learning in the classroom that he calls "constructionism", as opposed to the traditional style of "instructionism". In this approach, students can learn from designing, and assembling their own robots. Since robots capture the imagination of many younger people, they have been validated as useful aids for the teaching of mathematics and physics [5]. Furthermore, the use of robots is not limited to traditional engineering departments but is distributed across a variety of arts and science courses. The use of robotics by nonengineering, nontechnical instructors has been termed a "robotic revolution" [6].

Common categories of educational robots could be identified for three: learning materials; learning companions / pets; and teaching assistants. The classic example of robots as learning materials is the LEGO Mindstorms for Schools kits. In 1984, LEGO collaborated with the Media Lab at MIT. They developed instructional kits that combine toys with advanced technologies. LEGO Mindstorms are collectable and programmable teaching tools. Learners can design and develop their own robots in a competition and learn in the process. This results not only in increased motivation, but also in improved skills in mathematics, science, programming, problem solving, and collaboration [3].

On the other side, in one field of study [7] [8], a humanoid robot was applied in a primary school classroom in Taiwan, it could behave as a teacher's partner and tell stories for children to learn foreign language. In Japan [9] [10], two robots visited a children's elementary school for two weeks, with the purpose of teaching English to children. This experiment showed that, with the robot, children's recall of new words improved, and that there was a positive correlation between the frequencies of interacting with the robot and learning performance. However, motivation decreased over time. Although the effects are modest and the study length was short, the results of this study are impressive because this study is the first practical demonstration to support that students can learn from a humanoid robot.

Besides the learning companions, robots could play the role of teaching assistants. Robot IROBI [11] has been applied as an assistant in a classroom. This instructional medium displays information to students with a monitor in the belly of the IROBI. Moreover, the robot can move its arm to direct students to the key point on the monitor. In order to provide more effective interaction, in 2008, guidelines were proposed for

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 479–482, 2009.

designing the proper body feature for a teaching assistant robot [4] so that the interaction between teachers and students could become more varied.

Papers in This Workshop

Recent few years, there are more and more researchers and companies concentrated on educational robots in Taiwan. The governmental organization, Taiwan e-learning & Digital Archives Program encourages and fully support researches on the issues related to educational robots. For bringing forth wider collaboration and sharing, this workshop "Researches on educational robots of Taiwan e-learning & Digital Archives Program" aims at sharing the researches of educational robots in Taiwan and invite related experts in the world to share their experiences and expertise.

Seven papers will be presented in this workshop. They are the research results of a leading research group related to educational robots in Taiwan. The research group is led by Gwo-Dong Chen who is a professor in Department of Computer Science and Information Engineering, National Central University, Taiwan. In the seven papers, four are related to the development of systems with educational robots and three are related to the investigation of effects of robots to teaching and learning.

The first paper in the collection, entitled "A Task-based Role-Playing Game with Educational Robots for Learning Language" is by Gwo-Dong Chen and Chih-Wei Chang. They introduce an interactive foreign language-learning environment. The design of the games in this environment is based on Task-Based Language Teaching (TBLT). Students can control a robot by speaking English to complete tasks about traveling in a foreign country.

Mu-Chun Su, Gwo-Dong Chen, Yi-Shan Tsai, Ren-Hao Yao, Chung-Kuang Chou, Yohannes Budiono Jinawi, De-Uuan Huang, Yi-Zeng Hsieh, and Shih-Chieh Lin in this paper entitled "Design of an Interactive Table for Mixed-Reality Learning Environments" develop a low-cost Mixed Reality Interactive Table (MRIT). On this table, students can play an educational game via embodied interactions. The MRIT consists of a Web camera, a projector, animal-appearance robots, gloves with accelerometers, and a computer with an authoring tool. It can be used for different educational games. For example, teachers can use it to design a quiz game. First, teachers edit their learning materials into quizzes by using the authoring tool. The quizzes then are projected on the table. Later, students wearing gloves has to use his or her gestures to manipulate the animal-shaped robots to move to the location of right answer in time. Finally, a statistic record shows the competition scores at the end of the game.

Wu-Yuin Hwang, Sheng-Yi Wu, Chien-Ming Chen, and Yung-Hsun Hsieh in this paper entitled "A Study of Collaboration and Conflicts Using Multi-Robots" design a system of Multi-robots in which students can control several robots at the same time through MSN. They also conducted an experiment where students use the system in a group learning activity to explore the controlling models and conflicts.

Yi-Chun Lin, Tzu-Chien Liu, Maiga Chan, and Shiau-Ping Yeh in this paper entitled "Exploring Chirdren's Perceptions of the Robots" develops a questionnaire for exploring the children's general impressions of the robots, the role of the robots in the classroom, and the appearances of the robots. 167 fifth-grade students completed this

questionnaire. Several interesting results are found and discussed. And some recommendations are provided for the educational application of the robots.

Chun-Hung Lin, Eric Zhi-Feng Liu, Chan-Hsin Kou, Marjo Virnes, Erkki Sutinen, and Shan-Shan Cheng in this paper entitled "A Case Analysis of Creative Spiral Instruction Model and Students' Creative Problem Solving Performance in a LEGO Robotics Course" use the creative spiral instruction model for understanding the effect of the LEGO robotics course on students' creativities and problem solving performance. Six undergraduate students participated in a LEGO robotics course. The results are analyzed based on the model. Some interesting findings are proposed.

Jwu-E Chen, Lu-Tsou Yeh, Hua-Hsiang Tseng, G-W Wu, In-Hang Chung in this paper entitled "Development of an Emotional Robot as a Teaching Assistant" develop an affective robot. The robot can perform six basic emotion states including anger, fear, happiness, sadness, surprise, and disgust. It consists of five interactive operation modes and progressive scheduling scheme to support interaction and learning.

Chen-Yi Wang, Tzu-Chien Liu, Yi-Chun Lin, Shiau-Ping Yeh in this paper entitled "Gender differences in learning with robots applied in teaching creative curriculum: A pilot study" explore the effects of gender on learner engagement and attitude when they participated in a group learning activity in a robot programming curriculum.

Acknowledgments. This work was partly supported by the National Science Council, Taiwan, R.O.C, under NSC 97-2631-S-008-003 and NSC 96-2524-S-008-002.

References

1. Papert, S.: The Children's Machine: Rethinking School in the Age of the Computer. Basic Books, New York (1993)
2. Klassner, F.: A Case Study of LEGO MINDSTORMS' suitability for Artificial Intelligence and Robotics Courses at the College Level. In: Proceedings of the 33rd SIGCSE Technical Symposium on Computer Science Education, pp. 8–12. ACM Press, New York (2002)
3. Klassner, F., Anderson, S.D.: Lego MindStorms: Not just for K-12 anymore. IEEE Robotics and Automation Magazine 10(2), 12–18 (2003)
4. Ryu, H.J., Kwak, S.S., Kim, M.S.: Design Factors for External Form of Robots as Elementary School Teaching Assistants. The Bulletin of Japanese Society for Science of Design (JSSD) 54(5) (2008)
5. Cooper, M., Keating, D., Harwin, W., Dautenhahn, K.: Robots in the Classroom - Tools for Accessible Education. In: Buhler, C., Knops, H. (eds.) Assistive Technology on the Threshold of the New Millennium, pp. 448–452. IOS Press, Amsterdam (1999)
6. Hendler, J.: Robots for the Rest of us: Designing Systems out of the Box. In: Druin, A., Hendler, J. (eds.) Robots for Kids: Exploring New Technologies for Learning, pp. 2–7. Morgan Kaufmann, San Mateo (2000)
7. You, Z.-J., Shen, C.-Y., Chang, C.-W., Liu, B.-J., Chen, G.-D.: A Robot as a Teaching Assistant in an English Class. In: Proceedings of the Sixth International Conference on Advanced Learning Technologies, pp. 87–91. IEEE Computer Society, Washington (2006)
8. Shih, C.-F., Chang, C.-W., Chen, G.-D.: Robot as a Storytelling Partner in the English Classroom - Preliminary Discussion. In: Proceedings of the Sixth International Conference on Advanced Learning Technologies, pp. 678–682. IEEE Computer Society, Washington (2007)

9. Kanda, T., Hirano, T., Eaton, D., Ishiguro, H.: Interactive Robots as Social Partners and Peer Tutors for Children: A Field Trial. Human-computer interaction 19(1/2), 61–84 (2004)
10. Kanda, T., Ishiguro, H.: Communication Robots for Elementary Schools. In: Proceedings of the Symposium on Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction (AISB 2005), pp. 54–63. The Society for the Study of Artificial Intelligence and the Simulation of Behaviour (2005)
11. Han, J., Kim, D.: r-Learning Services for Elementary School Students with a Teaching Assistant Robot. In: Proceedings of the 4th ACM/IEEE international conference on Human robot interaction, pp. 255–256. ACM Press, New York (2005)

A Task-Based Role-Playing Game with Educational Robots for Learning Language

Gwo-Dong Chen and Chih-Wei Chang*

Department of Computer Science and Information Engineering,
National Central University, Taiwan
{chen,gogo}@db.csie.ncu.edu.tw

Abstract. In this paper we present our work in the design of playing with robots to learn language in a classroom. We outline our approach of design for emergence: to provide just enough of a game context and challenge for people to be creative, to extend and enrich the experience of play through their interaction in the real world. Robots were designed to put on our mixed reality game stage, a wireless location-based multiplayer game. This paper describes the design and implementation of the task-based role playing game with robots.

Keywords: Educational robots, Mixed reality, Game-based learning, Task-based language learning.

1 Introduction

In this decade, East Asia educators are intensively addressing the need to increase people who can communicate effectively in English. Hence, after 2000 year, syllabuses have been moving increasingly towards various versions of communicative language teaching (CLT) [1]. Surveyed the educational policies and practices in seven East Asia developing countries, Nunan (2003) [2] pointed out that 'all of the countries surveyed subscribe to principles of CLT, and in a number of them, [task-based language teaching] (the latest methodological realization of CLT) is the central pillar of government rhetoric' (p. 606). In Hong Kong, for example, the Education Department (now Education and Manpower Bureau) has promoted TBLT since the mid-1990s. In Mainland China, the national English Language Standards, published in 2001, 'strongly advocates task-based teaching, the latest methodological realization of communicative pedagogy' [3]. According to Lee [4], 'the National English Curriculum in Korea also focuses on the task-based approach'. Even in countries where official syllabuses have not been labeled task-based, the concept of 'learning through tasks' has become an intrinsic part of the professional discourse and local innovations with TBLT are frequently introduced (see e.g. in Philippines [5]; in Japan [6]). In traditional English learning in Taiwan, learners rarely have the opportunity to practice oral communication, so the acquisition of oral proficiency is a slow process. On the other hand, the task-based learning method enables learners to obtain communicative skills through the

* Corresponding author.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 483–488, 2009.

practice of particular "missions". As a result, the efficient improvement of communication skill becomes achievable.

However, Littlewood [7] summarized some concerns in implementing TBLT in East Asian classrooms, including classroom management [8], avoidance of English [9] [10], minimal demands on language competence [4] [10], incompatibility with public assessment demands [11] [12], and conflict with educational values and traditions [3]. This study attempts to improve the problems about classroom management, avoidance of English, and minimal demands on language competence of TBLT by developing a task-based role-playing game with robots for students. So that the instructor can be the helper, no more confusing between the teacher control and the pupil-centered learning. On the other hand, this study also effort to improve the engagement of learners by the game to reduce the problems of avoidance of English, and minimal demands on language competence.

Over the last few years, computer graphic and virtual reality technology have played increasingly important roles in language learning [13] [14]. Besides, using robots to support teaching and learning was also possible [15] [16]. This paper explores the use of robots to design the game allowed learners to control the robot to complete some missions.

2 The Task-Based Role-Playing Game with Educational Robots

2.1 Design Principle

Our game prototype is centered around the tasks of traveling in a foreign country. The system keeps track of how long time learners take to complete all the missions in a game session, and rewards good performance by advancing the learner towards higher difficulty levels. Through the use of speech recognition, language understanding and language generation technologies, the robot is able to provide immediate feedback to the learner by paraphrasing his or her utterances in both languages and judging if the perceived answer is correct.

This system, using TBLT methodology, provides the missions as tasks that need learners to control robots to complete. The learners are assumed to be people who studied English in junior high school in Taiwan. In this paper, the focus is applied to the acquisition of necessary English knowledge and skill for use in daily life. That is, the actions of the learner decide the outcome, which encourages learners to learn on their own and think for themselves in order to clear the task. The learner advances through tasks by 'talking' with English speaking characters in a virtual city environment.

This study introduced a robot acting as a learner's avatar in a game to learn foreign language. This made students to experience a more engaging learning activity, and allowed teachers to concentrate more on helping students improve their listening comprehension and revise their pronunciation in the class. The main work of instructors became to arrange the environment, to prepare the authentic learning activities and to help learners. Learners learned by experiencing, doing, and collaborating in the task-based role-playing game. The robot played the character in the learning activities

that can interact with students. The following sections described the hardware arrangement and the game design

2.2 Hardware Arrangement

This environment setting was based on the previous study [16]. As the result of making the robot to move precisely, this time, we replaced the robot from a humanoid robot, Sapien, to a vehicle-liked robot, Scribbler [17]. The robot has five infrared sensors, three photo sensors, a low- to medium-resolution color camera, programmable LEDs, a dualtone speaker, and a Bluetooth wireless communications link (built-in or through a USB Bluetooth dongle). Additionally, the robot can communicate using infrared and can detect colored regions onboard. In order to display the game scene, we placed a table as the floor, and put the robot on it. Then, a projector from ceiling screened the environment and game information on the table. Besides, we also needed to obtain the location information of robot on the table. So when the robot moved to some place, the system could show learners some hints or quizzes. We stuck an infra-ray signal light on the top of the robot, and used a camera to capture the signal. All of the actions by the robot were controlled by a small notebook, which was set apart from the robot and acted as its brain. We also needed a wireless speaker, which was hidden under the desk, to make the robot talk, and the students thought the sound was coming from the robot. The volume of the speaker was set loud enough to fill the whole classroom. Hardware arrangement is shown in the figure one.

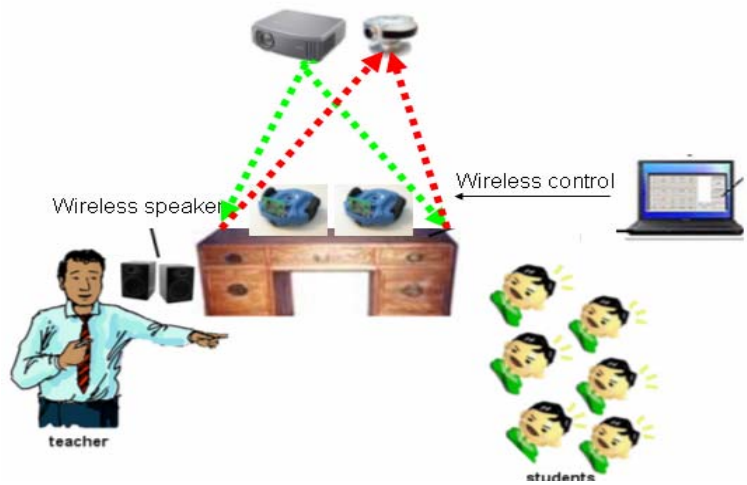


Fig. 1. Hardware Arrangement

2.3 Game Design

In this study, the game scene was primary designed by RPG maker which was developed and published by Enterbrain. Based on the Ruby Game Scripting System (RGSS), we could easily draw the game map, as figure two.

Fig. 2. Game Scene

We used Borland C++ Builder 6 to develop the game. This system contains four function modes: Robot Control Module, Dialogue Module, Circumstances Module, and Remote In-time Control Module, which will be explained as follows:

A. Robot Control Module. According to the sensors on the Scribbler, learners could control the robot directly by a light, by a color card, or by drawing a line that lead robots to follow. Besides, thought the bluetooth, system could wirelessly transmitted commands to control the robot. Main order was turn left, turn right, forward, and stop.

B. Dialogue Module. When the robot moved to some event spots, the system would give learners some information and quizzes. We used Microsoft Text-to-Speech Package to translate the characters into voice. The frequency, tone and volume can be adjusted by the controller in order to make the robot suitable for our interaction mode.

C. Circumstances Module. To create a authentic gaming environment, we added visual and audio effects. The projector can present the circumstance or other information. We can also create special audio effects, collected in advance, such as thunder, bells…etc.

D. Remote In-time Control Module. Because of the varied environment variable in the classroom, sometimes the robot was hard to be controlled. If the robot was idle too long, the feeling of game would disappear right away. We designed a remote in-time control module to overcome this problem. The robot's behavior could be controlled by an assistant when it did not follow the learners' command.

3 Summary

We try to create an authentic gaming experience supported by the robot for learners to solve problem, to collaborate, to practice, to reflect, and to experience a realistic

task/activity. We've developed a prototype to exploit the robot's interaction capability in order to develop an interactable foreign language-learning environment. The robot in the classroom is a practical character that leads students to focus on the class and stimulate children to speak English more nature. We believe that we have created the game that will provide students with the opportunity to put what they learn in lectures and from reading their textbooks into practice, with activities that will let them explore less boring aspects of learning language, and we expect that robots could be used to help language education even more extensively. We also hoped that this framework could inspire more education researchers to develop more novel and interactive pedagogies, and allow children to learn foreign languages in a, more natural, effective, and tension-free environment.

Acknowledgments. This work was partly supported by the National Science Council, Taiwan, R.O.C, under NSC 97-2631-S-008-003 and NSC 96-2524-S-008-002.

References

1. Kam, H.W.: English Language Teaching in East Asia Today: An Overview. Asia Pac. J. Educ. 22(2), 1–22 (2002)
2. Nunan, D.: The Impact of English as a Global Language on Educational Policies and Practices in the Asia-Pacific Region. TESOL Quarterly 37(4), 589–613 (2003)
3. Hu, G.W.: English Language Education in China: Policies, Progress, and Problems. Language Policy 4(1), 5–24 (2005)
4. Lee, S.-M.: The Pros and Cons of Task-based Instruction in Elementary English Classes. English Teaching 60(2), 185–205 (2005)
5. Vilches, M.L.C.: Task-based Language Teaching: The Case of EN 10. RELC Journal 34(1), 82–99 (2003)
6. Kiernan, P.: Story-telling with Low-level Learners: Developing Narrative Tasks. In: Edwards, C., Willis, J. (eds.) Teachers Exploring Tasks in English Language Teaching, pp. 58–68. Palgrave Macmillan, New York (2005)
7. Littlewood, W.: Communicative and Task-based Language Teaching in East Asian Classrooms. Language Teaching 40(3), 243–249 (2007)
8. Morris, P., Adamson, R., Lan, A.M., Ki, C.K., Yin, C.W., Yuk, K.P., Winnie, L.A., Ling, L.M., Morris, E., Ping, N.F., Ying, N.Y., Mei, W.W., Ha, W.P.: Target Oriented Curriculum Evaluation Project: Interim Report. Hong Kong: Faculty of Education, University of Hong Kong (1996)
9. Li, C.Y.: A Study of In-service Teachers' Beliefs, Difficulties and Problems in Current Teacher Development Programs. HKBU Papers in Applied Language Studies 7, 64–85 (2003)
10. Carless, D.: Issues in Teachers' Reinterpretation of a Task-based Innovation in Primary Schools. TESOL Quarterly 38(4), 639–662 (2004)
11. Gorsuch, G.J.: EFL Educational Policies and Educational Cultures: Influences on Teachers' Approval of Communicative Activities. TESOL Quarterly 34(4), 675–710 (2000)
12. Butler, Y.G., Iino, M.: Current Japanese Reforms in English Language Education: The 2003 'Action Plan'. Language Policy 4(1), 25–45 (2005)
13. Wang, C., Seneff, S.: A Spoken Translation Game for Second Language Learning. In: Proceedings of artificial intelligence in education, pp. 315–322 (2007)

14. Powers, D.M.W., Leibbrandt, R., Pfitzner, D., Luerssen, M.H., Lewis, T.W., Abrahamyan, A., Stevens, K.: Language Teaching in a Mixed Reality Games Environment. In: Proceedings of the 1st international conference on PErvasive Technologies Related to Assistive Environments (2008)
15. Kanda, T., Hirano, T., Eaton, D., Ishiguro, H.: Interactive Robots as Social Partners and Peer Tutors for Children: a Field Trial. Journal of Human Computer Interaction 19, 61–84 (2004)
16. Shih, C.-F., Chang, C.-W., Chen, G.-D.: Robot as a Storytelling Partner in the English Classroom - Preliminary Discussion. In: International Conference on Advanced Learning Technologies, pp. 678–682 (2007)
17. Balch, T., Summet, J., Blank, D., Kumar, D., Guzdial, M., O'Hara, K., Walker, D., Sweat, M., Gupta, G., Tansley, S., Jackson, J., Gupta, M., Muhammad, M., Prashad, S., Eilbert, N., Gavin, A.: Designing Personal Robots for Education: Hardware, Software, and Curriculum. IEEE Pervasive Computing 7, 5–9 (2008)

Design of an Interactive Table for Mixed-Reality Learning Environments

Mu-Chun Su, Gwo-Dong Chen, Yi-Shan Tsai, Ren-Hao Yao, Chung-Kuang Chou, Yohannes Budiono Jinawi, De-Yuan Huang, Yi-Zeng Hsieh, and Shih-Chieh Lin

Department of Computer Science and Information Engineering, National Central University, Taiwan, R.O.C.
muchun@csie.ncu.edu.tw

Abstract. This paper presents a prototype of a low-cost Mixed Reality Interactive Table (MRIT) which is equipped with a Web camera, a projector, animal-appearance robots, gloves with accelerator sensors, and a computer. The motivation of the development of the MRIT is to provide a low-cost learning environment where students can learn effectively when they play an educational software game on the interactive table via embodied interactions. We hope the MRIT can be a good entry point for studying how educational software games incorporated with an interactive table and embodied interactions are able to promote students' interest and improve students' engagement.

Keywords: embodied interaction, mixed reality, digital game-based learning.

1 Introduction

The concept of learning may have many different implications for children. Serious learning in schools certainly may not interest most children. In fact, play is our brain's favorite way of learning things [1]. Many psychologists also have the same observation that games are an important means through which children learn to understand their world [2]. Without any doubt, enjoyment and fun play an important role in the learning process. More and more researchers seek ways to promote students' motivation and engagement while they learn.

In the twenty-first century, various new technology tools for education are rapidly emerging. Since video and computer or digital games interest children, digital games may play an important role in helping children in learning materials that are not intrinsically interesting but which have to be learned. If approaches or learning tools really interest children then they will not have short attraction span for learning. More and more research projects try to develop software games for education to increase children's motivation and engagement [3]-[5]. Prensky provides many important and practical ideas of the application of digital game-based learning and a good overview of the trend of digital game-based learning in his book [6]. He suggested five levels- "How," "What," "Why," "Where," and "When/Where" in which learning happens in digital games. In addition, he also suggested that computer games can be classified into 8 "genres": action, adventure, fighting, puzzle, role playing, simulations, sports,

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 489–494, 2009.

and strategy. Furthermore, he made a comprehensive linkage between types of learning and possible game styles. For example, mnemonics and games show competitions are suitable for learning some kinds of facts such as laws, policies, etc. They involve in the learning activities such as questions, memorization, association, and drill. Greenfield has extensively studied the effects of video games on players' minds [7]. One of her findings is that video game skills can transfer to and lead to greater comprehension of scientific simulations.

Although education software games are sprouting now, are they really educational or just not-very-educational games? Many researches have been conducted for evaluating the education software's effectiveness [8]-[9]. Some researchers claimed that usability is an important factor that affects the educational effectiveness [10]-[14]. Virou and Katsionis conducted an evaluation on the usability and likeability of virtual reality games for education [15]. Their evaluation results revealed many important issues about further research on virtual reality educational games.

Embodied interaction (i.e., using the physical world as a medium for interacting with digital technology) is an active and attracting area of Human-Computer Interaction [16]. If users can use their whole bodies instead of just fingers to interact with games then the games will become more appealing. Romero et al. proposed that embodied interaction may have the potential to advance educational technology in many ways [17]. They claimed that embodied interaction have a positive effect on skills such as problem solving, narrative and literacy. Antie claimed that tying hands to a mouse and keyboard may limit children's cognitive performance and inhibit developing mental skills [18]. She found that new gaming platforms such as Nintendo Wii console with embodied interaction may offer opportunities to support the tight coupling of physical action with mental operations required for learning.

In this paper, we present a low-cost Mixed Reality Interactive Table (MRIT) and show how we use it to construct a learning environment where students can play an educational software game on the interactive table via embodied interactions. In 1994, Milgram and Kishino defined Mixed Reality (MR) environments as those in real world and virtual world objects are presented together on a single display [19]. Mixed reality technologies have been proven valuable in many applications (e.g., simulation based learning, interactive product content management, medical visualization, in arts and entertainment industries, etc). A good review of MR techniques for developing computer supported collaborative work interfaces can be found in [20]. Our mixed reality learning environment refers to a new environment where physical (i.e., animal-shaped robots) and digital objects (i.e., objects in an educational software game) coexist and interact in real time.

The rest of this paper is organized as follows. In Section 2, we introduce the MRIT. Finally, Section 3 concludes the paper.

2 The MRIT

The MRIT is equipped with a Web camera, a projector, animal-appearance robots, gloves with accelerometers, and a computer as shown in Fig. 1. The proposed MRIT creates an MR environment where digital and physical objects are aligned together and interact in real time. A crucial problem of the MR environment is how to track the

positions of the physical objects (i.e., the robots in our case) in order to accurately align them to digital objects in a game scene. Motivated by the low-cost multi-point interactive whiteboards using the Wiimote [21], we solve the problem with the use of a low-cost Web camera of which len is covered by a film to filter out visible light, robots with three infrared LEDs on their tops, and a tracking algorithm which can track many sources simultaneously. A calibration procedure has to be executed before we can correctly track the positions and orientations of the robots and then align them to the virtual game scene. The calibration procedure involves the following two steps. First of all, we sequentially place a small box with an LED on its top at the four corners of the image projected on the table. Then we adopt an affine transformation based on these four known corners' coordinates to implement the geometric transformation. Fig. 2 shows an example of the 12 sources of infrared light on the image acquired by the camera and how these 12 sources are clustered into 4 groups corresponding to 4 robots. Each robot is with three LEDs so that these three light sources can be used to calculate the position and orientation of the robot. After we have located the positions and orientation of the robots from the image acquired from the Web camera, we align them to the virtual game scene.

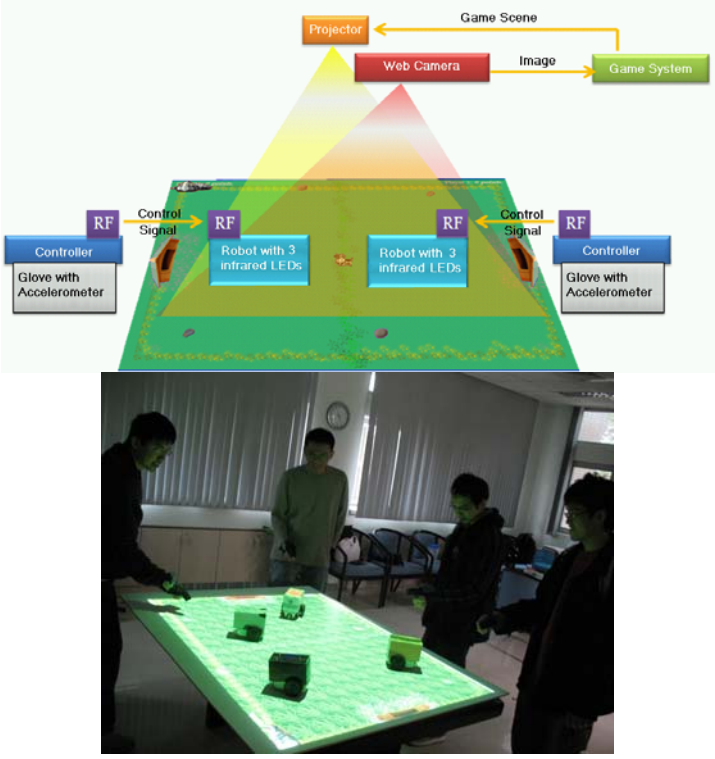


Fig. 1. The MRIT and its scene of the learning environment

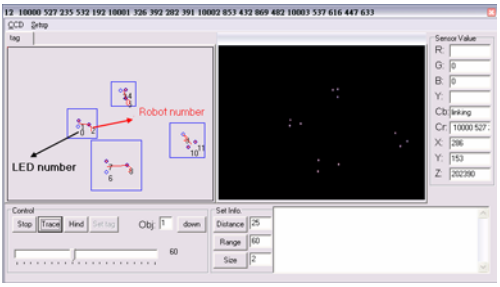


Fig. 2. An example of 12 sources of infrared light on the image acquired by the camera

The role of the MRIT is to support a new teaching paradigm. Teachers can use an authoring tool (shown in Fig. 3) to edit their learning materials into quizzes. In our present software game (shown in Fig. 4), a digital dice will be tossed to decide the number ofsteps which a targeted player has to take to go to the destination where a quiz will pop-out. Then the targeted player wearing a glove with an accelerometer has to use his or her body gestures (shown in Fig. 5) to manipulate the animal-appearance robots (shown in Fig. 6) to move to the destination in time to win the chance of answering the pop-out quiz shown on the game scene. If the player answers the quiz correctly then he or she wins a score. Sometimes, a player can have a chance of winning a bonus score if he or she can manipulate a robot to kick a digital ball into the goal on the digital soccer field. The introduction of such a soccer game into the software game is to educate the players to cooperate with each other to achieve respective goals because the players will be automatically and randomly grouped into two teams during the soccer game. Finally, a statistic record shows the competition scores at the end of the game.

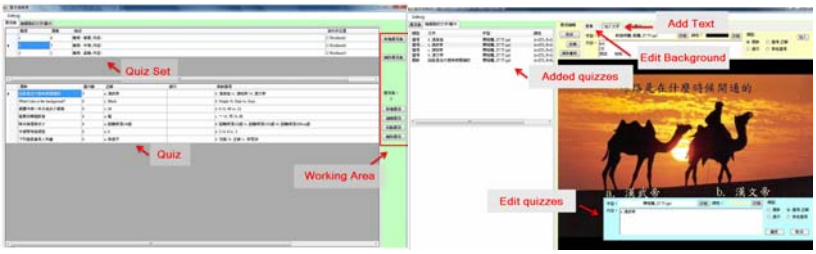


Fig. 3. The authoring tool for teachers to edit quizzes and add background images

Fig. 4. The game scenes

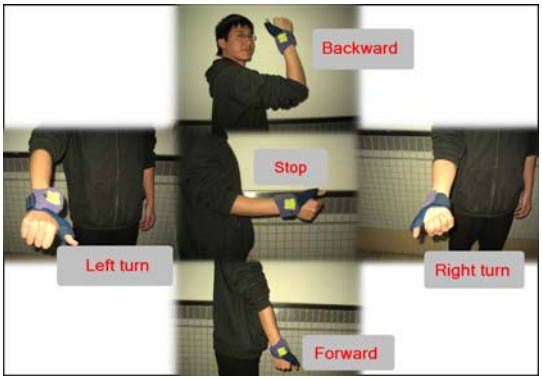


Fig. 5. The embodied interaction gestures for controlling the robots

Fig. 6. The glove with an accelerometer and an animal-appearance robot

3 Conclusions

This paper reports our efforts to develop a low-cost Mixed Reality Interactive Table (MRIT). We use it to construct an MR learning environment where students can play an educational software game on the interactive table via embodied interaction gestures. The goal of the MRIT incorporated with appropriate MR educational games is to explore the possibility of applying a low-cost education tool for learning some materials which are intrinsically boring but have to be learned. Responses from many high school students who have participated in our demonstrations show that the MRIT are very interesting and promising. In the near future, we will conduct field experiments to fully evaluate the educational effect and the usability of the proposed MRIT in order to explore the possibility of using the MRIT as a new educational tool to e promote students' interest and improve students' engagement for learning.

Acknowledgments. This work was partially supported by the National Science Council, Taiwan, R.O.C, under NSC 97-2631-S-008-003 and NSC 97-2631-H-008-001.

References

1. Ackerman, D.: Deep Play, Vintage (2000)
2. Fackelmann, K.: Very Young Kids Absorb Tragedy, USA TODAY (November 14, 2001)
3. Amory, A., Naicker, K., Vincent, J., Claudia, A.: Computer Games as a Learning Resource. In: Proceedings of ED-MEDIA, ED-TELECOM 1998, world conference on education multimedia and educational telecommunications, vol. 1, pp. 50–55 (1998)
4. Conati, C., Zhou, X.: Modeling Students' Emotions from Cognitive Appraisal in Educational Games. In: Cerri, S.A., Gouarderes, G., Paraguacu, F. (eds.) ITS 2002. LNCS, vol. 2363, pp. 944–954. Springer, Heidelberg (2002)
5. Kearney, P.: Engaging Young Minds - Using Computer Game Programming to Enhance Learning. In: Proceedings of ED-MEDIA World Conference on Educational Multimedia, Hypermedia and Telecommunications, pp. 3915–3920 (2004)
6. Prensky, M.: Digital Game-Based Learning. McGraw-Hill, New York (2001)
7. Greenfield, P.: Greenfield: Mind & Media: the Effects of Television Video Games & Computers. Harvard University Press, Massachusetts (1984)
8. Brody, H.: Video Games That Teach? Technology Review 96(8), 51–57 (1993)
9. Virvou, M., Katsionis, G., Manos, C.: Combining Software Games with Education: Evaluation of its Educational Effectiveness. Journal of Educational Technology & Society 8(2) (2005)
10. Jones, A., Scanlon, E., Tosunoglu, C., Morris, E., Ross, S., Butcher, P., et al.: Contexts for Evaluating Educational Software
11. Mayer, R.E.: Multimedia Learning. Cambridge University Press, New York (2001)
12. Squires, D., Editorial.: Usability and Educational Software Design: Special issue of Interacting with Computers. Interacting with Computers 11(5), 463–466 (1999)
13. Squires, D., Preece, J.: Usability and Learning: Evaluating the Potential of Educational Software. Computers & Education 27(1), 15–22 (1996)
14. Squires, D., Preece, J.: Predicting Quality in Educational Software: Evaluating for Learning, Usability and the Synergy between Them. Interacting with Computers 11(5), 467–483 (1999)
15. Virvou, M., Katsionis, G.: On the Usability and Likeability of Virtual Reality Games for Education: The case of VR-ENGAGE. Computers & Education 50, 154–178 (2008)
16. Dourish, P.: Where the Action Is: The Foundations of Embodied Interaction. MIT Press, London (2001)
17. Romero, P., Good, J., Robertson, J.: Embodied Interaction in Authoring Environments. In: Proceedings of the Second Workshop on Physicality (2007)
18. Antie, A.N.: Embodied Child Computer Interaction: Why Embodiment Matters. Interactions, 27–30 (2009)
19. Milgram, P., Kishino, F.: A Taxonomy of Mixed Reality Virtual Displays. IEICE Transactions on Information and Systems, Special issue on Networked Reality, 1321–1329 (1994)
20. Billinghurst, M., Kato, H.: Collaborative Mixed Reality. In: The First International Symposium on Mixed Reality, pp. 261–284 (1999)
21. Johnny Chung Lee-Projects-Wii, `http://johnnylee.net/projects/wii`

A Study of Collaboration and Conflicts Using Multi-robots

Wu-Yuin Hwang[1], Sheng-Yi Wu[1], Chien-Ming Chen[2], and Yung-Hsun Hsieh[3]

[1] Graduate of Network Learning Technology,
[2] Department of Computer Science and Information Engineering,
[1,2] National Central University
[3] Ren-ai Elementary School
32001 Jhongli City, Taoyuan County, Taiwan
wyhwang@cl.ncu.edu.tw

Abstract. Learning how to collaborate with limited resources was the key point for elementary students' social interaction and emotion development. This study designed a system of Multi-robots, allowing students to control robots to do dice moving by varied methods and discussing the process of collaboration and conflicts. From the study, conflict was not avoidable. Therefore, what we should do was not only to guide students the way to avoid conflicts but also to help them learning to face conflicts and to communicate with other people. Learners had to coordinate and find the way to avoid conflicts, improving efficiency of completing the task of collaboration. It was an important skill during students' socialization.

Keywords: Collaboration Learning, Conflict, Limited Resources, Multi-Robots.

1 Introduction

Learning how to collaborate with limited resources was a necessary task for students to learn [2,3]. Under this situation of collaboration, how students controlled their emotion and interaction with peers was related to their social and emotional development [6,10].

The operation of collaboration learning was to promote learners' development of cognition, emotion and social contact through the process of their interaction and communication with peers. With group collaboration learning, interpersonal relationship of being dependent on each other and sharing with each other could be constructed. With communicative skills of listening, accepting and respecting, students were encouraged to express their own opinion and viewpoints and to make constructive comments and point out mistakes. With chances of debate, students' ability of self-examination was promoted through interactive demonstration between con side and pro side and useful concepts of science were established.

During collaboration, individuals in a group shared the common goal and had competitive relationship with each other; that was what social exchange theories stood for. Social exchange theories [4] suggested that social interaction among people was a rational

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 495–500, 2009.

resource exchange that also counted gains and loss. Thereafter, teachers had to consider conflicts' happening in group while guiding students through collaboration learning.

In order to understand the process of students' collaboration and conflicts during collaboration learning, this study combined Multi-Robot system with MSN software, allowing students to do collaboration by many-to-many model. The biggest distinguishing feature of this system design was that each student completes the task with any of robots as their wish. While each student had only one robot, they were supposed to make the most of their own robot as the key point of collaboration that each plays his/her role well. While each student could use all robots, there were problems of resources distribution and conflicts dealing. The followings were aspects that the study was going to discuss:

1. Establish a many-to-many collaboration learning environment and discuss its acceptance to students.
2. Investigate models of task that students complete cooperatively under situations of different members and resources.
3. Investigate conflict of 3 kinds of task model as two or more students control the same robot in a short time.
4. Discuss reasons and solutions for actual conflicts of robots.

2 Literature Review

Aimed at research about collaboration learning, Klein & Pridemore [5] indicated that students who learn cooperatively with peers spend more time on exercises and practices and therefore gain more satisfaction than independent learners. Qin, Johson, & Johson [8] collected advantages of collaboration learning as the followings. (1) It pushed students into higher achievement and productivity. (2) It promoted students' sense of concern, support and identification. (3) It enabled students to be possessed of better psychological and physical status, and higher competitiveness and self-esteem. As a result, models and skills of collaboration learning received continuous concerns and supports in education.

As collaboration learning discussed, two factors were suggested to be mentioned, grouping and tasks. Collaboration learners stood for heterogeneous grouping because heterogeneous grouping provided more variety of learning environment with distinct backgrounds, thoughts, genders and racial characteristics among students. Some researches however challenged this concept, though it seemed fair and reasonable. These researches disclosed that it was unfavorable to academic achievement for specific colored races isolated from other colored races or specific girls isolated from other girls [9]. Because they felt lonely and not worthy noticed in group, or because of playing modeled roles, they did not perform actively. What's more, lack of common language in heterogeneous group, students were not easy to open their mind and share their knowledge, helpful to information completion and harmonious relationship. Due to different features and backgrounds of members, conflicts and unwillingness to collaborate constantly happened in group, seriously affecting normal teaching order. Theoretically, as long as teachers taught students social skills they needed and provided opportunities of practice, good cooperative relationship of mutual help and

interaction forms among students. It was worth notice that cultivating students' social contact skills was the purpose of collaboration learning, not the presupposition. In those experimental junior high schools and elementary schools, it was found that unfriendliness, no-listening and no-sharing happened frequently in group collaboration activities and afraid that this was the main factor interfering with promotion of collaboration learning. Hence in this study, students who attended willingly were grouped, three in one group.

Afterwards, Cohen [1] proposed task content of collaboration learning and said that the appropriate task for group collaboration had to enable members to share resources, including individual information, knowledge, ideas of problems, scripts or materials, devices and skills. What should be noticed was that these resources had to be not occupied by only one member; that was, each one had to do something with the group task. The collaboration learning task designed by teachers should lead to positive group interaction among students; that was, each one needed to rely on others instead of one-way reliance that the strong helped the weak.

3 Research Design and Implementation

3.1 System Implementation

To investigate process of collaboration and conflicts among students during collaboration, this study combined Multi-Robot with MSN system and generated a system that was able to record conditions of resources distribution and use during collaboration learning. This system allowed several students to control several robots at the same time through MSN and teachers to detect process of students' moving bricks, further analyzing their interaction models and resources use through log files and video. Here were photos of instruction of the system and those in real experiment.

Fig.1 Fig.2 Fig.3a Fig.3b

Fig. 1. Task of the study was to choose five of seven dices to move into a cross frame
Fig. 2. Each student was allowed to make command to any one MSN robots through the laptop in hand
Fig. 3. Commands included forward, backward, turn left, turn right and stop. What students had to do to complete the task was click the number keys. Fig.3 were photos that student A controls three robots, in which (a) displayed that robots were controlled by student A, (b) that robots were controlled by student A and student B.

3.2 Design and Practice of Experiment

The subjects of the study were sixth-grade students. There were eight groups, each composed of three students. Students chose their partners themselves. Before the

activity, every group was informed about the system's operation. Then three experiments began. The task students had to complete was to move five chosen dices from outside to inside of a cross frame, one dice in one cell. Those dices were originally positioned ten to thirty centimeters far from the cross frame. The three experiments were conducted with different numbers of students and robots. The followings were the instructions respectively.

- Three students had to complete dice moving by controlling three robots.
- Three students had to complete dice moving by controlling two robots.
- Two students had to complete dice moving by controlling three robots and the left one who did not control robots stood aside.

4 Data Analysis and Results

4.1 Discussion of Controlling Models

Controlling strategies and robots use was analyzed as follows through log files when students controlled robots.

Round 1: 3 students to 3 robots
In this round, it was found in all eight groups that each student controlled only one robot. From the videos, one student only control one robot distribution brought forth least mess or conflicts among robots. However, students in this situation seldom interacted and coordinated. Or there was still situation that one student assigned another one to move dice, leading to fewer conflicts.

Round 2: 3 students to 2 robots
In this round, we categorized controlling models into three based on MSN log files, seen as table 2.

Table 2. Controlling Model: 3 students to 2 robots

One controls one robot and the other two control the other one robot together.	2 groups
All three control more than two robots.	2 groups
Two control two robots respectively and another one does not control robots.	4 groups

After analyzed through videos, it was found in the scenario "one controls one robot and the other two controls the other one robot together" that as disharmony happened, the reason was often less communication, causing robots to move too many steps or turn the wrong side. Then always the students with better leadership stood out and directed someone to do some controlling. Coordination made robots move correctly and the task completed faster.

In the scenario "all three control more than two robots", disharmony happened more frequently. For example, there was once a group that robots just rotated or moved in disorder. Two of three students found it five minutes later and at last only one student controls robots after discussion. In this scenario, it was also found that behavior of

problem solving among peers was more significant when student A did inappropriate controlling. In the scenario "two control two robots respectively and another one did not control robots", although all students were allowed to control, the third one did not control. From those videos, the one who did not control usually played a role of coordinator. Therefore one more person, like coordinator, is needed to observe and think carefully to help completing the task and conflicts would decrease.

Round 3: 2students to 3 robots

In this round, researchers let students to pick up the one that was not going to control. There were two conditions, failing in the finger-guessing game and dropping out voluntarily, according to causes for their quit. The latter was in the majority. After the causes were disclosed, we could further figure out two main reasons: a) I just watch. b) I am the weak one. We sorted controlling models into two through MSN log files, seen as table 3.

Table 3. Controlling Model: 2students to 3 robots

One student controls two robots and the other one controls one robot.	5 groups
One student controls one robot and another one controls another robot, the third robot was not controlled.	3 groups

Analyzing the process from videos, we found that the one who did not control usually played the role of coordinator. Because this one student did not need to operate computers, he/she could give his/her full mind to analyze collaboration strategies, resulting in fewer conflicts and less time to complete.

4.2 Discussion of Conflicts

Conflict was the other focus in this study. Here was discussion on conflicts occurring as robots were moving.

In this part of robots' conflicts when moving, it could be seen in table 4 that conflicts were increased if without coordination whether robots were moving the same or different dices.

A further discussion was given for three models, showing that the three-to-two model had the most conflicts while two-to-three model had the least conflicts. From previous observation analysis from video; in the three-to-two model, one participant usually plays a coordinating role and helps others to control two robots and reduce conflicts.

Table 4. Survey of conflicts occurring as Robots were moving

Scenarios of conflict	Coordination	Total	3-3	3-2	2-3
Two robots moved the same dice and then collided.	Yes	2	1	1	0
	No	9	3	5	1
Two robots moved dices respectively at the same time and then collided.	Yes	4	1	1	2
	No	10	3	5	2
The robots moved in disorder or by inappropriate command.		8	3	3	2
			11	15	7

5 Discuss and Conclusion

For young children, proper conflicts could promote their adaptation to peer learning [7]. There are a few phenomena of collaboration and conflicts collected from experiments and observation in this study.

- When the number of robots is not equal to that of members, collaboration is prone to occurrence.
- Conflicts mostly arise from lack of efficient coordination.
- The best solution to conflicts is to allow somebody to handle the situation and direct other students.

Moreover, in this study students would slow down to discuss and communicate for completing the task with best efficiency as they came to conflicts. As a result, conflicts usually provided good chances for students to learn collaboration and teachers therefore had to consider resources distribution and conflicts' occurrence.

Above all, we could found that conflicts were not avoidable in group interaction and these conflicts all represented that every member in group was willing to share his/her resources for collaboration task. Consequently transferring conflicts into motivation was not only related to learning how to collaborate with others but also important as a life skill during socialization process.

References

1. Cohen, E.G.: Reatructuring the classroom: Conditions for Productive Small Groups (1994)
2. Green, V.A., Rechis, R.: Children's cooperative and competitive interactions in limited resource situations: A literature review. Applied Developmental Psychology 27, 42–59 (2006)
3. Green, V.A., Cillessenb, A.H.N.: Achievement versus maintenance of control in six-year-old children's interactions with peers: an observational study. Educational Psychology 28(2), 161–180 (2008)
4. Homans, G.C.: Social behaviour: Its elementary forms. Routledge & Kegan Paul, London (1961)
5. Klein, J.D., Pridemore, D.R.: Effects of cooperative learning and need for affiliation on performance, time on task, and satisfaction. Educational Technology Research & Development 40(4), 39–47 (1992)
6. Laursen, B., Hartup, W.W., Koplas, A.L.: Towards understanding peer conflict. Merrill-Palmer Quarterly 42, 536–553 (1996)
7. Putallaz, M., Sheppard, B.H.: Conflict management and social competence.. In: Shantz, C.U., Hartup, W.W. (eds.) Conflict in child and adolescent development, pp. 330–355. Cambridge University Press, New York (1992)
8. Qin, Z., Johnson, D.W., Johnson, R.T.: Cooperative versus competitive efforts and problem solving. Review of Educational Research 65(2), 129–143 (1995)
9. Sliver, W.S., Bufanio, K.M.: The Impact of Group Efficacy and Group Goals on Group Task Performance. Small Group Research 27(3), 347–359 (1996)
10. Shantz, C.U., Hartup, W.W.: Conflict in child and adolescent development. Cambridge University Press, New York (1992)

A Case Analysis of Creative Spiral Instruction Model and Students' Creative Problem Solving Performance in a LEGO® Robotics Course

Chun-Hung Lin[1], Eric Zhi-Feng Liu[2], Chan-Hsin Kou[2], Marjo Virnes[3], Erkki Sutinen[3], and Shan-Shan Cheng [2,4]

[1] Graduate Institute of Information and Learning Technology
National University of Tainan
No. 33, Sec. 2, Shu-Lin St., Tainan
Taiwan
[2] Graduate Institute of Learning and Instruction
National Central University
No. 300, Jhongda Rd., Jhongli City, Taoyuan County 32001
Taiwan
[3] Department of Computer Science and Statistics
University of Joensuu
P.O.Box 111 (Länsikatu 15) 80101 Joensuu
Finland
[4] Department of Information Management
Minghsin University of Science and Technology
No. 1, Hsin Hsin Road, Hsin Feng, Hsincu
Taiwan
sjohn1202@gmail.com, totem@cc.ncu.edu.tw, janshing04@gmail.com, marjo.virnes@cs.joensuu.fi, erkki.sutinen@cs.joensuu.fi, yes5433@must.edu.tw

Abstract. The creative spiral instruction model was applied into a LEGO® robotics course in this study. In order to understand the effect of the LEGO robotics course on students' creativities and problem solving performance, students' problem solving process and performance in the course were analyzed. Six undergraduate students participated in this study. The participants were divided into two groups, Group A and Group B, having three members per group. Results showed that during the problem solving process, students in both groups exhibited creativity and acquired knowledge about program design and assembly of LEGO robots. During the problem solving process, three strategies were mainly used by students to solve the problems: 1. Slight adjustment. 2. New elements adding. 3. Problems redefining. After analyzing the creative problem solving process, the result showed richness of data collection being beneficial for understanding the problem solving modes.

Keywords: Creative spiral instruction model, Creative problem solving, LEGO robotics, Learning and instruction.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 501–505, 2009.

1 Introduction

Recently, Taiwan students have achieved notable success in international robotics competitions. Teams of Taiwanese students received good grades for example in the World Robot Olympiad 2008 [1], which indicates successful robotics education in Taiwan. In order to understand factors of success and enrich the understanding about robotics instruction, methods of creative problem solving in groups were elaborated. Methods of creative problem solving in groups of students were examined through qualitative analysis with creative spiral instruction model [2].

2 Purpose

The purpose of this study would focus on undergraduate students' creative problem solving process under the LEGO® robotics course based on the creative spiral instruction model. By analyzing the students' learning process in the LEGO robotics course, the relationship between the learning process and creative problem solving ability was elaborated, and the learning process would be examined to see if it fitted the creative problem solving process.

3 Literature Review

3.1 Creative Thinking Spiral in the Course of LEGO Robotics

Novel technologies have been found out to arouse and inspired learner's creativity. On the one side, the fast development of new technologies could help to locate the needs of creative thinking; on the other side, by suitable design and usage, technologies could help people to become creative thinkers. From this point of view, LEGO Robotics could be a suitable material to inspire the learners' creative thinking.

Resnick [2] proposed the model called creative thinking spiral which included five elements: imagine, play, share, reflect, and the next expended creative thinking spiral. At this time, the model of creative thinking spiral was proposed because of the development of robotics instruction, and the model was used to reflect the creative thinking process during designing robots.

3.2 Integrating Creativity and Problem Solving Ability into Robotics Instruction

Robotics is a tool that can improve learners' creativity and working motivation [3]. During the robotics instruction, learners can develop different kinds of skills, like: creativity, team work, robot design, and problem solving [4]. Amabile [5] proposed three elements of creativity that are valid also within robotics: related skills in specific domain, creative thinking skills, and motivation on the task. Learning of robotics requires the skills of mechanic construction, programming, and the creative thinking regarding constructing a mechanic structure and creating an algorithm for the program. Only with a combine of these skills, the learners can operate the robots to complete the tasks.

4 Method

Content analysis and observation were the methods used in this study. The creative problem solving process was used to analyze the students' reports and reflection during the LEGO robotics course. In LEGO robotics instruction, instructional material is very important. A well-developed instructional material not only can arouse students' motivation, but also help students learn better. Motivation, content, interface design, and feasibility are four important dimensions to evaluate a LEGO multimedia instructional material [6]. In this study, the multimedia instructional material for robotics education developed by Liu, Kou, Lin, Cheng, and Chen was adopted in this study [7].

4.1 Participants

Six prospective teachers from a national university in northern Taiwan participated in the study. The participants were divided into two groups, and there were three members in each group. All the participants came from the Department of Literature, and most participants did not have any experience about writing of programs or constructing of robots. The LEGO robotics course lasted for eighteen weeks, two courses a week, and fifty minutes for each course.

4.2 Research Questions

1. What are students' learning methods under creative spiral instruction model?
2. What kind of students' performance on creative problem solving process is?

4.3 Instructional Process

After each chapter in the LEGO robotics course, the learners took the chapters for example to prepare their midterm and final presentation. The presentation should include the story, the figure of the robot, the programming design, and the design of the tasks. Besides, the learners should present their work in slides, and each group did an oral presentation.

5 Results

The creative problem solving process was used to analyze the content of students' presentation including story, design journal, robot assembling, program design, task design, and debugging.

5.1 The Methods of Problem Solving in Students' Learning Process Based on the Creative Spiral Instruction Model

5.1.1 Imagination

The task was the only difference between the stories in the mid of the semester and in the final of the semester in the course. The story at the end of the semester was the extended version of the story in the mid of the semester. In the midterm presentation,

both of the groups created their new characters to the story. In Group A, the story was similar to the story in the textbook, and the task "ring the golden bell" was similar to the task "get the treasure map" in the textbook. In Group B, the group members created the story by themselves, which resulted a different story from those in the textbook. In the presentation of final of the semester, Group A created a story "the castle of Dragon", and the mission for the robot was to defeat the dragon and save the prince. The story and the task were much different to those in the textbook. In Group B, some elements from news were added in the story, and there were three missions in their story. Therefore, after the semester, the richness of story imagination of both groups were improved. Group A gradually got rid of the effect of the textbook, and Group B expressed more creativity in the beginning making the story and the mission richer and richer.

5.1.2 Create

According to the analysis of students' design journals, in the presentation both groups not only used the actions like forward, stop, turn left, turn right which were used in the textbook, but also added some new actions in the mid of the semester. In Group A, "360°gyration" was added, and in Group B, the new actions like "follow the black line", "detect the black line and skip it", and "detect the black line and stop" were added. Group A used more actions showed in the textbooks, and Group B created more new actions than Group A. In the presentation at the end of the semester, Group A did not create any new actions, but Group B used the program design that was similar to their presentation in the mid of the semester. The tasks designed by Group A were similar to the example in the textbook, but the tasks designed by Group B were different from the example in the textbook, which expressed more creativity.

5.1.3 Play and Share

Some differences were discovered after comparing the design of the tasks of both groups. In Group A, the tasks were similar to the tasks in the textbook, but the group members complicated the tasks, which made the adventure activities more challenging. Differently, in Group B, the tasks were much different from the tasks in the textbook and new strategies and methods were acquired to complete the missions.

5.1.4 Reflection

Students' reflection journals showed two groups met different kinds of problems. There were three kinds of problems: 1. Machinery malfunction. 2. Program design. 3. Task design. In Group A, the program design problem was the type of problem they met mostly, and when they met this kind of problem, the strategy, slight adjustment, was applied to solve the problems. In Group B, the machinery malfunction was the type of problem they met mostly. In Group B, when they met the program design problem, two strategies were used to solve it: 1. Slight adjustment. 2. New elements adding. When they met the task design problem, they tried to redefine the mission to solve the problems. Analysis showed that during the course, both groups devoted to dig out different ways to solve the problems they met.

5.2 Students' Performance on Creative Problem Solving

After analyzing the reports of both groups, failure in the adventure activities was the problem the two groups met most. Group A did not search help from others, but attempted to solve the problems by trial and error. From the trial and error process, they adjusted their strategies, and learned the knowledge and the skills about LEGO robots. Group B usually searched different kinds of resources to solve the problems, like referencing the samples in the textbook, consulting the instructor, search information on internet. Results showed that during the LEGO robotics course, both of the groups expressed their creativity to solve the problems.

6 Conclusion and Discussion

In this study, LEGO robots were used as an instructional media, and the creative thinking spiral model [2] was used to lead the students to perform their creative problem solving ability. Result showed that the students did express creative problem solving ability on different aspects, like imagination, create, play, share, and reflection. Therefore, creative spiral instruction model in LEGO robotics course really could deepen the students' creative problem solving ability, and helped the students to acquire the knowledge and skills about robot design.

Acknowledgments

The authors would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract No. NSC 97-2631-S-008-003.

References

1. WRO 2008, `http://www.wroboto.org/awards/kekka.html#reg`
2. Resnick, M.: Sowing the Seeds for a More Creative Society. Learning & Leading with Technology 35(4), 18–22 (2007)
3. Fernandez, J., Marin, R., Wirz, R.: Online Competitions: An Open Space to Improve the Learning Process. IEEE Transactions on Industrial Electronics 54(6), 3086–3093 (2007)
4. Gerecke, U., Wagner, B.: The Challenges and Benefits of Using Robots in Higher Education. Intelligent Automation and Soft Computing 13(1), 29–43 (2007)
5. Amabile, T.: Creativity in Context: The Meaning and Measurement of Creativity. Westview Press, Colorado (1996)
6. Liu, E.Z.–F., Cheng, S.–S., Lin, C.–H., Chang, Y.–F., Chen, W.–T.: The Development of Evaluation Indicators for LEGO Multimedia Instructional Material. WSEAS Transactions on Computers 7(10), 1782–1791 (2008)
7. Liu, E.Z.–F., Kou, C.–H., Lin, C.–H., Cheng, S.–S., Chen, W.–T.: Developing Multimedia Instructional Material for Robotics Education. WSEAS Transactions on Communications 7(11), 1102–1111 (2008)

Gender Heterogeneous Groups in Cooperative Learning Applied in "Robots in Creative Course": A Pilot Study

Chen-Yi Wang, Tzu-Chien Liu, and Yi-Chun Lin

Graduate Institute of Learning & Instruction, National Central University, Taiwan
{971207007,ltc,961407001}@cc.ncu.edu.tw

Abstract. Cooperative learning is often adopted as a teaching strategy when robots are introduced into the classroom. Previous research suggested that there was a relative correlation between a group's level of interaction and its gender composition. In this study, we utilized experimental design to explore the degree of satisfaction and involvement when students learning with "robots in creative course" in terms of its varied gender composition (male group, female group, gender-mixed group). Analysis of the questionnaire results demonstrates that the gender-mixed group and male group claim higher degrees of satisfaction and involvement of "robots in creative course" than the female group. The instruction suggests and recommendations for future research are made.

Keywords: Cooperative Learning; Gender heterogeneous groups; Robots.

1 Introduction

Over time, more and more educators and researchers have become interested in developing learning activities that stimulate learner creativity. At stake is the improvement of problem-solving ability and creativity through the introduction of different problem-solving methods. Cejka[1] presumed that robots could enhance the capacity of learners to create meaningful works, by developing their meta-cognition and other higher-order thinking skills with practice. Earlier studies of robots as teaching tools also confirmed that learners could gain additional, practical knowledge, further by designing and producing the robots [2].

Cooperative learning is often adopted as a teaching strategy when robots are introduced into the classroom. According to the definition of cooperative learning, it is an arrangement in which individuals learn and share information with their peers of different ability, status, gender or race [3]. Through the process of learning and assessing others works with the intention of helping them revise, learners could improve their learning effects and the cooperative behaviors are also enhanced. However, cooperative learning needs to be constructed on a good grouping strategy, so it may inspire learner motivation and help individuals, as well as the whole group learn. Some experimental studies proposed that learners in a heterogeneous group could signficiantly improve their learning effects. A heterogeneous group could be presented with different dimensions, including Achievement Levels and Ability, Gender

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 506–511, 2009.

Differences, Patterns of Learning, Social Interaction, Motivation and Attitude, etc[4]. The results of past studies showed that the grouping of learners in such ways could promote their learning ability Webb[5] introduced a gender-based division of heterogeneous grouping research. The results showed that a gender-mixed group outperformed a male-dominated learning group in cooperative learning .

The gender differences in children's toy preferences have already been explored in some detail. Boys prefer construction and transportation toys, whereas girls prefer dolls, doll furnishings, and kitchen supplies [6]. An examination of student's attitudes and experiences of science indicated that males had more extracurricular experiences with a variety of tools, such as batteries and electric toys. Conversely, females had more experiences with bread-making and knitting. More male students indicated that they were interested in computers and technology, compared with female students [7].

Based on constructionism and theories of cooperative learning, our research team designed a set of creative course aimed at the introduction of robots into the elementary course. Within the course, students are grouped to facilitate discussion about their learning activities, prior to producing their final results. According to the results from the initial study, students who attended all had a positive attitude toward the course and programming robots [8]. Therefore, the researchers wonder if cooperative learning is involved in a robot course and especially the programming unit is the focus of learning activities. A major issue to be addressed is whether groups with a different distribution of genders would have different thoughts and attitudes about the course that could be anticipated. Therefore, this study will explore learner attitudes and involvement in the heterogeneous groups with respect to their gender distribution, to see if there is any difference among groups after they progress through the "robots in creative course".

2 Method

2.1 Participants

The participants were 34 students from an elementary school in central Taiwan (approximately 11–12 years of age). 18 males and 16 females were included, and all of them had attained 20 percent of their expected level of academic performance in their original classes. We had verified that they had 2 or 3 years computer experience.

In this experiment, students were allocated to six groups according to genders and grades: two male groups (containing 5 and 6 males, respectively), two female groups (containing 5 and 7 females, respectively), and two mixed groups (containing 5 and 6 students, respectively. Both included two girls.)

2.2 Research Tools

In this study, the research tools included robots (called BeRobot) and a questionnaire aimed at soliciting student feedback about the "robots in creative course". The robots were developed by GeStream Technology .Inc, which have been cited as the "Smallest Robot of All Time" by Guinness World Records. The robots were comprised of 15 sever motors, with users able to edit robot motions with the software developed by the

research team and the company. A six-point Likert-type scale was used as the questionnaire, based on the features of the learning activities.

2.3 Design and Procedure

In this research we used quasi-experiment design; it mainly explored the degree of satisfaction and involvement of "robots in creative course" cooperatively. Firstly, all participants took the 8-item questionnaire intended to determine their perceptions of robots before the learning activities. The participants were then grouped and progressed through the 7-hour "robots in creative course", which included the current development of robots, introduction of the robots programming interface, learning tasks, and presentation. During the process, the learner behaviors and involvement were recorded on videos. Finally, all participants contributed to the satisfaction scale to ascertain if there was any change in their perceptions of robots after the learning activities.

3 Results and Discussion

For avoiding the effects of the previous perceptions of robots, ANCOVA was used in this study. The scores obtained from the pre-questionnaire were taken as the covariates in order to analyze the responses on the feedback questionnaire about the course. The results could be separated into three sections: satisfaction with the course, satisfaction with programming motions of robots, and involvement in the learning process. The results will be presented below along with the records taken at the time.

3.1 Dimension 1: Involvement of "Robots in Creative Course" (8 Items)

This dimension is used to understand the different degrees of involvement and feelings in each gender grouping. We asked students questions such as whether they felt the time passes quickly when they were in class. Meanwhile, we also asked them to self-evaluate their degree of concentration, curiosity and pleasure during the learning processing. A one-way analysis of covariance (ANCOVA) was used to examine the differences between the three groups on their post-test scores of Dimension 1, with the pre-test scores used as a covariant. The results showed that the difference was significant between the three groups ($F_{(2,30)} = 7.51$, $P < .05$). The results of post-hoc comparisons revealed that the male group (M=40.83) significantly outperformed the female group (M=30.17) ($p < .05$). The gender-mixed group (M=40.99) significantly outperformed the female group (M=30.17) ($p < .05$), so it can be concluded that these results are consistent with our expectations. According to the data gained from observation, the male and gender-mixed group show more concentration than the female group when they are listening to a lecture and practicing the programming of the robot. The female group were distracted and usually stopped to wait for assistance when they encountered difficulties, but the groups with male members showed more activity because when they had any problems they would find the solutions immediately. We suggest that in "robots in creative course" class the instructor can consider using a gender-mixed grouping to prove the degree of involvement in the leaning activity.

3.2 Dimension 2: Comprehending the Programming Interface (7 Items)

This dimension is about the viewpoint of students after they had learned about the programming interface. We used a questionnaire to ascertain their feelings about learning the robot programming and the degree of ease of use and comprehension with respect to the programming interface developed by our research team. Students were also asked to evaluate their learning efficiency, particularly whether they could apply the skill and memorize the operating steps easily or not, in addition to whether they would continue to try to solve the problems during the practice time. A one-way analysis of covariance (ANCOVA) was used to examine the differences between the three groups on their post-test scores of dimension 2, with the pre-test scores used as a covariant. The results show that the difference was not significant between the three groups ($F_{(2,30)} = 2.83$, $P > .05$). Based on observation of the class, we found that because every group in the course consisted of 5~6 students working together with one computer to practice the robot programming, every group gave lower feedback in this dimension(male group, M= 25.83; female group, M=26.19; gender-mixed group, M=31.05;7items). The results showed that every group had difficulty learning the robot programming. Because the "robots in creative course" was designed to last for 7 hours per day, the time that students could practice was limited, leading to lower feedback levels that influenced the students' comprehension of the programming interface. In future course design, we will arrange a greater number of learning hours and adjust the number of group members to three or four persons to enhance the programming skill and comprehension of the programming interface.

3.3 Dimension 3: The Likeability of "Robots in Creative Course" (5 Items)

The use of robots in this research differs from the "LEGO MINDSTORMS Robotics Invention System". Therefore, the extent of likeability of "robots creative course" on the part of learners is a cause for concern. Indeed, the result can be a basis for reconsidering the course. The questionnaire inquired as to the likeability of activities in both the whole course and our use of BeRobot in the classroom. A one-way analysis of covariance (ANCOVA) was used to examine the differences between the three groups on their post-test scores of dimension 3, with the pre-test scores used as a covariant. The results show that the difference was significant between the three groups ($F_{(2,30)} = 4.11$, $P < .05$). The results of post-hoc comparisons revealed that the male group (M=26.10) significantly outperformed the female group (M=20.88) ($p < .05$). The gender-mixed group (M=24.52) also significantly outperformed the female group (M=20.88) ($p < .05$). These results are consistent with our expectations that a gender-mixed group will have more positive feedback. The learner will feel satisfied and prefer the course when they experience a pleasurable mood, curiosity and consequently greater psychological investment.

3.4 Dimension 4: The Expectation of Participation in Robot Course (3 Items)

In this dimension we want to explore the expectations of future participants in "robots creative course". We aspire to a greater number of classes in the robot course, leading to an attitudinal shift towards it as a formal course. A one-way analysis of covariance (ANCOVA) was used to examine the differences between the three groups on their

post-test scores of dimension 4, with the pre-test scores used as a covariant. The results showed that the difference was significant between the three groups ($F_{(2,30)} = 6.10$, $P < .05$). The results of post-hoc comparisons revealed that the male group (M=16.14) significantly outperformed the female group (11.38) ($p < .05$). The gender-mixed group (M=15.18) significantly outperformed the female group (M=11.38) ($p < .05$).These results show that peer interaction among females and males have some influence on the gender-mixed group. The members encourage each other and this facilitates cooperative learning. When the course is considered interesting and inspires the student's motivation to learn, they will aspire more towards participation in the robot course.

4 Conclusions

Previous studies have shown that the gender composition of team members is closely related to their academic performance. These investigations of the "robots in creative course" also found that there is a relative correlation between a group's level of interaction and its gender composition. For example, males were generally more positive toward the learning environment. Cooperative learning is often adopted as a teaching strategy when robots are introduced into the classroom. The precise gender composition of the group and how to gain the most satisfactory learning outcomes through "robot in creative course" are both important issues meriting further exploration.

In this study, we utilized experimental design to explore the degree of satisfaction and involvement in "robots in creative course" in terms of its varied gender composition (male group, female group, gender-mixed group). This has highlighted the different gender composition of the team members whether there are any significant differences in the degree of satisfaction and involvement in this course. Questionnaire analysis showed that the gender-mixed group and male group report greater satisfaction and involvement than their female counterparts. In keeping with these results, we suggest that teachers in cooperative learning for "robot creative course" adopt gender-mixed grouping because this not only achieves an effective interaction but also enhances the involvement of the course and inspires learning potential.

Moreover, the course content is too compact. Therefore, children learning and operating the robot programming interface in such a brief time find their familiarity with the editing interface affected. This is apparent from their lower levels of feedback. In the future this study will rearrange the time of the robot programming unit by adding more practice time and providing more adequate equipment to assist learner familiarity with the robots programming interface and thereby facilitate communication among the group members. Ultimately, this study is a pilot study about gender heterogeneous groups in cooperative learning with "robots in creative course". Spatial constraints prevent this study from elaborating on the creative performance and problem solving ability of learners. Future studies will try to use content analysis to explore the process of cooperation such as the frequency of discussion when student editing programming. In addition, the functional roles of the group member's differing gender composition will be an important issue in the future when accounting for variable learning outcomes.

Acknowledgement

The authors would like to thank the Taiwan National Science Council, for financially supporting this research under grant NSC 97-2631-S-008-003- and NSC 96-2520-S-008-007-MY2.

References

1. Cejka, E., Rogers, C., Portsmore, M.: Kindergarten Robotics: Using Robotics to Motivate Math, Science, and Engineering Literacy in Elementary School. International Journal of Engineering Education 22, 711–722 (2006)
2. Klassner, F., Anderson, S.: Lego MindStorms: Not just for K-12 anymore. IEEE Robotics and Automation Magazine 10, 12–18 (2003)
3. Parker, R.E.: Small-Group Cooperative Learning Improving Academic: Social Gains in the Classroom. NASS Bulletin 69, 48–57 (1985)
4. Cheng, S.H.: Study on Student Team Forming in a Collaborative Learning Environment. Unpublished master's thesis. National Chiao Tung University, Taiwan (2000)
5. Webb, N.M.: Student interaction and learning in small groups: A research summary. In: Slavin, R., et al. (eds.) Learning to cooperate, cooperating to learn, pp. 147–172 (1985)
6. Connor, J.M., Serbin, L.A.: Behaviorally based masculine and feminine activity preference scale for preschoolers: correlates with other classroom behaviors and cognitive tests. Child Development 48, 1148–1416 (1977)
7. Jones, M.G., Howe, A., Rua, M.J.: Gender differences in students' experiences, interests, and attitudes toward science and scientists. Science Education 84, 180–192 (2000)
8. Wang, C.Y., Liu, T.C., Lin, Y.C., Wang, H.Y., Yeh, S.C., Wu, S.Y.: The Development and Evaluation of Robots Applied in Elementary School Instruction: A Pilot Study. In: 13GCCCE, Taipei (2009)

Exploring Children's Perceptions of the Robots

Yi-Chun Lin[1], Tzu-Chien Liu[1], Maiga Chang[2], and Shiau-Ping Yeh[1]

[1] Graduate Institute of Learning & Instruction, National Central University, Taiwan
[2] School of Computing and Information Systems, Athabasca University, Canada
{961407001,ltc}@cc.ncu.edu.tw,
maigac@athabascau.ca,
a5261219@yahoo.com.tw

Abstract. In order to introduce robots into education field appropriately, it is necessary to consider the children's perceptions of the robots. In this study, the researchers developed the questionnaire for exploring the children's general impressions of the robots, the roles of the robots in the classroom and the appearances of the robots. A hundred and sixty seven fifth-grade children took this questionnaire. The results show that most students have good impressions of the robots and positive attitude to see the robots in their classroom. Their responses also reveal that they might have over expectations of the robots. Besides, the results show that most of children like cartoon character-like robots and animal-like robots, because the robots are very cute.

Keywords: Robots, Children, Educational settings, Attitude, Classroom.

1 Introduction

Robots with different shapes and functions are already applied in various instructional environments. For example, robots are commonly used as a medium for programming course. The learners could practice the complex concepts by editing the codes for manipulating the robots. Robots in teaching programming can provide the learners authentic practice opportunities and immediate feedback [1]. Furthermore, Robots are also applied as the teaching assistant or learning companion in the classroom to enhance students' learning motivation and improve students' leaning achievement [2].

Like other innovative technologies, some researchers point out that even exciting educational technology innovations have taken hold in some places, such as intelligent service robots, in many places, this new technology lies unused in schools. One reason to this statement comes from the perception differences between robot designers and the users. Therefore, the perceptions of the users are needed to be taken into consideration. Children are the frontline users, hence, we need to know children's perceptions of different robot designs [3].

Few studies explored the related issues [4]. Lee, Lee, Kye and Ko [5] had developed a Likert-scale questionnaire to survey the perceptions and needs of intelligent educational service robot among 1,528 people, including teachers, students and parents in Korea and found some valuable information for using robots in schools. Due to the

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 512–517, 2009.

limitation of the questionnaire format, the study could only know the perceptions of the students toward to the robots, but could not get the reasons from the students. On the contrary, Shin and Kim [4] interviewed 85 students about their perceptions of learning form robots and learning with robots. However, the considerable effort and time required in interviewing and data analysis make the technique unsuitable for a large-scale study.

In order to meet the educational needs of using robots in schools, this study developed the questionnaire with multiple item types. The questionnaire can not only help researchers to identify students' perceptions of using robots for educational purpose in school, but also help the teachers to get more information and well prepared before using the robots as a new technology to educational practices. The purpose of this study is to understand children's perceptions of the robots, especially to the intelligent educational service robots.

2 Method

A hundred and sixty seven fifth-grade children from three primary schools at the northern Taiwan were participated this study. They all had ideas about robots. Seventy eight girls and eighty nine boys were included, and they aged between 11 and 12 years.

The questionnaire used to explore children's perceptions of the robots in this study was developed by the researchers. The original contents of the questionnaire referred to three sources: the members of the robots company (robots designer), the researchers who study educational robots, and the literatures about the students' perceptions of the robots.

The questionnaire is composed of 20 items and the questionnaire covers four topics presented in three types. The distribution of the items for different topics and types is showed in Table 1. The first part consists of 5 items which aimed to collect the essential information of the respondents, including their experiences with the robots. The second part consists of 8 items which aimed to investigate the children's general impressions of the robots. The third part consists of 4 items which aimed to explore the children's thoughts about the robot roles in the classroom. The final part consists of 3 items which aimed to investigate the children's thoughts about the robot appearances.

In order to make sure that the questionnaire is readable and suitable to the children, ten fifth-grade students were invited to discuss the first edition questionnaire after they completed the questionnaire. The researchers revised the sentences which were not described clearly according to children's comments. The revised questionnaire (the 2nd and formal edition) then was used to collect the perceptions of the robots among 167 children. The average time spent in completing the questionnaire was 40 minutes. The content analysis was used to analyze the three item types and classify the responses into different topics. Furthermore, the description analysis was conducted by SPSS 13.0.

Table 1. The questionnaire for exploring children's perceptions of the robots

The topics of the questionnaire	The types of the items	Items	The examples of the item
Respondents' essential information	Short answer questions	5	• Item 1: What are my name, gender and age? • Item 4: What are the top three favorite cartoons I like?
General impressions of the robots	Short answer questions	3	• Item 6: If I have a robot, what kind of work I hope the robots can do?
	5-point Likert scale + short answer question	5	• Item 10-1: I think the robots are novel. • Item 10-2: Why I (do not) think that the robots are novel?
Robot roles in the classroom	Short answer questions	1	• Item 9: In which subject I would like to let the robots be the teacher and why I think they can teach?
	5-point Likert scale + short answer question	3	• Item 17-1: I want to have a robot companion in the classroom. • Item 17-2: Why I (do not) want to have the robot companion in the classroom?
Robot appearances	5-point Likert scale + short answer question	2	• Item 19-1: I like mini robots. • Item 19-2: Why I (do not) like mini robots?
	Multiple choice question + short answer question	1	• Item 20-1: Among the 16 types of robots displayed below. Which is my favorite one? • Item 20-2: Why I like this robot?

3 Findings and Discussions

Due to space limitations, the researchers will touch upon the last three topics of the questionnaire: General impressions of the robots, robot roles in the classroom, and robot appearances.

3.1 What Are the Children's General Impressions of the Robots?

What the feeling a child will have when he/she hears something about robots? This question is concerned by the researchers who focus on the children's perceptions of the robots. There are 8 items related to this issue in the questionnaire. The results of item 6 and item 10 can be good examples to summarize children's perceptions or impressions of robots in Taiwan. Item 6 is used to investigate the expectations of the robots that the children have. The top two expectations are (1) be my servant (26.5%), e.g. "I hope it can help me deal with a lot of things, such as doing homework" and (2) Keep company

with me (26.5%), e.g. "I hope it can be my good friend and accompany me forever". Based on the results, some children like to have robots be their servants and help them handle lots of things, and some children prefer to have the robots as their companions. But so far, the developed robots can not reach the goals. It seems that the children had over expectation of the robots. In addition, it is obviously that none of the children would like to have robots to assist them in learning.

Item 10 is used to investigate that whether the children consider the robots are novel or not and why they have the thoughts. The results show 66% of the children agree or strongly agree the robots are novel and 22% of the children disagree or strongly disagree that the robots are novel. The top two reasons about why the children think the robots are novel are (1) the robots have multiple functions (77%), e.g. "the robot can fly and transform" and (2) the robots are stronger than human beings (14%), e.g. "the robots are smarter, and they can do many things which we human beings can not do". Those responses also show that children have high expectations of robots, and they thought that robots can do much more things than human beings.

The top two reasons about why the children do not think the robots are novel are (1) robots are created by human beings (44%), e.g. "robots can exist just because human beings make them, so they are not novel" and (2) the prevalence of robot (39%), e.g. "you can easily get the robots, thanks to the remarkable technology that almost everyone has his or her own robot". When robots are applied in education, it might be an issue to investigate that if there are differences in learning effects between the children who think the robots are novel and who do not.

3.2 How about the Children's Thoughts If the Robots Are Placed in the Classroom?

What feeling the children may have when they know a robot will be their teacher or classmates tomorrow? This question should be concerned when someone wants to introduce the intelligent educational service robot to the classroom. There are 4 items related to this issue in the questionnaire. The results of item 9 and 17 are good examples to investigate the children's thoughts if the robots are placed in the classroom. Item 9 explores which subjects the children would like to have robots to teach them. The results show that "Nature science" is the subject that most of children choose (26%). The top two reasons are (1) robots are machines (68%), e.g. "we can observe their mechanical structure" and (2) natural science is the most difficult subject (15%), e.g. "natural science is hard to understand, but robots seem could deal with that kinds of problems". The contents of nature science in Taiwan primary schools include physics. Therefore, the children may think the robots are good teaching aids due to the robots are machine.

Item 17 is used to investigate that if the children would like to learn with robots and why they have the thoughts. The results show 59% of the children agree or strongly agree that they want to have a robot companion while learning and 27% of the children disagree or strongly disagree. The top two reasons of why the children want to have a robot companion are (1) robots could be the tutors (34%), e.g. "if I lose some important points told by teachers during class, I can ask the robots repeat those points for me" and (2) learning with robots might be interest (29%). On the other hand, the top two reasons of why the children do not want to have a robot companion are (1) negative learning

effects (53%), e.g. "robots might distract me from learning" and (2) robots are not living creatures (18%), e.g. "I prefer to learn with real person". According to the children's responses, it shows that when and how the robots are used in the classroom should be carefully considered when the educators introduce robots as learning companions in the classroom. Furthermore, the robots don't like living creature or don't have emotions may be the crucial reason for why the children did not like the robots becoming their companions. The limitations might be solved by the researches of human and robots interactions [2].

3.3 How about the Children's Thoughts of the Robot Appearances?

What feeling the children may have when they see different robot appearances? Some studies have shown that people have different feelings to different shapes of robots [3] and the robots with good appearances can enhance the learners to engage in their learning [6]. Therefore, the robot appearance is a crucial issue to the designers and the researchers. There are 3 items related to this issue in the questionnaire. The results of item 19 and 20 are good examples to explore what robot appearances the children like. Item 19 focuses on the robot sizes and item 20 focuses on the robot shapes. The results of item 19 show that 65% of the children agree or strongly agree that they like mini robots and 18% of the children disagree or strongly disagree. The top two reasons for why the children like the mini robots are (1) mini robots are very cute (66%) and (2) mini robots are very convenient (32%), e.g. "it is small, so I can carry it with my back bag or pocket very easily". The top two reasons for why the children don't like the mini robots are (1) the functions of the mini robots are weak (66%), e.g. "the robots can not do many things" and (2) the mini robots look not cool.

Item 20 shows the children 16 different robots which belong to four main shapes, including cartoon character-like robots (such as PAPERO), animal-like robots (such as AIBO), humanoid-like robots (such as Sapiens) and machine-like robots (such as LEGO). Forty one percents of the children like cartoon character-like robots and 32% of the children like animal-like robots, and they both had the similar reason to their selections, that is, "the robots look cute". Therefore, the robot designers should take it into consideration when design the robots.

4 Conclusions

Robots are the innovative technology which has potential to be broadly applied in education in recent years. In order to introduce robots into education field appropriately, it is necessary to consider the children's perceptions of the robots. Therefore, in this study, the researchers developed the questionnaire with multiple item types for exploring the children's perceptions of the robots. In overall, the results show that most of fifth-grade children have good impressions of the robots and have positive attitudes to see the robots in their classroom. However, they also show higher expectations to the robots and that might be resulted from the mass communication about the robots. The significant differences between student expectations and the real robots might have negative impact on the application of using robots in educational field. To solve this

problem, the educators should make the children know more details about the limitations of the robots before introducing the robots to the classroom.

With respect to the children's perceptions of the robot appearances, the results show that most children like cartoon character-like robots and animal-like robots, because these two kinds of robots are cuter than humanoid-like robots and machine-like robots. For enhancing the children's learning motivation, the robot designers need to consider the result while designing the robots. In order to successfully apply robots in the education field, not only the robot designers but also researchers should take this study's results into consideration. The study results could help the robot designers and educators use robots appropriately and successfully. The researchers also suggest that the future studies could further explore the deferent users' perceptions of the robots with different educational purposes.

Acknowledgement

The authors would like to thank the Taiwan National Science Council, for financially supporting this research under grant NSC 97-2631-S-008-003- and NSC 96-2520-S-008-007-MY2.

References

1. Fagin, B., Laurence, M.: Measuring the Effectiveness of Robots in Teaching Computer Science. SIGCSE Bull. 35, 307–311 (2003)
2. Kanda, T., Hirano, T., Eaton, D., Ishiguro, H.: Interactive Robots as Social Partners and Peer Tutors for Children: A Field Trial. Journal of Human Computer Interaction 19, 61–84 (2004)
3. Woods, S.: Exploring the Design Space of Robots: Children's Perspectives. Interacting with Computers 18, 1390–1418 (2006)
4. Shin, N., Kim, S.: Learning about, from, and with Robots: Students' Perspectives. Robot and Human interactive Communication. In: 16th IEEE International Symposium on Robot & Human Interactive Communication, pp. 1041–1045. IEEE Press, Jeju (2007)
5. Lee, E., Lee, Y., Kye, B., Ko, B.: Elementary and Middle School Teachers', Students' and Parents' Perception of Robot-Aided Education in Korea. In: ED-Media 2008, pp. 175–183. AACE Press, Vienna (2008)
6. Van Vugt, H.C., Konijn, E.A., Hoorn, J.F., Keur, I., Eliens, A.: Realism is not all! User Engagement with Task-Related Interface Characters. Interacting with Computers 19, 267–280 (2007)

Development of an Emotional Robot as a Teaching Assistant

Jwu-E Chen[1], Lu-Tsou Yeh[1], Hua-Hsiang Tseng[1], G-W Wu[2], and In-Hang Chung[2]

[1] Dept. of Electrical Engineering, National Central University, Taiwan
jechen@ee.ncu.edu.tw, buhdda@ms.chinmin.edu.tw, huahsiang@gmail.com
[2] Dept. of Electrical Engineering, Chung Hua University, Taiwan
{m9101013,ihchung}@chu.edu.tw

Abstract. Robot as a teaching assistant is a popular topic in recent years. A development for the robot assistant is presented, which includes five interactive operation modes and a progressive scheduling scheme to facilitate the use by a teacher and parent. In storytelling, this robot assistant can play a role assigned in advance and cooperate with the teacher and parent to react to some events. Or replacing the sound of teacher and parent, the robot can talk to the students or children. Or the robot can just be a faithful audience within the conversation of teacher-and-students or parent-and children.

Keywords: Emotional robot, Teaching assistant, Human computer interface.

1 Introduction

In the early years, the industry machine arm was taken as granted for a robot, and managed in product lines in many factories. Different types of robot have appeared in recent and changed pick varied. Maybe you will not surprise that a familiar human face appears in front of you, but how about a robot face does. We can find many robots have body, arm, even it's a car-like toy. A facial robot may have the advantages for interaction with human, especially for its many kinds of expressions. Some people are fascinated with the humanoid robot, e.g., ASIMOV, with the educational toys, e.g., LEGO Mindstorms, and with the learning assistant, e.g., our Acrylic and Little-wood.

Robot as a teaching assistant is a popular topic, not only the applications for daily life services, but also for the learning field on education. There are lots of robot design styles for its appearance, but less discussion about its impact to the learning field. People cannot afford an expensive robot in daily life. Especially for the limited cost in education, a robot is significant for the educational purpose must be taken account of. Under the prerequisite, an affective robot is developed to meet the educational goal.

A development for the robot assistant is presented, which includes five interactive operation modes and a progressive scheduling scheme to facilitate the use by a

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 518–523, 2009.

teacher and parents. In storytelling, this robot assistant can play a role assigned in advance and cooperate with the teacher and parent to react to some events. Or replacing the sound of teacher and parent, the robot can talk to the students or children. Or the robot can just be a faithful audience within the conversation of teacher-and-students or parent-and children. The robot style like this will change the point of view in the application for learning.

In section 2, the system overview about our robot will be presented, which includes system architecture and human computer interface. In section 3, we will introduce the developed interactive operation modes and some examples are presented for applying the emotional robot to act as the role of teaching assistant. Finally there is a conclusion given in section 4.

2 System Overview

Maybe you will not surprise that a familiar human face appears in front of you. Robots may have body, arm, but little have the eyes, noise, mouth and eyelid clearly. A facial robot may have the advantages for interaction with human, especially for its many kinds of expressions.

In MIT [1], a social robot "Kismet" was developed and it has many expressions and can interact with human. Behind the robot, there are several computers aiming at processing many tasks. There are many actuators, sensors and electronic and mechanical devices within it. People cannot afford an expensive robot in daily life. Especially for the limited cost in education, a robot is significant for the educational purpose must be taken account of. Under the prerequisite, an affective robot is developed to meet the educational goal.

2.1 Architecture

For each robot like a performer, it will behave individually in its own distinctions including character, expression and emotion. Hence, they can reply different responses to the same stimulus. The stimulus-response flow is shown in Fig. 1, where the (external and/or internal) stimulus will directly affect the built-in emotion module of a robot and the robot will react on its SFA (sound, facial, action) expressions. Inherently, the robot is emotion-driven.

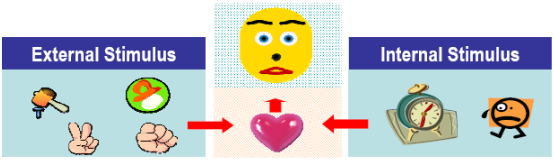


Fig. 1. The stimulus-response flow

When external/internal stimuli come in, they, at present, need to describe what they affect the emotion. A machine perception process, in turn, is divided into three phases: *alertness, identification* and *recognition (AIR)* will start. The signal of stimuli is transformed to the one of emotion. Six basic emotion states including anger, fear, happiness, sadness, surprise and disgust are used in our system and an emotion state transition formula is derived to handle the emotion change.

There are three different types of expressions including sound, facial, action (SFA) in the driving process. As their name, SoundGen driving process deals with the speech and a text-to-speech tool is used. According to the current emotion state, FacialGen generates the facial controlling signal to the actuators driving the movable mechanical parts of robot. ActionGen combines with FacialGen to move the head and eyes. After these x*Gen's* operation, a robot will drive smoothly.

2.2 Human-Computer Interface

The Human-Computer Interface is programmed with MS Visual Basic 6.0. A GUI (Graphic-User Interface) controlling panel is designed for monitoring and controlling the robot, as shown in Fig. 2, where a movable face expression, the status of emotion and the status of what kinds of received stimuli are given. The diverse forms can be designed to let the user manipulate easily. On the other screen, a real-time progressive scheduler is displayed. The events, either pre-programmed or on-line input, will be listed on the time line, as shown in right of Fig. 2. The scheduler determines what event to be first or late. If an input triggers a pre-programmed event, this event can be expanded, e.g. "say-hello" or "ask-name" events. We can use touch screen to control the functions. A selected iPhone is easily used to communicate to the PC screen to perform a remote control. This facilitates the teacher and learner's interaction by means of the affective robot.

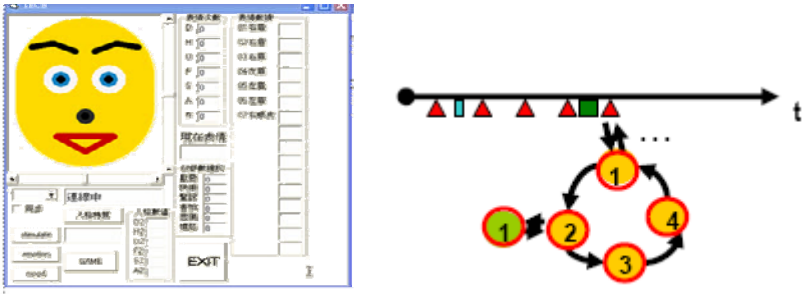


Fig. 2. Graphic-User Interface GUI controlling panel and the progressive scheduler

3 Development of Interactive Operation Modes

The industry robot is just a mechanic arm operating on the product lines. But what the role of robot can be. Besides, what the attributes for the kind of robot has. In general, the robot is designed for the specific purposes, and has many functions. For

Fig. 3. The children face to little-wood controlled by the teacher behind the background

the sake of safety, we know it is a security robot. For library or museum service, it is a navigation robot. Many researches[2] have shown that robots can elevate the learning interests on education. In 2008, Chen[3] have applied robots to second language learning at elementary school. Liu[4] proposed human-robot interaction research issues of educational robots. Here, we present what role and what kind of the function for the purpose, a robot is able to be a teaching assistant.

The developed interactive operation modes will be introduced in this section and some examples are presented for applying the emotional robot to act as the role of teaching assistant. Fig. 3 shows the children face to little-wood controlled by the teacher behind the background.

For the learning objectives, we have developed five interactive operation modes to facilitate the use of robot in teaching, and, in turn, to motivate children's interests in learning.

First, in $\mathbf{R_{CC}}$-Solo mode, the robot is controlled by the prescheduled program, as shown in left of Fig. 4. Teachers/parents can program the robot to tell a story or sing a song beforehand. Multiple segments of programs can be stored and are playing by using the progressive scheduler, e.g. press the icon on the screen or iPhone at the right time. (Remark: $\mathbf{R_{CC}}$ is the designation of a computer-controlled robot.)

Second, in $\mathbf{R_{CC}}$**<->**$\mathbf{R_{CC}}$-Robot Comic Show mode, robots talk to each other, as shown in right of Fig. 4. This mode is an extension of Solo mode if multiple robots are available. The progressive scheduler allows to monitoring multiple robots at the same time. It is depended on the performance of computer and the link between robots and computer. As the figure shown, Little-wood and Acrylic may make the ambiance more colorful.

Fig. 4. R_{CC}-Solo mode and R_{CC}<->R_{CC}-Robot Comic Show mode

Third, in **R_{CC}<->Human<->R_{CC}**-Interaction mode, robots and people interact together, as shown in left of Fig. 5. In this mode, the pre-scheduled robots may ask some questions and/or requirements to children and react to the following steps while children reply. It can be applied for playing a game or learning. One experience is given that robot hopes children to teach him 9-by-9 multiplying table.

Fourth, in **R_{CC}<->R_H**-Interaction mode, computer-controlled robots interact with human-controlled ones, as shown in right of Fig. 5. Teachers/parents fully control one of robots to interact with the others. This mode can be seen as the extension of Robot Comic Show mode. Since people deeply invest in the playing and fully controls one robot, whole scenario can be running smoothly. (Remark: **R_H** is the designation of a human-controlled robot.)

Fig. 5. R_{CC}<->Human<->R_{CC}-Interaction mode and R_{CC}<->R_H-Interaction mode

Last, in **Human<->R_H**-Interaction mode, people uses input device, e.g., a keyboard, a text editor, a touch panel, even a PC to interact with other people, as shown in Fig. 6. It is no different that two people talk to each other, except robot in the middle. In this mode, controller is normally hidden behind background. As in figure, teachers/parents can tell the story and talk to children. It is to notice that the situation in Fig. 6 is also by applying this mode.

Fig. 6. Human<->R_H-Interaction mode

4 Conclusion

Learning is an important process in one's lifetime. Especially in childhood, learning capability is flexible and like sponges. In popularity of robots, it plays the role "Teaching Assistant" will aid to children's learning.

In this paper, the affective robot as a teaching assistant we present here, will facilitates the instruction in classroom. And we have proposed these operation modes for the definitions of robot roles. Among these modes, an affective robot plays an active or inactive character to interact with people or each other. These modes will benefits children in learning on education.

References

1. Breazeal, C., Edsinger, A., Fitzpatrick, P., Scassellati, B.: Active Vision for Sociable Robots. IEEE Trans. on Man, Cybernetics and Systems (2000)
2. Chan, T.W.: Learning Companion System, Ph.D. Thesis, Department of Computer Science, University of Illinois at Urbana-Champaign (1989)
3. Chen, G.-D., Chang, C.-W.: Using humanoid robots as instructional media in elementary. In: Second IEEE Int'l Conf. on Digital Games and Intelligent Toys Based Education (2008)
4. Liu, T.-C., Chang, M.: Human-Robot Interaction Research Issues of Educational Robots. In: Second IEEE Int'l Conf. on Digital Games and Intelligent Toys Based Education (2008)

Empirical Research and Design of M-Learning System for College English

Wei Wang[1], Shaochun Zhong[1,2,3,4], Zhuo Zhang[1], Senlin Lv[5], and Lina Wang[1]

[1] Ideal Institute of Information and Technology in NENU, JiLin ChangChun, 130024
[2] Engineering & Research Center of E-learning, JiLin ChangChun, 130024
[3] E-learning laboratory of Jilin Province, JiLin ChangChun, 130024
[4] School of Software in NorthEast Normal University (NENU), JiLin ChangChun, 130024
[5] LearnEasy Soft Co.ltd, Suzhou China, 215028
wangw577@sina.com, sczhong@sina.com, zhangzhuo_ca@sina.com, greenforrest@163.com, wangln014@nenu.edu.cn.

Abstract. M-learning is an important research area in educational technology nowadays, but the design of m-learning system needs more empirical research in China. This study uses experience research, survey research and interview means to find out suitable m-learning models for Chinese college students. Based on the empirical research, this paper brings up an m-learning system model of colleague English, which can provide with personalized services and can integrate with e-learning seamlessly. This study will benefit those who would like to develop and design m-learning systems or materials.

Keywords: M-Learning; System Model; Curve of Ebbinghaus; Empirical Research; EFL.

1 Introduction

With the rapid growth of wireless and mobile technologies, m-learning has been gradually considered as an effective way to support learning, because it can make learning more flexible and portable where students can learn anytime and anywhere. Many papers report on the limitations of m-learning such as the small screen size of the devices, being liable to be distracted, limited processing power, battery life, memory capacity and interaction condition, which can never cover its characteristics of inheriting all the advantages of e-learning and breaking the limitations of learning in time and space. Many studies and projects on m-learning have great achievements all over the world, which can applied to different conditions varying from school to home, from workplace to museum, and from city to country. English learning is also taught by mobile devices. Chih-Ming Chen (2008) has proposed a personalized intelligent mobile learning system and validated that it can support effective English learning by experimental results. Yanjie Song and Robert Fox (2008) showed that students had made various uses of PDAs to improve their vocabulary in the curriculum of academic studies both in and after class. Thornton, P and Houser, C. (2008) rated the educational effectiveness of m-learning highly. [1][2][3]

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 524–535, 2009.

M-learning systems of different subjects may emphasize different functions, media, learning or practice methods, etc, and even for the same subject, system design may vary from application to application. It's important to acquire students' real attitudes and requirements for m-learning system in China where there is little empirical research yet.

2 Methodology and Process

2.1 Research Goal

First, this study intends to put forwards a suitable m-learning system of EFL for Chinese college students based on empirical research. Experience research, survey research and interview means are used to acquire the current situation of m-learning for EFL, students' need for m-learning, their preferred contents, media and duration of the micro-content, their attitudes towards design and implement method of m-learning system, and so on .The system design for college English then will be put forward and built on these momenta.

2.2 Software and Hardware

The study adopts the software called "Mobile Learning Center" developed by LearnEasy Soft Co.ltd, which is founded by the same person who is also the founder of the first professional website of m-learning in China, and its structure is shown in Fig.1. The curriculums for research are from parts of the lessons of "College English Intensive Reading (Third Edition, Book 2 and Book 4)" of Shanghai Foreign Language Education Press. The adopted mobile device is one PPC of Dopod CHT9000 which has a T-flash Card of 2G capacity.

2.3 Implementation Process

The empirical study carries out in Software College of Northeast Normal University. The participants are freshmen and sophomores whose specialties are software engineering, and they learn the same contents as the "Mobile Learning Center" has. By stratified sampling method, the sample adopted includes 20 freshmen and 20 sophomores with sex ratio for 1-1 respectively.

First of all, the aim of the study, basic information of m-learning and the main purpose of the software was briefly explained, and then participants were asked to use the hardware and software mentioned earlier to experience m-learning themselves, try every function of the system, and record the confusion and problems encountered. Experience time varies from person to person, but is 30-40 minutes on average; then, they fill out the questionnaire involving their attitudes towards m-learning and their evaluation and requirements for learning contents, system function, ways of learning, etc; Finally, a 40-60min face-to-face interview is taken, and it covers many aspects such as the evaluation on the functional modules, human-computer interaction, learning habit, so as to have a better understanding of participants' true attitudes towards m-learning.

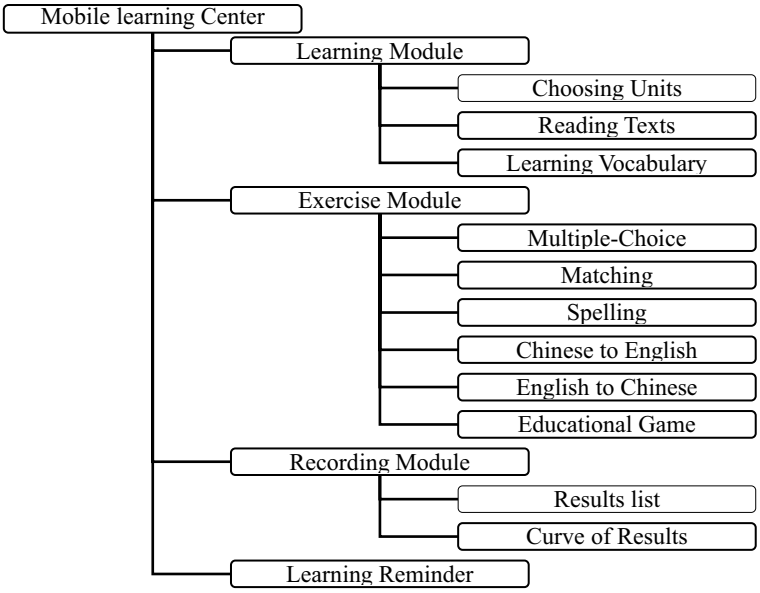


Fig. 1. The Structure of "Mobile Learning Center"

Later, main conclusions are drawn based on the empirical research conclusion, which contributes to the design of an English m-learning system for college students.

3 Empirical Research Analysis

3.1 Questionnaire Results and Analysis

English Learning Tools

The study shows that the most widely used English learning tool is laptop, desktop PC, electronic dictionary, learning machine, and MP3 / MP4, and nobody picks mobile phone as the most commonly used learning tool. But the result of the question "Have you used mobile phones for learning" shows that 70 percent of those surveyed have the experience of using mobile phones for learning, nearly half of the participants have download the learning text, mp3 or video to the mobile phone to learn, 10 percent of the participants have downloaded and run the mobile learning software, and a few participants uses SMS or WAP learning websites to learn. It indicate that although mobile learning is not the mainstream in college students' learning style at present, mobile device with advantages of lightweight, flexibility and mobility can attract the eyeballs of college students. As a consequence, when design the m-learning system, we should consider this novel learning style's impact on the commonly used learning tools. The learning effect may be better if we can combine m-learning with other learning styles, because it's not only convenient to choose proper learning style anytime, but also can combine learning activities under different scenarios effectively.

Curriculum Content

Resource construction of m-learning is one of the keys to carry out m-learning and to optimize its effect. [4]With the limitation of screen size, display format, memory capacity and data-processing capacity, m-learning curriculum has its own special requirements. The result of "which of the six English learning contents (vocabulary, listening, speaking, reading, grammar and writing) is the most important one for you to learn, or the one you find most wanted in m-learning?" shows that 67.5% of the participants select vocabulary, listening follows by 65% in the second, speaking, reading, grammar, occupy 32.5%, 20% and 15% respectively, and writing is only 5%. Further analysis shows that learners who choose vocabulary as a prime function of m-learning is 37.5%, listening as a secondary function of m-learning accounts for 35 %, while the proportion occupied by the other English learning contents (speaking, reading, grammar and writing) is comparatively less. From the analysis above, we can conclude that m-learning curriculum depends on the characteristics of m-learning, and not all the curriculum is suitable for mobile learning. According to the results of questionnaires and interviews, vocabulary, listening and speaking are of great needs in College English m-learning.

Media Types

By chi-square test, the difference in media forms of m-learning is not significant to participants (Table 1). It means that m-learning curriculum needs supports of various media resources, and every media form is in demand. Different media have their own advantages: audio and video's effects mainly embody in the sensory aspect; text is easy to access, with less space and shorter downloading time; the processing speed of picture and animation is faster than audio/video, and with rich vividness. In the development of mobile learning curriculum, we should consider the target learners, mobile terminals, communication technology and other relevant factors and select the appropriate media and development tools.

Table 1. Media Preferences

Text	Picture	Audio	Video	Animation	Edutainment	Others
52.5%	30%	67.5%	55%	30%	47.5%	0

Learning Fragment Duration

Our research shows that 72.5% of the participants choose to use m-learning in their fragmented time and they generally tend to spend less than two hours on m-learning every day. 20% of the participants tend to learn the content fragment in less than 5 minutes, the choice of 5-10 minutes reaches 42.5 %, 10-15 minutes is 32.5% and the choice of longer than 15 minutes is only 5%. The average duration of one learning fragment is between 5 and 10 minutes, but the specific duration depends on the content of the learning. For the constraints of small screen size and low-resolution, coupled with the fact that the application environment of m-learning is usually informal learning environment, so learner's attention is usually easy to be distracted.

M-learning curriculum which is suitable for informal learning and piecemeal learning is different from other types of curriculum. M-learning curriculum should be dapper, in order to meet the needs of learners in the mobile environment.

Function preferences

According to the research, inquiry, learning and exercise are the three main functions in m-learning system, of which inquiry is the most important (Table 2). The reason is that m-learning is mainly used in informal learning, so the inquiry module can help learners to link up the learning content each time, and it plays an important role in problem solving, knowledge sorting out and review particularly. In addition, m-learning can make full use of its hardware advantages – convenient operation anytime and anywhere. This study used four types of exercises: gap filling, multiple-choice, matching and educational game. These four types have been recognized by the respondents, but the participants figured that they need more types of exercises. Record tracking and performance evaluation are beneficial for students, but they usually ignore the factors. According to the results of this study, the interface design of record tracking function should be easy to understand, and it is best to point out learners' major deficiencies according to their learning portfolios, and make recommendations for improvement, so as to exert students' positive initiatives, for example a network ranking function can be designed among learners. It is believed personally that learning reminder function based on the Curve of Ebbinghaus is useful in students' good study habits development and memory effectiveness improvement; moreover, this feature is also an ascendant part of m-learning.

Table 2. Function Preferences

Learning	Exercise	Inquiry	Recording	Learning Reminder	Others
67.5%	62.5%	77.5%	5%	20%	0

Implement mode

For implement mode of mobile learning system, the participants selecting "WAP online learning" accounts for 23%; "mobile software mainly and WAP online necessary" accounts for 40 %, "Download learning resources to the local mobile phone" is 65%, and participants who select "learning by SMS" only cover 10%. By chi-square test, in the implementation mode of mobile learning options, there are notable differences. Choosing the learning mode, learners mainly consider terminal configuration performance, curriculum learning fluency, network and communications costs, the degree of resource-richness, and the level of learning initiative stimulation. From the above analysis, we can draw the conclusion that constrained by the current poor mobile learning device technology popularization, the learning mode of "online updating, off-line learning" becomes the most popular, with "download learning resources to the local mobile phone" and "mobile software online interactive learning " as representatives.

3.2 Interview Results and Analysis

During the interview, participants are asked about the evaluation of function modules, human-computer interface, and the preferences of learning habits and so on. Some of the conclusions are as follows:

Individual Requirements
When study with a mobile phone, participants show more personalized demand, for instance: in interface design, participants expected software can integrate the advantages of other handheld devices, such as IPOD interface design; in content display, they expected to set up according to their individual needs, for example, only the translation to the selected part of the texts can be seen, and the listening fragment can be intercepted; in earning reminder, they recognized the role of Curve of Ebbinghaus and wanted to experience it eagerly. But they wanted to control the administration purview by themselves. Also, they looked forward to setting up other learning content in accordance with their own memory curves which could remind them when to learn.

Updating Information timely
Mobile learning contents include formal courses, extra-curricular knowledge, real-time information and some other kind of services. But no matter what kind of learning content participants select, they indicated that it should provide timely information updating. They pointed out that professional curriculum should be sync with teaching information; vocabulary learning should be linked to current news; some participants even suggested the latest game information service. In addition, some participants regarded SMS as a useful approach.

Rich Referential Contents
Participants generally expressed the hope that the material relevant to learning content should be rich. In the process of vocabulary learning, it is better to add "synonym", "Antonyms" and other related entries. They also expected to use mobile phones to review knowledge-point of some difficult subjects, so the curriculum content should add analysis column to important and difficult points.

3.3 Enlightenment to System Design

Based on the conclusions of empirical research combined with related literature review, we believe that attention should be paid to the following points in the system design:

- Make full use of the advantages of m-learning, and integrate learning styles provided by others tools;
- Present curriculum and resource which is suitable for mobile devices in the form of various media types;
- The systematic function should be simple and practical, and the system should strengthen the function of inquiry on the basis of meeting learning and exercise requirements;
- Allow users to have more rights on interactive control and interface presentation;

- Update learning content in time and provide relevant advice;
- Learning content should be authoritative, effective, refining and condensed. Moreover, reference related to curriculum must be rich and orderly;
- Whether formal or informal learning, m-learning activities would mostly be outside the classroom.

4 System Design of College English M-Learning System

4.1 System Overview

In order to achieve good performance, the selected terminal of this m-learning system is the combination of phones (PDAs) and personal computers. At the same time, we will maintain the advantages of other terminals, such as English learning machine, in the design of m-learning system; thus, users can adapt to this learning approach in the shortest time. Based on literature review and empirical results of the study, m-learning system of college English is better to provide variety of learning contents and to give the initiative of “what to learn and how to learn” to the learners. It should meet learners’ needs of learning content and styles subscribing first. Handheld mobile terminals can access the learning content through the mobile communication protocols. At present, there are two forms of mobile communication protocols: one is based on the SMS, and the other is based on the connection-browsing. The two forms of mobile communication protocols are not compatible [5].There are four types of access in the system: mobile software, SMS, website based on WAP, and website based on WWW.

- Mobile software: learners can set up and run the software that is suitable to their mobile phones, and it must be online only when updating.
- SMS: deliver learning resources and information in the form of SMS provided by mobile phones;
- Website based on WAP: access internet via mobile phones;
- Website based on WWW: access internet via personal computers. On the one hand, it will serve as an effective complement to mobile learning, and it can be a seamless platform integrating various functions and services of mobile phones; on the other hand it can be regarded as "stations" to provide more complete services.

4.2 System Design

Structure Model

Currently, there is much theory and practice research on m-earning system. Literature 6 divides the function of mobile learning system into four major parts as teaching support, interactive exchanging, educational administration and management of the system, which can meet the demand of teachers, students, and administrators, and it analyzes and expounds the functions of each part in detail [8]. Based on that, we sample the modules used by learners to form another system (Fig.2), and it should be constructed and integrated with SOA. Thus, learners can make choice of the services according to their mobile devices situations and requirements.

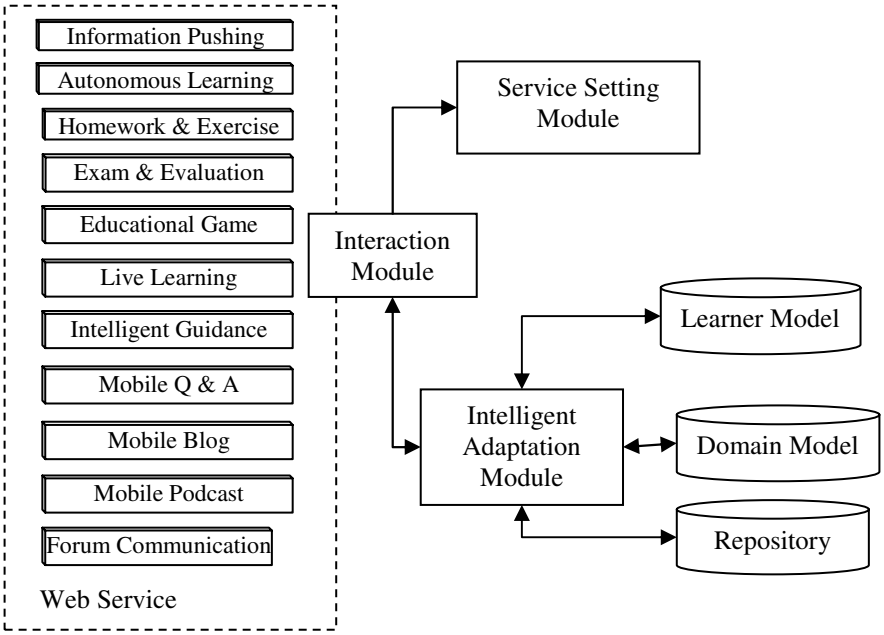


Fig. 2. Structure Model of M-learning System

Interactive Modules: the general term for the entire human-computer interaction interfaces related to learning activities. It mainly includes the modules such as service subscription, information push, autonomous learning, homework & exercise, examination & evaluation, educational game, live learning, intelligent guidance, mobile Q & A, mobile blog, mobile podcast and forums communication. According to the empirical results, each module should be integrated application of various media to meet the needs of different learners.

- Information Push module primarily pushes related information directly or indirectly on the basis of learner's motivation and concern;
- Autonomous learning module includes real-time content such as daily song / sentence, also includes outline or detailed description of the classroom content and extra-curricular learning content, etc.; in addition, it is available for learners set whether use Ebbinghaus Forgetting Curve and the corresponding learning content;
- Homework & exercise module provides single-choice, multiple-choice, matching, educational games, etc, but efficiency and convenience should be taken into account in designing;
- Examination & evaluation module, in accordance with the Item Response Theory, can provide corresponding tests, and is normally considered as the boundary of old and new learning content;
- In the educational game module, learning is provided in the form of entertainment, moreover, games should be informative than entertaining according to the empirical study;

- Live learning module can play live remote teaching process, therefore, it will bring convenience to remote students, but the actual implementation requirement is quite high;
- Intelligent Guidance module can give recommendations according to the students' learning;
- Mobile Q & A module is generally favored by the learner, where problem-based learning can be conducted. In addition, it is an important source of learner's characteristics model values;
- Blog, podcasts and forums are important ways for collaborative learning, and also make full use of the advantages of m-learning.

Through the series of interaction modules, learners can make choice of suitable services, and carry out various learning activities. At the same time, the interaction process and its results would be tracked by the Intelligent Adaptation Module to update the value of the learner model, domain model and repository.

Service Setting Module: On the one hand, specific format SMS, websites base on WAP, websites based on WWW, as well as the mobile phone software interface are available for the selection of suitable access, services and function, such as SMS and mobile Q&A. The choices of services will be expounded in "access analysis" section below. On the other hand, its function is also reflected in the aspects that learners can flexibly set up the presentation, color, layout and other details of each functional module, so as to better meet the needs of those who have adapted other learning devices for a long time.

Learner Model: Learner model contains the cognitive status of learners, which reflects the learners' learning schedule, knowledge proficiency, misconceptions and the disparity to expectations. At present, learner model for m-learning at home and abroad has not been formed yet, but the existing learner models will be of some reference, such as CAL Model of Cross, characteristic dimensions of distant learners put forward by Kaye and Rumble, and the "theoretical analysis system for distance learner" established by Ding Xingfu, etc.

Domain Model: Domain model is the teaching structure of the domain knowledge, and defining a domain means to determine its entities and the relationship among entities. In teaching, the domain knowledge is the knowledge for student to learn, including concepts, theories, examples, exercises and other knowledge. Establishing a domain model includes the knowledge point library establishment, example library establishment, item bank establishment, media library establishment, etc. [9] Domain model should be established according to authority, and break down into micro-elements in order to facilitate the application of m-learning.

Repository: Different from the domain model that stores knowledge in the perspective of teaching, repository contains the knowledge of facts, viable operations and rules in the perspective of system operation, for example, the knowledge to diagnose students, to make learning program and to update the value of Ebbinghaus Curve.

Intelligent Adaptation Module: it is the engine of the whole system. On the one hand, it can analyze and excavate characteristics of learners and provide personalized learning process automatically. Specifically, it can choose, assemble and self-adapt to the display interface according to the learner model and the terminal interface, do

learning diagnosis based on the interaction and evaluation results recording, as well as provide with the most appropriate learning content self-organization, learning strategies self-adjusting, navigation type self-update, etc. On the other hand, this module can analyze and excavate the effective factors that can improve learners' outcomes and find out the knowledge that can improve the availability of the system, so as to achieve self-adaptation, such as updating the learning model threshold and the diagnostic knowledge.

Access Analysis

According to literature review and empirical results, the appropriate access of each module is summarized as follows (Table 3):

Table 3. Appropriate Access of Each Module

Module Name	SMS	WAP	Software	WWW
Service Subscription	2	3	3	3
Autonomous Learning	2	3	3	3
Homework & Exercises	2	3	3	3
Exam & Evaluation	1	2	3	3
Educational Game	1	1	2	3
Live Learning	1	2	2	3
Intelligent Guidance	1	3	3	3
Mobile Q&A	3	3	3	3
Mobile Blog	2	2	2	3
Mobile Podcast	1	3	2	3
Forum Communication	1	3	2	3

(Note: Number stands for the suitability: 3- high; 2 – normal; 1 - low).

In conclusion, although website based on WWW is appropriate access to all service, it makes learners greatly restricted by time and place. In the College English m-learning system, mobile phones have three roles. First, it is a way of learning style – it facilitates the realization of learning anytime, anywhere, and with any content. It can not only be used as an effective complement for formal learning, but also as a more convenient way to obtain practical learning, so as to achieve the purpose of lifelong learning. Second, it can access to critical information at any time, anywhere, or ensure the consistence of crucial data. The last but not the least, the use of m-learning can effectively integrate and unify the learnt knowledge at different times, different places or different circumstances.

5 Key Technology

In order to establish an m-learning system which can truly understand learners and provide effective services, there are a few key technologies.

5.1 Learner Model

Learner model is the base of the realization of intelligent adaptation, because perfect learner model enables m-learning system to understand the situation of each learner, then provide with personalized guidance. SMS, websites based on WAP, mobile phone software with the narrow-band business and websites based on WWW are available to access the system. Characteristics of learners vary from person to person, because of their different choices of terminals, access ways or services. Learner model should be divided into domain model and non-domain model, and will be applied in knowledge development, learning diagnosis, the presentation of learning content and control of exploring learning space. In addition, it is necessary to increase information of the learner model on mobile terminals, network performance, location and learning time. In this way, the learning content, which is suitable for different terminals, can transmit adaptively, and learning process based on contexts can be controlled and managed. [10]

5.2 Intelligent Adaptation

Intelligent adaptation technologies of m-learning system include adaptation to learners, content learning, learning context and mobile devices. The technologies are based on the construction and updating of learner model, domain model and knowledge in the repository, and the algorithm to intelligent adaptation is the key point. This system model can be applied to different mobile terminals, and the system should returned corresponding interface in different equipment; message can pass through the conversion mechanism among different mobile terminals; released curriculum resources can be suitable for different mobile terminals. In the design of the system, the teaching platform should be divided into related and unrelated parts to the mobile terminals, and the business processes may compose of the Web Services, so it only needs to assemble the corresponding Web services when develop the application system to fit for different terminals; M-learning system provides an end-to-end unified message communication mechanism for different devices and each device has its unique identifier; The number of learning objects on one page depends on specific mobile terminals, and the learning object media types and the solution to the issue of network bandwidth, and also depends on the hardware and software conditions of the mobile terminals [11]. Of course, pattern recognition technique must be employed for learner diagnosis and intelligent guide. In addition, the system should have the function of machine learning, by tracking, analyzing and excavating a large number of learning examples to do self-modification of the repository.

5.3 Integration with Curve of Ebbinghaus

German well-known psychologist Ebbinghaus in 1885 discovered that the memory of forgotten, physiological characteristics, life experiences, learning contents and other factors lead to different memory habits, memory mode and characteristics. Thus, Curve of Ebbinghaus should be personalized. M-learning will greatly increase the possibility and convenience of Ebbinghaus curve application. Basing on the theory of memory nuclear system of Long draw in (U.S.) Technology Development Co., Ltd, memory forgotten dot can be found by tracking human-computer interaction and

learning process combining gold sequence mode. Then adjust the memory forgotten dots to form personalized curve of Ebbinghaus, which can be used to make decision on the frequency of learning contents. In this way, in nearly forgotten memory point, students can repeat contents to form a long-term memory.

6 Conclusion

Based on the empirical research results, this paper gets a series of important information covering English learning tools, content of m-learning, medium, duration of the micro-content, system function ,access method, etc. Under the inspiration, it brings up an m-learning system model of colleague English, which can provide learners with choices of access methods and services, and it can integrate with e-learning seamlessly. The system combines with artificial intelligence, data mining, Curve of Ebbinghaus, which can improve the efficiency of learning effectively. However, the system effect depends on the learner model, domain model, repository and reasoning, which requires a large amount of samples to be gradually perfect.

References

1. Chen, C.-M., Hsu, S.-H.: Personalized Intelligent Mobile Learning System for Supporting Effective English Learning. J. Educational Technology & Society 11, 153–180 (2008)
2. Song, Y., Fox, R.: Integrating incidental vocabulary learning using PDAs into academic studies: Undergraduate student experiences. In: Fong, J., Kwan, R., Wang, F.L. (eds.) ICHL 2008. LNCS, vol. 5169, pp. 238–249. Springer, Heidelberg (2008)
3. Thornton, p., Houser, C.: Using mobile phones in education. In: 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education 2004, pp. 3–10. IEEE Press, New York (2004)
4. Lu, P.: Research on the Construction of M-learning and the Resources. J. Primary and Middle School Educational Technology 10, 13–15 (2006)
5. Li, Y.-b., Liu, J.-x.: A Novel Learning Method–M-learning. J. Modern Distance Education Research 1, 30–33 (2005)
6. KISS Principle, `http://en.wikipedia.org/wiki/KISS_principle`
7. Hug, I.: MicroLearning and Narration. In: Proc. of the fourth Media in Transition conf. (2005)
8. Wang, W., Zhong, S.-c.: Research on Support System for M-Learning Using Kinds of Terminals. J. China Educational Technology 7, 108–112 (2008)
9. Liu, F.-j.: Research of Domain Model in Adaptive Learning System Based on the Semantic Web. D. Northeast Normal University, Jilin (2007)
10. Ye, C.-l.: Research on Modeling and Design of Mobile Learning System Based on Grid. D. South China Normal University, Guangzhou (2006)
11. Cui, G.-z., Chen, F., Chen, H., Guo, J.-l.: Concept of Mobile Education and Research of Critical Technology. J. China Distance Education 9, 42–45 (2005)

Designing an e-Learning Reactivate Promotion for Unpopular Collections in Academic Library

Bo-Yen Wang, Yuan-Hsun Liao, Chia-Ming Liu,
Ming-Hsiang Su, and Pao-Ta Yu

Department of CS&IE, National Chung Cheng University, Taiwan
jackie2014@gmail.com, {lyh96p,smh,Ljm,csipty}@cs.ccu.edu.tw

Abstract. In this paper, a promotion design to improve lending rate of collections in library has been developed. This main ideal of this design is focused on unpopular collections in library with theoretical basis on Long Tail theory proposed by Christ Anderson. According to Long Tail Theory, the unpopular merchandise could be promoted by several strategies such as developing multiple distribution channels for the products, letting the user as a participant in the process of marketing, and customizing the product involved with customer demand. The situation of unpopular collections in library was similar to the merchandise in the tail part of popularity distribution; it could be promoted through reactivate process. This research had analyzed the transaction of the reader lending records to find out the popular books and the unpopular books as the primary step in designing reactive promotion, therefore the process of library data mining could reflect the reader behavior in lending collection of library. Specific readers who had lent the unpopular reading may contribute the improvement in that lending frequency. This research had designed a reactivate promotion to recommend unpopular collections in library by broadcasting readers' interview. The advertisement job is accomplished by Near-Real system which was an e-Learning tool to perform readers' interview around the corners of library.

Keywords: multimedia learning, academic library, long tail.

1 Introduction

The implementation of library services has been inspired by five laws of library science which proposed by Ranganathan in early 30's [8]. These five laws had drawn a skeleton for the libraries to provide adequate service to patrons. Library science researchers argued the services provided by libraries should consider (a) readers may borrow books out of the library, (b) readers might read journals and books in the library, and (c) reader might recommend new reading for library to purchase [5]. Lending service was an important service in library services and lending frequency of collections was also a measure of library performance on providing resource for teaching and learning [3]. Since libraries have to provide lending service of collections, the behavior of patrons could be observed by the lending frequency of

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 536–543, 2009.

collections. How to promote the lending frequency has become an important issue in contemporary library researches.

The popularity of collections in library was determined by readers' lending frequency. Popular books could stay on the hot list every month in library; on the contrary, unpopular books rare items in the records of lending transactions. This phenomenon had been fitted with the long tail theory proposed by Christ Anderson [4]. The relation between library and readers could be considered as the similar relation between producer and consumer in the real business market. How to reactivate the niche item? Find out explicit factors and implicit factors which may vitalize the tail item. The most obvious explicit factor would be the readers' lending frequency. Data mining technology could be used in analyzing the readers' behavior through the library transaction log. In this paper, clustering technology is used in classifying the popular items and unpopular items. Since the data items in long tail model have the characteristic of similarity, cluster technology can be applied to group data with the pattern of popularity so that data items could be divided into popular items and unpopular items [1].

Whenever the explicit factors were addressed, unpopular items were promoted by using e-Learning tools as an alternative approach which was based on the long tail theory. According to long tail theory, multiple distribution channels would make niche items had higher possibility to expose before customers [4]. The Near-Real system was an e-Learning system that could transmit multimedia message to potential readers. This system could be thought as an extra channel in advertising unpopular books to the reader other than internet web sites.

Customers' participation would be another rule for successful long tail [4]. This research applies the long tail rule in view of readers' participation in designing the reactivate promotion of the unpopular books, the readers who had strong interest on the unpopular books will be invited to give their comments while this interview is tapped as book review with promotion content. This multimedia content could be broadcasted through Near-Real system. The readers' experiences could be shared through these promotions; the lending frequency might be increased when potential readers had noticed by these multimedia books reviews. Consequently, the object of long tail could be accomplished by this way of recommendation.

The following sections will introduce the detail works of promotion design. Section two describes the background of related theories. Section three states the methodology of promotion design and the experiment steps. Section four expresses the result. The final section would be some conclusion and future works.

2 Background

2.1 The Primary of Long Tail Theory

The primary ideal of Long Tail Theory was focused on the marketing strategy of internet [4]. On-line bookstore has made a great success in internet market by the strategies such as virtual store in order to cut down the stock cost and web recommendation system to promote unpopular items [6]. According to "80/20 Rule", approximate twenty percent of hot products would produce approximate eight percent of

profits in the market [9]. Long tail theory is the aggregator to collect the rest of eight percent of products with their values so that more profits were made from these "niche" items. Internet is the power to carry out the long tail theory, for example, online stores make use of the internet technology with the zero cost of shelf and the powerful media transparency had become the impact of physical stores.

2.2 The Long Tail and Library

Aggregation of supply and demand depicts the library service with long tail consideration [7]. The library collections would be aggregated through extra- and inter-library loaning process which may produce transaction cost. Traditional library has originally higher transaction cost than the library with networked interchange loaning system. Using the convenient of internet, the library may collect the patrons' preservation of the books or make recommendation with the presence of related web pages. It constructs the aggregation of demand under the networked environment. Library services may fit with long tail theory when aggregation issue on supply and demand was applied in network technology.

2.3 Near-Real System

Live/on-demand Internet broadcasting of lectures in work-place, conferences and educational settings has attracted more and more research interest due to the improvements in broadband network bandwidth, compression techniques, and new distribution architectures [2]. The Near-Real system integrates various video streams sources and audio source to display the combination of these sources as stream media format. Besides, this system also has scrolling text marquee to perform advertising effect. In e-Learning application, this system combines the technique of Windows Media Services and learning content management system (LCMS) to provide distance learning activity. This e-Learning activity could be synchronous or asynchronous. Near-Real system demonstrates more flexibility as a tool in e-Learning or conferences environment. The following screen captures show some Near-Real system demonstration (Figure 1).

Fig. 1. Interaction mode and presentation mode of near-real system

3 Methodology of Promotion Design

The main object of this research is to design a promotion for unpopular collection. Finding out these unpopular items can be determined by the lending frequency from the transaction analysis. Whenever the distribution of lending frequency was built, there is no explicit basis in labeling the popular items and unpopular items. The research for determining the cut point on long tail distribution had been proposed recently [10]. But the research cannot efficiently divide these items into unpopular ones and popular ones. In thinking of the characteristic of long tail distributed items, the items in tail group could be sparser than the items in head groups. The reason for this phenomenon is the items from head groups which contribute higher frequency than tail items, but the total number of head items is less than the total number of tail items. The significant difference between tail items and head items can be recognized through cluster analysis. When the clustering technology is applied in the research, the frequency of a book and the total of readers to lend a book would be two major dimensions in clustering analysis.

After the popular items and unpopular groups had been divided, unpopular items had to be filtered from worth factor. The theoretical reason of filtering process is based on the microstructure of long tail. The microstructure could be defined as the head item groups and tail item groups, the filter process will be more effective only on tail item groups than the whole items in the market [4]. In this research, the design of filtering process would be based on finding the significant reader in each unpopular collection. As the long tail theory had mentioned, each tail item had its own scenario. Finding out the characteristic of tail items could be helped in recommending unpopular items. The unpopular collections to be promoted were filtered by the process using kurtosis checking. The process of kurtosis checking was performed the formula on each item in tail groups. The kurtosis formula is defined as follow:

$$Kurtosis = \frac{\sum_{i=1}^{N}(Y_i - \overline{Y})^4}{(N-1)S^4} - 3 \tag{1}$$

$$\mathrm{S}: \text{Standard Deviation}$$

$$\overline{Y}: \text{Mean of the distribution}$$

S in this formula means standard deviation of whole distribution $\overline{Y}$ means average of the distribution, Y_i describes each item in the distribution and N indicates the number of the items in distribution.

The result after calculating from kurtosis formula may express the possibility of the distribution with peak value. When checking the collections with peak value, the reader who had the most lending frequency in this collection would be chosen as the significant reader. Then, the reader will be invited to record promotion content.

Since the significant reader from tail items group may be thought as an explicit factor in reactivate the tail items. There will be another factor that could also reactivate the tail items. The relations between head items and tail items could be explored

through query process of the lending transactions. If a reader had lending books which was consists of head items and tail items. The reader may have some idea in interesting the tail items. The process will be performed in finding out these readers and inviting them to record promotion contents.

4 Result of Research

In this research, the transaction of lending records was obtained from the library of National Chung Cheng University. The records interval was between January 2008 and December 2008. The transaction data was imported into Microsoft SQL Server and the data mining tool from Microsoft was applied. The lending frequency of library collections with long tailed distribution has been showing in Figure 2. The result of clustering process was produced by Microsoft SQL analysis services and 10 Groups of clusters was generated. The relation diagram of clusters (Figure 3) expresses significant difference between cluster group one (cluster 8 through 10) and group two (cluster 1 through 7).

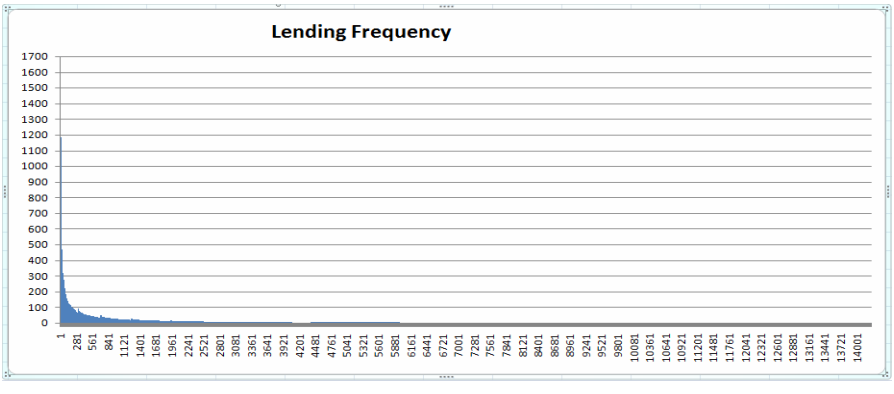


Fig. 2. Lending Frequency of library collections

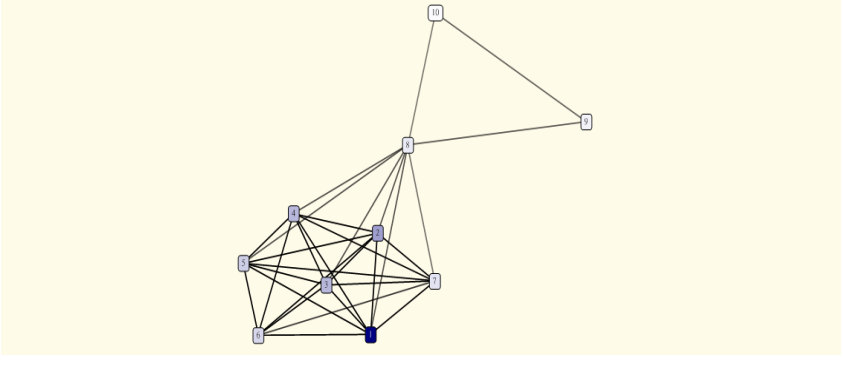


Fig. 3. Cluster relation diagram

The items in group one (cluster 8 though 10) could be labeled as head items and the items in group two (cluster 1 through 7) could be labeled as tail items. The following steps were to generating the significant reader list through Kurtosis checking process. Figure 4 shows some statistic results for the significant readers in cluster 7, 6, 5, and 4. For example: Reader No:493330056 was the significant reader for 10 collections in library. 4 of 10 collections belong to cluster 7, 3 of 10 collections belong to Cluster 6, 1 of 10 collections belongs to Cluster 5 and 2 of 10 collections belong to Cluster 4. While the items in cluster 1, 2 and 3 have few lending frequencies in performing meaningful Kurtosis checking, they were eliminated from calculating process.

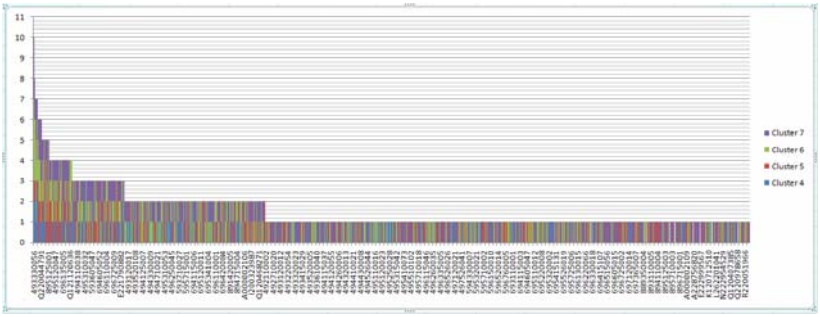


Fig. 4. Significant readers in clusters items 4 through 7

The other query process to find out readers who can participate in promotion process would be generated from the data set of lending transactions. The lending records of readers were analyzed by the readers who had both lent collections belong to head group and collections in the tail groups which had only been lent once. The result was showed in Figure 5.

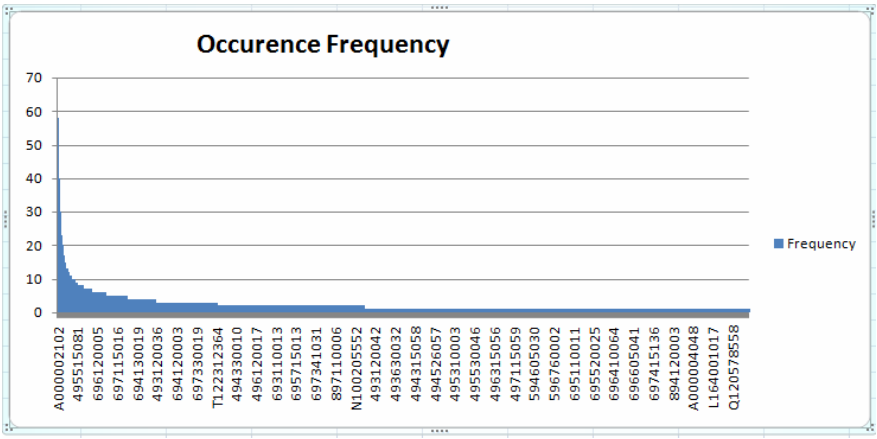


Fig. 5. Occurrence Frequency for readers

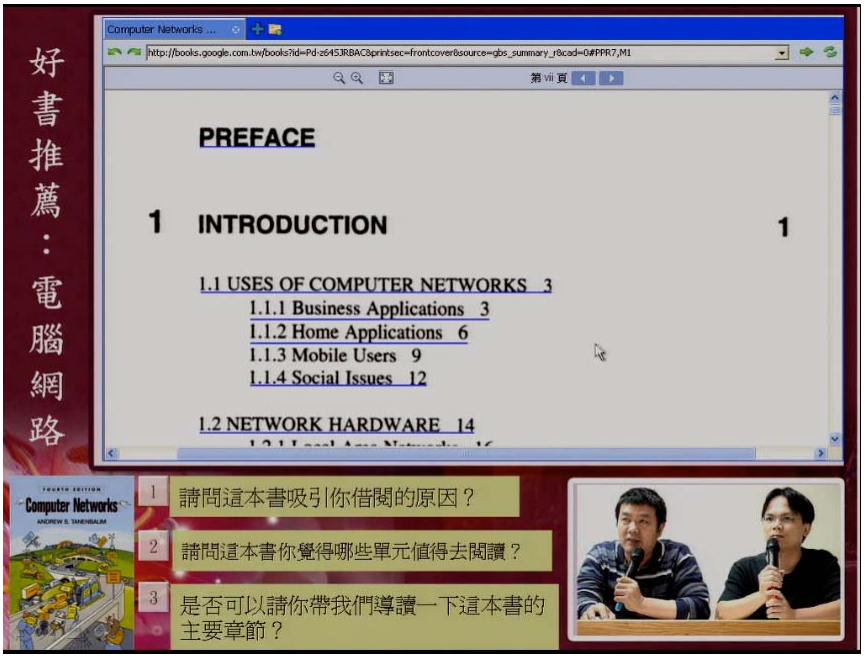


Fig. 6. An example for promotion content

Once the suggestion of participant readers was generated, they will be invited to the studio for promotion content recording. The promotion content was recorded by Near-Real system in 5-7 minutes. These multimedia contents will be broadcasted to the screens around library corners via Near-real system. Figure 6 shows an example of promotion content.

5 Conclusion and Future Works

When Long tail model leads out a new concept in business marketing, the same application could be carried out in library and information science. Readers' participation is an important indicator that "Library 2.0" cares about. Using e-Learning tools to design reactivate promotion is another approach to achieve long tail rule except web page technology. The diversity of library advertising strategies could be explained in this research.

The explicit factor of reactivate promotion only focuses on data similarity in this research. The detail discussion on knowledge representation has not developed yet. The future work of library long tail research will be continue on the influence of collections categories and the identity of readers. The implicit factors may be found in the further research.

References

1. Jain, A.K., Murty, M.N., Flynn, P.J.: Data Clustering: A Review. ACM Computing Surveys 31(3), 264–323 (1999)
2. Zhang, C., Rui, Y., Crawford, J., Li-Wei, H.: An Automated End-to-End Lecture Capture and Broadcasting System. ACM Transactions on Multimedia Computing, Communication and Applications 4(1), 1–23, Article 6 (2008)
3. Kao, C., His-Tai, H.: Ranking University Libraries with a Posteriori Weights. International Journal of Libraries and Information Services 53, 282–289 (2003)
4. Christ, A.: The Long Tail. Hyperion Press, New York (2006)
5. Gelman, E., Sichel, H.S.: Library Book Circulation and the Beta-Binomial Distribution. Journal of the American Society For Information Science 38(1), 4–12 (1987)
6. Brynjolfsson, E., Hu, Y., Smith, M.D.: From Niches to Riches:The Anatomy of the Long Tail. Sloan Management Review 47(4), 67–71 (2006)
7. Lorcan, D.: Libraries and the Long Tail. D-Lib Magazine, April 1-9 (2006)
8. Ranganathan, S.R.: The Five Laws of Library Science. Goldston, London (1931)
9. Richard, K.: The 80/20 Principle: The Secret to Success by Achieving More with Less. Nichokasbrealey Publishing, London (1998)
10. Park, Y.-J., Alexander, T.: The Long Tail of Recommender Systems and How to Leverage It. In: RecSys 2008, October 2008, pp. 23–25 (2008)

Multi-media e-Learning Platform Using Green Design with Near-Real Approach

Yuan-Hsun Liao[1], Chia-Ming Liu[1], Bo-Yen Wang[1], Ming-Hsiang Su[1], Xiaso-Hui Lee[2] , and Pao-Ta Yu[1]

[1] Department of CS&IE, National Chung Cheng University, Taiwan
{Lyh96p,Ljm,wby,smh,csipty}@cs.ccu.edu.tw
[2] Department of IM&GIHIM, National Chung Cheng University, Taiwan
xiaso_hui@ms55.url.com.tw

Abstract. The most of e-Learning and video conference platform receives the limitation of population and the file format, the inconvenience to the users, and requirement of specific software. This paper proposes an effective method and the solution for this problem. The solution uses well-known multimedia stream format and uses green design concept with near real approach. The limitation of extra software installations, the limitation of user licensees and the limitation of location will be solved with this design.

Keywords: multimedia learning, green design, near real approach.

1 Introduction

e-Learning and video conference technology has been promoting by the progress of network technology, therefore many application platform production has been implemented under this circumstance.

In the recent years, many studies propose many research results and the application system of e-Learning [1-5].In [1] Hernandez et al. shows that a enhanced pedagogical model for effectively providing courses to a large number of students and producing media-rich content which is suitable to be managed by the open-source e-learning platform .LRN. This open-source platform successfully exploits students' learning experiences in engineering education. In [3] Ganchev et al. implements a creation and utilization of user profiles and user service profiles within an InfoStation-based mobile eLearning (mLearning) environment. In [4] Stoyanov et al. shows that a system development environment for creating the Sharable Content Object Reference Model (SCORM) compatible electronic content.

Additionally, information system design starts to consider green design concept seriously, therefore computer resources and network resources should not waste. The present studies on this domain [6-7] had been developed. This paper applies green design concept with near real approach to carry out e-learning and video conference objects.

This paper presents the current results of Near-Real system in application on learning and video conferencing. The structure of this paper is as following: session two

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 544–550, 2009.

introduces the related work. Session tree describes the system architecture. The implementation and application scenario of system are described in session four. Session five makes a brief conclusion and gives on some future work.

2 Related Work

2.1 Green Design

The green design (also called "the ecology design") is the process of design that gives the environment resources as the core concept [7]. The green design system guaranteed that the development of system research and the consideration of design to avoid using the harmful concept. The main ideal of green design system would be focused on the usability of system with recycling concept.

The green design concept should be included during system design stage. Burall [10] argues that the designer should follow the green technology and protect idea investment in design standard and criteria. It may guarantee the designer in designing the product to meet the environmental protection condition. The reuse of computer resources is also a consideration by resource recovery measurement in order to achieve the environmental protection and the requirement of green design.

2.2 Streaming Media System Technology

To support the streaming paradigm, servers and the network must guarantee the continuous display of the SM object without disruptions (i.e. hiccups) [8]. Figure 1 depicts the architecture of streaming media system.

While display station requests to display a SM object which is stored at streaming media server, the data blocks are retrieved from the server to the client for display through network. At this moment, the data blocks are processed as soon as they are received by the client without waiting for download process. Moreover, these blocks are not written back to the storage at the client side and it does not reduce the copyright violations.

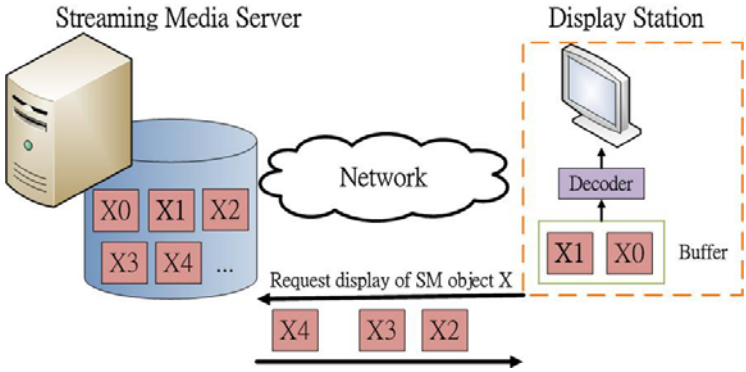


Fig. 1. The architecture of Streaming Media System

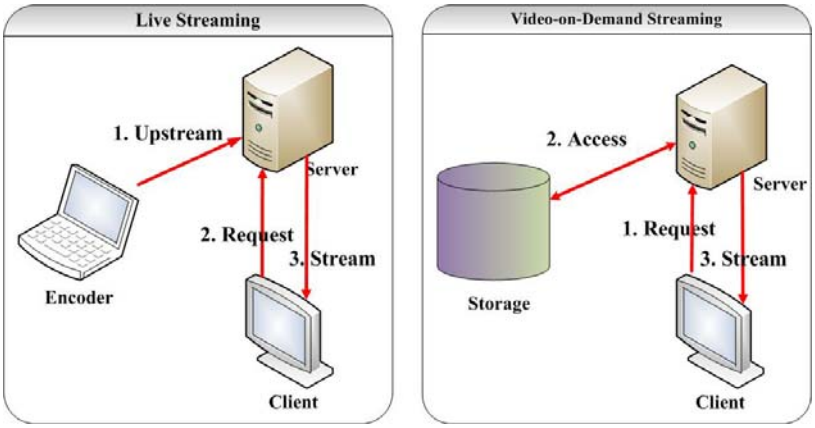


Fig. 2. The Live and Video-on-Demand Streaming

The content of streaming media is divided into two types, live and on-demand. Figure 2 describes the live and on-demand streaming.

Live Streaming
In the type of live streaming, server does not store any file. Streaming is generated by and encoder and the encoder to send the signal which belongs to audio or video the server in real time. When the server receives the signal from an encoder, it forwards the signal to client after client's requesting.

Video-on-Demand Streaming (VoD)
The term Video-on-Demand is widely used for a system that allows one to watch a certain video content at any point in time via communication systems such as cable TV, satellite or the Internet [9]. Furthermore, the user can control the streaming, like jumping to any position and operating similar to those offered by a VCR. The user can operate functions such as fast-forward, fast rewind or pause.

3 Architecture

The multi-media e-Learning platform can be divided into two modes that physical-link mode and network-link mode. There are two modules in the physical-link mode that e-Broadcasting module and live module. The e-Broadcasting module is used to mix audio and video devices and to integrate these signals to one signal. The live module is used at a live show that people need not participate in this locality personally and need not surf the internet. There are four modules in the network-link, Encoder module, Broadcast module, LMS module and Presentation module. Encoder module is used when we deliver the integrated signal through Internet and restore it to a WMV file. Broadcast module. The major purpose of LMS module is to manage users who browse the live show webpage. Presentation module provides users some information about the live show through the Presentation server.

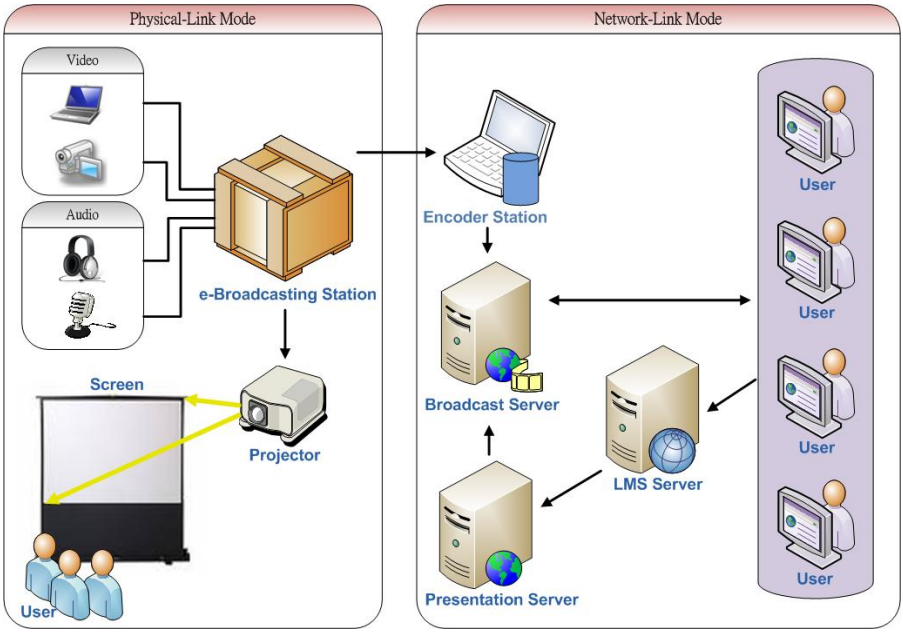


Fig. 3. System Architecture Diagram

We construct the diagram to simply describe the system from user's view as illustrated in Figure 3.

Because there are both users in two modes physical-link mode and network-link mode, we divide system into two modes to illustrate from user's view.

Physical-link mode

The main purpose of physical-link mode is that users can watch the projection screen outside the meeting-place to see the live show in the chamber. The signal of the projector comes from e-Broadcasting station. Briefly speaking e-Broadcasting is an integrated device. It combines the signals of video and audio devices, like DV, VGA input, microphone, etc. We can make those sentences that the text makes up into scrolling text marquees. Finally, all signals are integrated into a signal to pass to a projector or Encoder server.

Network-link mode

The main purpose of network-link mode is that users can stay at home or all parts of the world watch live via the network without at the scene in person. This can apply to the distant learning and meeting. Users get on internet and login LMS websites. LMS server stores a lot of information about courses. Users must link presentation server through LMS server, besides utilizing LMS server to get course information.

We design six parts for multi-media e-learning platform. There are Live Station, e-Broadcasting Station, Encoder Station, Broadcast Server, Presentation Server and LMS server. Figure 4 illustrated six parts of the system.

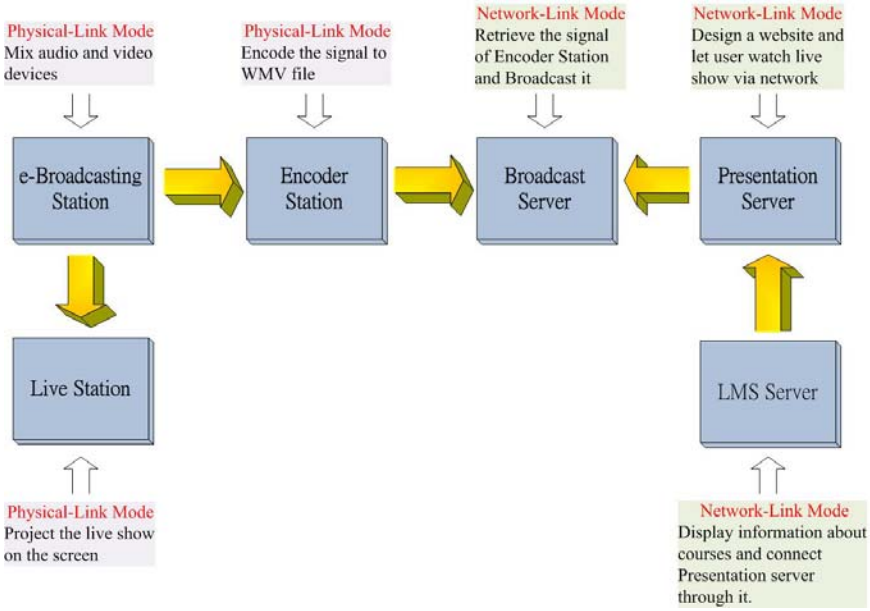


Fig. 4. Six parts of the System

4 Implementation

The demonstrations of multi-media e-learning platform are actually in figure 5 and figure 6. There were the four people joined on the conference while many people watch on-line program in this platform.

Fig. 5. Implement of multi-media platform

Fig. 6. Implement of multi-media platform

In this design joinNet[11] meeting pattern were joined and provides near real scenario with this platform to as many as possible users.

We believe that this architecture of platform can provide convenient services and save the computer resources.

5 Conclusions

The development of multi-media e-learning platform uses green design with near real approach which has some advantages.

- User unlimited
- Software unlimited
- Location unlimited
- Not waste of Resource
- Near real environment

The platform allows the remote viewers to watch conferences both in live mode and on-demand mode. If viewers cannot participate in lectures, they will watch this content though worldwide internet or long-distance live station. Moreover, when viewers want to review any lecture in any time, they can use the function of video-on-demand which is in the multi-media e-learning platform. Future works of multi-media e-learning platform will involve network transaction technology (p2sp) and synchronous issues.

References

1. Hernandez, R., Pardo, A., Carlos Delgado, K.: Creating and Deploying Effective eLearning Experiences Using. LRN. IEEE Transactions on Education 50(4), 345–351 (2007)
2. Zhang, X., Ractham, P., Daniel, F.: KEEP SLS: an Enhanced ePortfolio System Supporting Constructive Social Learning Activities. In: International Conference on Advanced Computer Control, January 2009, pp. 310–314 (2009)
3. Ganchev, I., O'Droma, M., Damien, M.: Profile Implementation and Service Adaptation within an InfoStation-based mLearning Environment. In: 2008 International Conference on Computer Science and Software Engineering, December 2008, vol. 5, pp. 863–866 (2008)
4. Stoyanov, S., Mitev, D., Minov, I., Glushkova, T.: eLearning Development Environment for Software Engineering Selbo 2. In: 19th International Conference on Database and Expert Systems Application, September 2008, pp. 100–104 (2008)
5. Nordmann, M., Jens, N.: Learning Application Suite – Creating and Playing SCORM Compatible Web and Computer Base Training. In: Eighth IEEE International Conference on Advanced Learning Technologies, July 2008, pp. 572–573 (2008)
6. Fangyi, L., Guanghong, D., Jinsong, W., Dong, X., Xueping, L., Peng, M., Wei, M., Li, S.: Green design assessing system model of products. Electronics and the Environment, 123–127 (May 2002)
7. Xiaoye, Z., QingShan, Z., Miao, Z., Li, X.: Research on Evaluation and Development of Green Product Design Project in Manufacturing Industry. Wireless Communications, Networking and Mobile Computing, 1–5 (October 2008)
8. Dashti, A., Kim, S.H., Shahabi, C., Roger, Z.: Streaming media server design. IMSC Press Multimedia Series. Prentice Hall PTR, Englewood Cliffs (2003)
9. Michael, Z.: Scalable video on demand: adaptive internet-based distribution. John Wiley & Sons, Chichester (2005)
10. Burall, P.: Green-ness is good for you. Design, April 1994, pp. 22–24 (1994)
11. joinNet, `http://www.webmeeting.com.tw/`

Interactive Whiteboard Teaching in English Education Based on Dual Code Theory and Bloom Teaching Quality

Chia-Ming Liu, Bo-Yen Wang, Yuan-Hsun Liao, Ming-Hsiang Su, and Pao-Ta Yu

Department of CS&IE, National Chung Cheng University, Taiwan
{Ljm,byw,lyh96p,mhs,csipty}@cs.ccu.edu.tw

Abstract. The current trend is towards multimedia educational materials in the classroom for Cognitive Theory of Multimedia Learning. Electronic Interactive Whiteboard which is innovative equipment can be used to improve instructional environment and to increase the teacher-student interaction. But there is no appropriate management and integration of teaching with multimedia and whiteboard. This thesis designs a humanized teaching system with two-column whiteboard which conveniently manages activities in the classroom. A teacher uses two-column scenario to present the teaching materials of dual-channels, image and text to integrate the teaching materials of complete lecture and the designs of teaching activities for classroom management. In summary, teachers will be more lively and interesting in teaching and easily to realize classroom management and students have more motivation in learning.

Keywords: multimedia learning, whiteboard, dual code, Bloom teaching quality.

1 Introduction

It is important point how to integrate the multimedia, likes text, voice, images, animation, and video for teaching multimedia interaction. At present, teaching usually uses a PowerPoint document and a projector in the classroom. According to Media Richness Theory and the Information Richness Theory, teaching doesn't display a single slide any longer. Educators need to present several types of multimedia teaching materials and more hardware media at the same time for improving the effectiveness of teaching and learning objectivities. Electronic Interactive Whiteboard is an important issue, because it can allow teachers to teach face-to-face with students. In addition to convey the digital information, teachers transmit information to the students via nonverbal message (such as physical movements, facial expressions, etc.). Teachers can control of the students studying reaction in real-time by observation and interaction.

Teaching is the transformation process of several teaching activities, presentation of diversification, and the interaction between teacher and students. Instructors still don't have a well-designed computer aided system to help them to integrate the presentation of multimedia materials and maintain classroom management in whiteboard teaching. The study develops a comprehensive and innovative learning mode hybrid

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 551–558, 2009.

system (Vivid Builder System), solves the disadvantages of whiteboard and multimedia teaching materials respectively in teaching as following.

- The disadvantages and solutions in whiteboard teaching
  1. It is hard to realize Cognitive Theory of Multimedia Learning in whiteboard teaching. Two-column whiteboard teaching is the answer. Our system uses two-column containers to map the theory.
  2. It is not easy to reuse the instructional material designed by using the editor tool which provided by different whiteboard's vendors, because of each vendor has their own data format to store their files. The teaching materials designed by our system are normal PowerPoint document, and educators can use them in different whiteboard.
- The disadvantages and solutions in multimedia materials teaching
  1. Integration of materials Issue: Most instructors use not only PowerPoint but also some other applications such as Excel, Word, Acrobat Reader, IE, picture viewer, and media player to support their teaching. They can not be properly controlled while being executed simultaneously. Multi-Application Containers is the answer.
  2. Video Demand Issue: There is not such an easily used tool for instructors to analyze and explain each shot of the video in real time.
  3. Classroom management Issue: It is not easy to transition in multimedia teaching. So we design an instructional Strategy to solve the problem.

2 Related Technologies

2.1 Electronic Interactive Whiteboard

Electronic interactive whiteboard which is innovative technology can be used to improve instruction environment and methodology. Teachers explore ways to use interactive whiteboard with students mutually developing new teaching and learning strategies, resulting in changes in pedagogy [1]. Many studies showed that using interactive whiteboard can improve learning motivation, increase efficiency of teaching and outcome of learning, advance information literacy, and provide positive effects for educational investment [2][3][4]. The great efficacy of interactive whiteboard is the ability of interaction so that interaction could enforce interest and learning motivation. We can summarize some excellences of interactive whiteboard:

- Greatly improved the flexibility and versatility of teaching
- Increased the efficiency of teaching
- Powerful in multimedia/multimodal presentation
- A big promotion for students' learning motivation and learning attitude
- Much more interaction and participation in classroom.
- Establishes a clean classroom without chalk ash.

2.2 Cognitive Theory of Multimedia Learning

The Cognitive Theory of Multimedia Learning, proposed by Mayer, provides empirical guidelines that help instructional designer to promote the meaningful learning. This theory suggests that meaningful learning occurs when students mentally construct coherent knowledge representations [5]. The theory is based on three assumptions:

- Dual Channels - Humans have separate channels for processing visual/pictorial information and auditory/verbal information in working memory.
- Limited Capacity – Each channel of working memory has a limited capacity for processing information at one time.
- Active Processing – Meaningful learning occurs when humans learn by selecting relevant material, organizing it into coherent representation and integrating it with existing knowledge.

The kernel of Mayer's theory occurs in working memory. Sensor memory is a capacity-limited temporary memory so it must get a proper amount of learning information in different formats at the same time [6]. Dual Channels Theory suggests that students learn best when both channels are processed together. For this reason, the aided system intends to support verbal and pictorial form corresponding to these multimedia formats while in presenting [7].

2.3 Classroom Management

Many studies showed that Classroom Management impact students' learning and teachers' working morale greatly. The purpose of traditional Classroom Management is to achieve class control and order [8].

- Administration Management
  Class is like a small society. There is much work to do in order to maintain the normal operation. The seating arrangement, cleaning work assignments, curriculum arrangement, and class regulations are parts of Administration Management. Instruction Management
  Instruction Management includes equipment, course design, teaching method, evaluation, etc.
- Student Guidance
  There are many students in the class and each student has different situation. So it is important to give guidance. Let instructional activity be orderly, deal with problem behaviors, etc.
- Classroom Atmosphere
  Class Atmosphere is an interaction relationship between student to student or student to teacher. It will affect the outcome of learning such as the grade or the communicative competence.

3 System Architecture and Interactive Whiteboard Interface

3.1 System Architecture

Vivid Builder system consists of three main components, Education Layer, Instruction Component Layer, and Basic Component Layer.

- Basic Component Layer

This Layer is based on the Easy Edit and View (EEV) system [9]. EEV focused on multimedia leaning and multi-displays system's learning. We modify certain of functionalities and design some new for whiteboard teaching and facile teaching.

- Instruction Component Layer

Educators can design their special lecture by those components. Instruction components divided into three groups, presenting, managing, and authoring, according to teaching behavior.

1. Presenting

   Presenting behaviors are modules for teacher presets teaching materials. These behaviors about presenting consist of Interaction, Dual-Coding, and Feedback.

2. Feedback

   Vivid Builder system implements a good solution for instructors to analyze the frame of film played in the classroom by the snapshot functionality. Instructors can present and explain the snapshot for students by handwriting.

3. Managing

   Managing behaviors are modules for classroom management. These behaviors about managing consist of Activities Transition, and Humanized Interface. Activity flow is the point of effective classroom management, and fifteen percents of activities are activities transition in elementary classroom [10].

- Education Layer

This layer consists of all teaching activities. Educators can design the instruction flow by their needs. In this study, we design a novel instructional strategy. This instructional strategy contains the activities from preparation to review of lecture. The instructional strategy is detailed in chapter 4. Educators follow the instructional strategy can conveniently complete the design of a lecture.

3.2 Interactive Whiteboard Interface

Users must control almost the functions on electronic interactive whiteboard, and every control pad should have good flexibility of being to be tuned to proper placement.

- Content awareness for Presentation

Our system can present two teaching materials in two-column scenario at the same time. Sometimes according to Cognitive Theory of Multimedia Learning, teachers need to present two materials in two-column at the same time to help learners' left-right brain learning. Sometimes teachers need to focus on one of two materials in teaching, and our system provides five layouts to realize that.

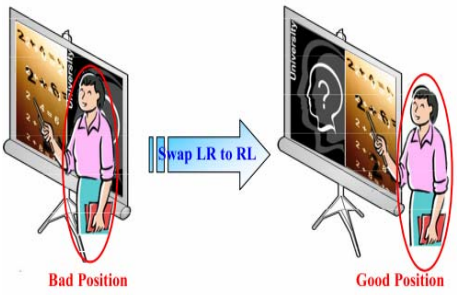


Fig. 1. Solution of Teacher's Position

- Position awareness for Presenter

When the educators teach scenario of two columns by using electronic whiteboard, they maybe obstruct students' view of one column's application container. The right-handers are used to stand right side of the electronic whiteboard. When they teach left column's application container content, they will obstruct the right column content. So the left-handers maybe obstruct the left column application container in general. Our system supports swap functionality to solve this problem.

- Focus awareness for Interaction

Teacher-student interaction is important in the classroom. The action of Interaction needs to be analyzed by teacher uses DV focused on speaker in interaction. TVideo contents can be as teaching materials or as learning feedback materials which are recorded from student's class activities.

4 Instructional Strategies and a Scenario of English Teaching

Multimedia teaching has three disadvantages, difficult to integrate different types of instructional materials, difficult to analyze video, difficult to manage classroom activities transition. We provide instructional strategy to realize those disadvantages. In terms of interactive whiteboard, our system provides an instructional design in Figure 3-5.

Vivid Builder system can easily and flexibly integrate a lot of files with different formats into a two-column system such that teachers can handle the classroom activities with fruitful instructional material to improve students' learning performance. So teacher

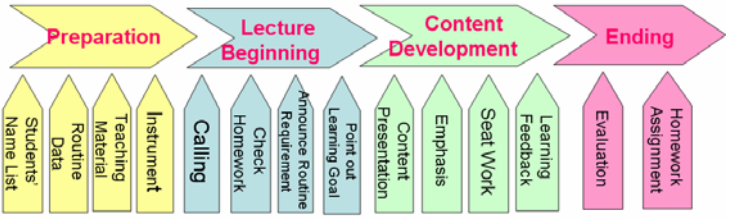


Fig. 2. Instructional Strategy for whiteboard teaching

can apply the control functions of Vivid Builder system to arrange their instructional activities including the interaction. The instructional strategy consists of four continuous steps, Preparation before Class step, Beginning of the Class step, Content Development step, and Closing step. An explication of each of these steps is shown as follows.

- Preparation before Class

The purpose of this step was to let teacher taught with fluency. In this step, teacher can use Vivid Builder system to open all data which be related to the lecture. This step consists of following components generally:

1. Students' Name List: The document consists of all students' name in this lecture.
2. Data of Formula: The document consists of the discipline and the overview of this lecture.
3. Teaching materials: They consist of all data of teacher presents in this lecture. Maybe they have PowerPoint, Word, Excel, PDF, Image, and Video, etc.
4. Teaching Aids: Teacher needs some hardware to teach, such as DV, whiteboard, notebook, etc.

- Beginning of the Class

The purpose of this step was to let students transition their mind from pro-lecture to the current lecture.

1. Call the roll: Teacher can use that to affirm students' attendance at the lecture
2. Checking: Teacher can check homework or examination paper, then gives learning feedback to students or re-teaching.
3. Announcement of Formula: Teacher can announce the formula to let students know the code of conduct lays down the classroom rule for the lecture by discipline data, and know how they do can achieve the course objective.

- Content Development

In this step, teacher can present teaching materials, prompt keywords, do the seatwork, and give students feedback to check students' apprehension and to hold out students' attention and attendance.

1. Presentation of Content: There are all kinds of presentation. Maybe use video and PowerPoint, even operate the software related to lecture actually.
2. Prompt of Keyword: Teacher must address himself or herself to the keyword. Students can get the knowledge teacher delivers.

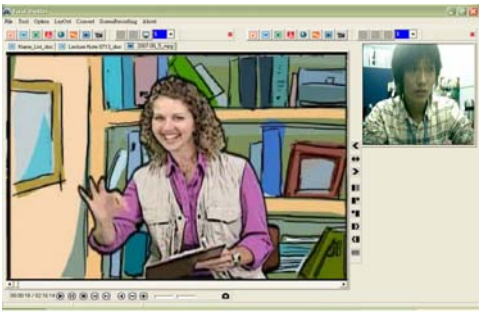


Fig. 3. A teacher shows materials in left column and students shot by DV in right column

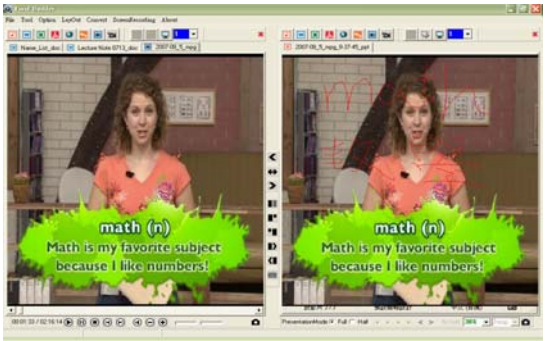


Fig. 4. A teacher captures video content in left side and annotates content in right side

3. Seatwork: Seatwork is also called as class work. The purpose of this work was to let student exercise or review the contents teacher taught just a moment ago. Seatwork has two types of class event. The first is called "supervised study". Every student does his work alone. The second type proceeded with small group instruction. Teacher only instructs one small group of students in the same time.
4. Learning Feedback: The purpose of this work was to strengthen student's learning motivation. If students have learning motivation, they are able earnestly to study. Fig 5 shows a record of a student say the word "math" at course.
5. Recitation: Teacher uses the QATE (question and answer with teacher elaboration) in general. In the other word, teacher proposed the question replied to the student and was extended in meaning [11]. That may provide the students to practice, review contents, and also may inspect the understanding of contents of the preceding lecture.

- Closing

This step consists of following components generally:

1. Arrangement of Keyword: Teacher must let students have time to collate the keyword of this lecture.
2. Homework Standard: Teacher refers a task assigned to students outside of class. The task is able to let students more understand the keywords of this lecture.

Fig. 5. A teacher analysis the record immediately at course

5 Conclusions

We have solved two critical problems in whiteboard teaching. In multimedia teaching, it is not also hard to manage various multimedia teaching materials and learning activities, but also hard to integrate them. The design of two-column teaching scenario is useful to present two different teaching materials related to each other that can solve manage and integrate multimedia materials. The novel Instructional Strategy is the solution of classroom management that it decreases the transition time. In whiteboard teaching, it is hard to realize Cognitive Theory of Multimedia Learning, and also hard to teach fluently. Two-column whiteboard teaching is the answer for realizing Cognitive Theory of Multimedia Learning. Humanized Interface is the answer for teaching fluently.

References

1. Chris, P., Mowbray, L.: Use of SMART Boards for teaching, learning and assessment in kindergarten science. The Journal of the Australian Science Teachers Association 54(2), 50–53 (2008)
2. Dombey, Henrietta: Editorial. Literacy 41(1), 113–114 (2007)
3. Fay, S., Frank, H., Higgins, S.: The impact of interactive whiteboards on teacher–pupil interaction in the National Literacy and Numeracy Strategies. British Educational Research Journal 32(3), 443–457 (2006)
4. Martin, Sheena: Interactive whiteboards and talking books: a new approach to teaching children to write. Literacy 41(1), 26–34 (2007)
5. Miriam, R., John, G.: Epistemological resources for thought experimentation in science learning. International Journal of Science Education 22(5), 489–506 (2000)
6. Tabbers Huib, K., Martens Rob, L., van Merriënboer Jeroen, J.G.: Multimedia instructions and cognitive load theory: Effects of modality and cueing. British Journal of Educational Psychology 74(1), 71–81 (2004)
7. Mayer, R.E., Moreno, R.: Aids to computer-based multimedia learning. Journal of Learning and Instruction 12, 107–119 (2002)
8. Matus, D.E.: Traditional classroom management revisited in the urban school. American Secondary Education 30(1), 46–57 (2001)
9. Huang, W.-B.: Using Multi-Display Presentation and Multimedia Synchronization Technologies to Implement a Scenario Computer Aided Teaching System, July 2007, pp. 24–56. CSIE National Chung Cheng University (2007)
10. Rosenshine, B.V.: How time is spent in elementary classrooms. In: Denham, C., Lieberman, A. (eds.) Time to Learn, vol. 17(1), pp. 16–25. National Institute of Education, Washington (1980)
11. Korth, W., Cornbleth, C.: Classroom activities as settings for cognitive learning of the opportunity and instruction. Paper presented at the annual meeting of the American Educational Research Association, New York (March 1982)

A Cognitive-Interactive Approach to Chinese Characters Learning: System Design and Development

Yu-Ju Lan[1], Yao-Ting Sung[2], Chia-Yu Wu[3], Rui-Lin Wang[2], and Kuo-En Chang[3]

[1] Department of Applied Chinese Languages and Literature, National Taiwan Normal University, No.2, Sec. 1, Ren-ai Rd., Linkou Township, Taipei County 244, Taiwan
yujulan@gmail.com
[2] Department of Educational Psychology and Counseling, National Taiwan Normal University, National Taiwan Normal University, 162, Sec. 1, Ho-Ping E. Rd., Taipei, Taiwan
sungtc@ntnu.edu.tw
[3] Graduate Institute of Information and Computer Education, National Taiwan Normal University, 162, Sec. 1, Ho-Ping E. Rd., Taipei, Taiwan
kchang@ntnu.edu.tw

Abstract. A solid knowledge of Chinese characters plays an important role in Chinese reading. Essentially, Chinese characters, a graphic- based orthographic rule, are much different from the words of an alphabetic language, such as English, French, etc. The uniqueness of Chinese characters make it is extremely difficult for most of the CFL/CSL learners no matter what their nationalities are. In this paper we developed a Chinese character learning system based on a cognitive-interactive perspective to help CFL/CSL learners learn Chinese characters. The results of a preliminary survey show that most of the surveyed CSL learners approved the learning system's design rationale as well as made positive comments on the system learning effect upon their Chinese character knowledge construction.

Keywords: Chinese character, romantic radicals, Chinese as a foreign/ second language (CFL/CSL), cognitive-interactive.

1 Introduction

Students' reading abilities play an important role in their academic achievement. Undoubtedly, reading is a key for anyone to acquire knowledge of the literature world, particularly for students. Moreover, there is a growing recognition that reading provides important opportunities for second language (L2) development [1], especially for learners in a language setting with limited L2 resources [2]. Many studies show that foreign language (FL) learners' metalinguistic awareness [3] which includes the awareness of phonological regularity, orthographic regularity [4], and morphological regularity [5] strongly affects FL learners' reading development. However, most of the related studies have been conducted with alphabetic language, such as English and French, "could those findings also apply to learning to read Chinese for a CFL learner?" is an issue worthy of further consideration and have drawn many researchers' attention.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 559–564, 2009.

Chinese characters, essentially a graphic- based orthographic rule, are much different from the words of an alphabetic language, such as English. Unlike the case of an English word in which the sound is encoded in all letters, an English reader can guess the pronunciation of an unknown English word via the relation between the letters and the corresponding sounds. Chinese characters are made up of strokes. Strokes are then combined in such a way as to form structure that can be called "radicals." The knowledge of the structure of a Chinese character is therefore important for beginning learners to identify the made up radicals of a Chinese character [6]. Furthermore, there are two kinds of radicals: semantic and phonological, the former gives a cue to the meaning of the character and the latter gives a cue to the pronunciation of the compound. For instance, in the character 清 [qing1] "pure, clear", 氵[shui3] "water" is the semantic radical, and 青 [qing1] "blue, green" is the phonetic radical. Based on Kang's study [7], about 80% to 90% of Chinese characters comprise a semantic radical and a phonological radical. According to Shu, Chen, Anderson, Wu, and Xuan [8], the semantic cueing function of the semantic radical in a Chinese character is stronger than the phonological cueing function of the phonetic radical. In addition, recent studies have shown that the radical is an important processing unit for children in processing Chinese characters [9] as well as for adult skilled readers in recognizing Chinese characters [10].

Because of the remarkable difference between Chinese and other alphabetic language, the uniqueness of Chinese characters makes it difficult for most of the CFL/CSL learners to recognize the written Chinese text no matter what their nationalities are [11]. To deal with the language barrier, some researchers emphasized the importance of explicit instruction on positional regularities of both semantic and phonetic radicals [9]. "Concentrated character learning method" is another popular new Chinese character teaching method in which characters with the same semantic radicals or phonetic radicals are taught together [12]. Lam, Ki, Law, Chung, Ko, Ho, and Pun [13] designed a computer-assisted Chinese character learning software based on the knowledge of the structure of Chinese characters as well as radicals (both semantic and phonological). Although Lam's software got supportive evidence on the feasibility, the results of classroom experiment also revealed the importance of contextual way of teaching Chinese characters. The problem found in Lam's study also can be found in other web-based Chinese character learning system. Based on Lan's study [14], most of the computer-assisted Chinese character learning system much focused on the instruction of radicals and stroke order rather than embedded the essential knowledge of Chinese character in meaningful context has led to less self-learning effect.

The deal with the problem of decontextualized Chinese character learning, this current study applied cognitive perspective to design a two-way interactive Chinese character learning system in which CFL beginning learners first learn the essential knowledge of Chinese character such as character structure and radicals and then apply the learned knowledge to comprehend a meaningful context. The following sections briefly describe the Chinese character learning system, and finally present conclusions.

2 Cognitive Chinese Character Learning System (CCCLS)

CCCLS was designed based on a cognitive-interactive perspective. Based on Carroll [15], a FL learner will effectively learn the target language (here means Chinese) in an interactive learning mode in which all the learning materials are divided into several small units, the FL learner first learn the lower level linguistic skills such as words and phonological rules and then is given a meaningful context to apply what has learned to comprehend the written text in the target language (Fig. 1 shows the interactive model). The beta version of CCCLS consists of 5 units and each unit includes 3 Chinese characters which all contain a common radical. At the beginning, the knowledge of Chinese character structure is introduced via animation and interactive manipulation (Fig. 2 shows an example). Then, the CFL learners learn the materials unit by unit. Besides, the learning flow of each unit is as the following: (1) radical; (2) characters related to the radical; (3) words and sentences related to the characters; (4) comprehension of a meaningful context. After the CFL learners finish all the learning activities of each unit. A summative assessment will be.

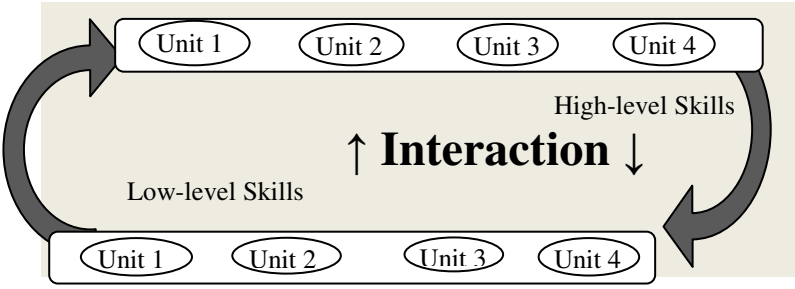


Fig. 1. The interactive model of Chinese character learning system

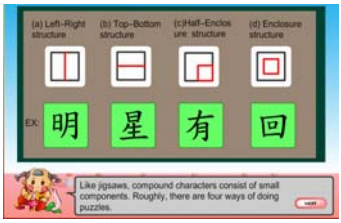


Fig. 2. The instruction on the structure knowledge of Chinese characters

2.1 Radical Instruction

Each radical is introduced via sound, related characters with the radicals based on the approach of concentrated character learning method, and the animation of the radial. Fig. 3 shows an example of radical instruction.

Fig. 3. An instruction example of a semantic radical 人 [reng2] "person" with character origin animation

2.2 Character Instruction

The instruction followed the radical instruction is about 3 characters with the radical taught in the unit. For instance, the radical taught in unit 1 is人 [reng2] "person", and the 3 introduced characters are 來 [lai2] "to come", 他 [ta1] "he", and 你 [ni3] "you". In addition to the same functions as shown in radical instruction interface, "word" and "sentence" made up by the character will be also shown to depict how the target character used in context. Fig. 4 shows an example of the character instruction interface.

Fig. 4. An instruction example of a character來 [lai2] "to come" with the semantic radical 人 [reng2] "person"

2.3 Interactive Practice

After the CFL learners finish the character learning, CCCLS provides them with an interactive practice activity to strengthen the learning effect. The practice includes radical recognition, character meaning, and character usage. Fig. 5 shows an example of radical recognition. The screen will shown a learned character and ask the CFL learner to choose the correct radical of the character.

Fig. 5. An interactive practice on radial recognition

2.4 Meaningful Context

A meaningful context with the corresponding sentence will be shown to the CFL learners after they finish the learning activity of lower level Chinese skills such as radical, characters, and words. The CFL learners will be asked to apply what they have learned to comprehend the meaning of the context even some characters in the sentence are new to them. Fig. 6 shows an example of an authentic context of four friends having a picnic in a park.

Fig. 6. An authentic context of four friends having a picnic in a park to depict the usage of character來 [lai2] "to come"

2.5 Summative Assessment

After the CFL learner accomplishes the learning mission, a summative assessment is administered online. In the assessment, items on each activity (such as radical, character, and meaningful context) will be used to measure CFL learners' mastery of all the taught materials which are including radicals, characters and their usage in meaningful context. CCCLS will keep the learning and test records of each CFL learner. The information can help individual learner understand their learning status as well serve as a reference framework for CFL teachers to develop an adaptive teaching program for each individual CFL learner.

3 Conclusion

The Beta version of CCCLS was evaluated by four Americans with basic Chinese language skills. The evaluation focused on several dimensions which include the instruction flow, material introduction, teaching strategies, interactive practice, and individual learning effect. All of the reviewers represented their satisfaction with the learning effects of CCCLS, as well as gave positive comments about all the dimensions. However, all of them also suggested that CCCLS should expand its materials bank. They indicated that CCCLS will contribute more to CFL learners' Chinese reading development if there are more radicals and characters included. Based on the positive comment got from those American reviewers, the future work will focus on the development of learning materials of CCCLS as well as the conduction of a practical experiment to evaluate its learning effect on CFL learners' reading development.

Acknowledgments. This research was supported by the grants from the National Science Council, Republic of China, under contracts nos. NSC 97-2511-S-152-012-MY3, NSC 96-2520-S-003-012-MY3, and NSC 97-2631-S-003-002.

References

1. Day, R.R., Bamford, J.: Extensive Reading in the Second Language Classroom. Cambridge University Press, Cambridge (1998)
2. Gehard, J.G.: Teaching English as a Foreign or Second Language. University of Michigan Press, Ann Arbor (1996)
3. Nagy, W.E., Anderson, R.C.: Metalinguistic awareness and literacy acquisition in different languages. In: Wagner, D., Venezky, R., Street, B. (eds.) Literacy: An International Handbook, pp. 155–161. Garland, New York (1999)
4. Berninger, V.W.: Introduction to the Varieties of Orthographic Knowledge 1: Theoretical and Developmental Issues. In: Berninger, V.W. (ed.) The Varieties of Orthographic Knowledge 1: Theoretical and Developmental Issues, pp. 1–25. Kluwer, The Netherlands (1994)
5. Tyler, A., Nagy, W.E.: The Acquisition of English Derivational Morphology. J. Memory and Language 28, 649–667 (1989)
6. Taft, M., Chung, K.: Using Radials in Teaching Chinese Characters to Second Language Learners. Psychologia 42, 243–251 (1999)
7. Kang, J.S.: Analysis of Semantics of Semantic-Phonetic Compound Characters in Modern Chinese. In: Chen, Y. (ed.) Information Analysis of Usage of Characters n Modern Chinese, pp. 68–83. Shanghai Education Publisher, Shanghai (1993)
8. Shu, H., Chen, X., Anderson, R.C., Wu, N., Xuan, Y.: Properties of School Chinese: Implications for Learning to Read. Children Development 74, 27–47 (2003)
9. Ho, C.S.H., Ng, T.T., Ng, W.K.: A "Radical" Approach to Reading Development in Chinese: The Role of Semantic Radicals and Phonetic Radicals. J. Literacy Research 35(3), 849–878 (2003)
10. Taft, M., Zhu, X.-P.: Submorphemic Processing in Reading Chinese. J. Experimental Psychology: Learning, Memory, and Cognition 23, 761–775 (1997)
11. Shen, H.H.: An Investigation of Chinese-character learning strategies among non-native speakers of Chinese. System 33, 49–68 (2005)
12. Tian, B.-N.: The Concentrated Character Learning Method: A Primary School Reading Instruction Reform Project. In: The Proceedings of the Third International Conference of the Language Education Institute, Hong Kong (1987)
13. Lam, H.C., Ki, W.W., Law, N., Chung, A.L.S., Ko, P.Y., Ho, A.H.S., Pun, S.W.: Designing CALL for learning Chinese Characters. J. Computer Assisted Learning 17, 115–128 (2001)
14. Lan, Y.J.: The Content Analysis Checklist of Web-based Learning Materials of Chinese as a Foreign Language Based on a Social Cognitive Perspective. Technical report, Corporate Synergy Development Center, Taipei (2008)
15. Carroll, D.W.: Psychology of language. Foreign Language Teaching and Research Press, Beijing (2000)

An Automatic Course Generation System for Organizing Existent Learning Objects Using Particle Swarm Optimization

Yen-Ting Lin[1], Shu-Chen Cheng[2], Jin-Tan Yang[3], and Yueh-Min Huang[1,*]

[1] National Cheng Kung University, Department of Engineering Science, No. 1, Ta-Hsueh Road, Tainan 701, Taiwan, R.O.C.
[2] Southern Taiwan University of Technology, Department of Computer Science and Information Engineering, No. 1, Nantai St, Yung-Kang City, Tainan 710, Taiwan, R.O.C.
[3] Ming Chuan University, Department of Teaching Chinese as a Second Language, No. 250, Sec. 5, Zhong Shan North. Road, Taipei 111, Taiwan, R.O.C.
ricky014@gmail.com, kittyc@mail.stut.edu.tw, yangdav@mcu.edu.tw, huang@mail.ncku.edu.tw

Abstract. The purpose of this study is to consider that how to help instructors re-organize a well-structured teaching material utilizing existing learning objects. To cope with this problem, this study adopts a novel approach - particle swarm optimization (PSO) to achieve this aim. By employing this algorithm, the proposed approach can automatically re-organize a teaching material and meet multiple criteria specified by the instructors. In addition, evaluation results have demonstrated that the proposed approach is applicable that can help most instructors re-organize teaching materials efficiently and effectively.

Keywords: Particle Swarm Optimization, Learning Object Composing, Artificial Intelligence.

1 Introduction

Over last decade, e-learning has widely applied in educational domain. Unlike traditional in-class education, e-learning aims at bringing learning activities off classroom freed from the restrictions of time and space [1]. Moreover, the interoperability and reusability of developed learning materials are other aims of e-learning [2]. Form the view, the flexibility and the cost saving are the two obvious benefits over traditional classroom training.

Since popularization of e-learning today, many learning objects have been produced by educational specialists for satisfying learning demand. Moreover, the produced learning materials could be the useful resources for further education [3]. In order to help instructors reuse these resources, first of all is to consider that how to assist the instructors re-organize the existing learning objects. Furthermore, the instructors may face a large number of the learning objects that may make them recombine a new teaching material laboriously. Additionally, the instructors have to

* Corresponding author.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 565–570, 2009.

take more than one factor or criterion into account when they organize a well-structured teaching material.

Bearing this in mind, this study adopts a novel approach - particle swarm optimization (PSO) to generate particular teaching materials automatically. By employing this novel approach, the proposed system can re-combine existing learning objects and produce a new teaching material. Moreover, the teaching material can fit the specific requirements to satisfy the expectation of the instructors.

The rest of the paper is organized as follows: Section 2 gives reviews of PSO. Section 3 describes the course generation problem. Furthermore, Section 4 presents the automatic course generation system, and the experimental results are shown in section 5. Finally, the conclusions and further works are made in section 6.

2 Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a population-based optimization algorithm, which was proposed by Kennedy and Eberhart in 1995 [4][5]. The original concept of the PSO is derived from fish schooling and bird flocking that is a kind of social behaviors. In order to simulate the phenomena, the two inventors applied a swarm of particles as fish schooling and bird flocking to develop a social behavior model.

In addition to the original version of the PSO, Kennedy and Eberhart further presented a discrete binary version for the PSO algorithm [6]. The purpose of the discrete PSO is used to combinational optimization problem where each particle is structured by a binary vector. Moreover, a bit of each particle will be restricted to value 0 or value 1.

3 Problem Description

In this study, we propose a model to formulate a course generation problem under different assessment criteria that are difficulty degree of selected learning objects, range of expected lecture time, and relationship between selected learning objects and specified topics.

Assume that there are n learning objects, O_1, O_2,…, O_i,…, O_n. An instructor requires organizing a teaching material which aims at k topics, T_1, T_2,…, T_x,…, T_k, and the lecture time of the teaching material is expected range from l seconds to u seconds. Moreover, suppose that the instructor expects the teaching material with specific difficulty degree, D. In order to organize the teaching material, therefore, c learning objects would be selected from the n learning objects. Furthermore, each selected learning object is unrepeatable with each other in the final result and the result satisfies the requirements specified by the instructor. Naturally, the c learning objects are a subset of the n learning objects, $c \in n$. The variables used in this model are given as follows:

- n, number of existing learning objects.
- k, number of topics to be taught in a teaching material.
- c, number of learning objects would be organized in the teaching material.
- O_i, $1 \le i \le n$, the ith learning object in the n existing learning objects.

- T_x, $1 \le x \le k$, the xth topic to be taught in the k topics.
- s_i, $1 \le i \le n$, s_i is 1 if the O_i is organized in the teaching material, 0, otherwise.
- D, target difficulty degree for the teaching material generated.
- d_i, $1 \le i \le n$, degree of difficulty of O_i.
- r_{ix}, $1 \le i \le n$, $1 \le x \le k$, degree of association between the learning object O_i and topic T_x. r_{ix} is 1 if the O_i is relevant to the T_x, 0, otherwise.
- e_i, $1 \le i \le n$, expected time needed for lecturing O_i.
- l, lower bound on the expected time needed for lecturing the teaching material.
- u, upper bound on the expected time needed for lecturing the teaching material.

The formal definition of the model is described as follows:

$$Minimize\ Z(\boldsymbol{P}_{y,i}) = f + C_1 + C_2 + C_3 \tag{1}$$

$$f = \left| \frac{\sum_{i=1}^{n} s_i d_i}{\sum_{i=1}^{n} s_i} - D \right| \tag{2}$$

f indicates the difference between the average difficulty degree of the selected learning objects and the target difficulty level.

$$C_1 = \frac{\sum_{x=1}^{k} \left(1 - \frac{\sum_{i=1}^{n} s_i r_{ix}}{\sum_{i=1}^{n} s_i} \right)}{k} \tag{3}$$

C_1 represents the degree of the relevance between the selected learning objects and particular topics.

$$C_2 = \max\left(\min\left(l - \sum_{i=1}^{n} s_i e_i, 1 \right), 0 \right) \tag{4}$$

$$C_3 = \max\left(\min\left(\sum_{i=1}^{n} s_i e_i - u, 1 \right), 0 \right) \tag{5}$$

C_2 and C_3 indicate that the expected lecture time of the selected learning objects are beyond the specified lower bound or upper bound.

As mentioned previously, $Z(\boldsymbol{P}_{y,i})$ is a fitness function which is consisted of four assessment criteria. Since the problem is a kind of combinational problem, the discrete binary version of PSO is adopted in this study. To satisfy this problem, a particle can be represented by $\boldsymbol{P}_{y,i} = [s_1 s_2 \ldots s_i \ldots s_n]$, which is a vector of n binary bits where $\boldsymbol{P}_{y,i}$ indicates the ith bit of the yth particle, s_i is equivalent 1 if the O_i is organized in a teaching material and 0 otherwise. Moreover, the sigmoid function is used to transform velocities into probability [6].

$$S(v_{y,i}) = \frac{1}{1+e^{-v_{y,i}}} \tag{6}$$

4 Automatic Course Generation System

Automatic course generation system is a web-based teaching material recombination system. Fig. 1 shows the architecture of the automatic course generation system. The procedure of the proposed approach is described in detail as follows.

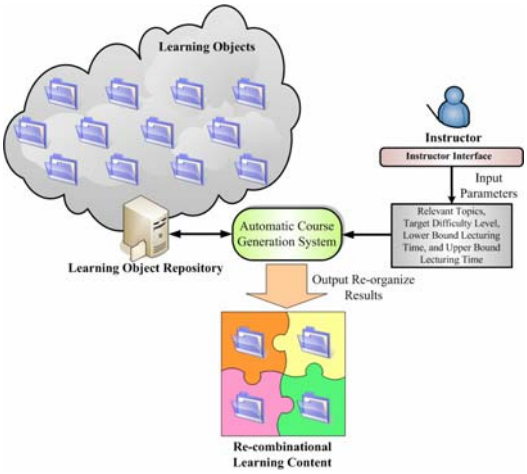


Fig. 1. Architecture of automatic course generation system

Phase 1. Requirement verification

This phase requires the instructor to specify the relevant information of a teaching material, which include k topics $T_1, T_2, \ldots, T_x, \ldots, T_k$, the target difficulty level D, the lower bound lecture time, l, and the upper bound lecture time, u.

Phase 2. Learning object re-combination

Step 1. Generation initial swarm

To generate the initial swarm, the selection probability of each learning object (bit) is based on the selection rule $(S-|d_i-D|)/S$ which gives higher selection probability to

the learning objects that have closer difficulty level to the target where d_i is the difficulty degree of learning object O_i and S is a constant [7].

Step 2. Fitness evaluation of particles

We measure the quality of each particle based on the fitness function.

Step 3. Determination of PBbest and Gbest

In this step, each particle compares the present fitness value with personal best fitness value to find the *PBest*. Moreover, a global best (*GBest*) fitness value will also be found among all particles in the swarm.

Step 4. Update of velocities and positions

According to the sigmoid function of *Equation* (6), if a particle owns a better fitness value, only a very small number of bits will be changed. Contrarily, the particle will be changed more number of bits since it owns a worse fitness value.

Step 5. Determination of termination

This step is to determine whether this phase can be terminated, and if not then it goes back to the second step in the phase 2 and repeats these steps until termination.

Step 6. Learning content generation

Through this step, the instructor can view the result from the web-based interface.

5 Evaluation

To verify the usability of the system, we surveyed 12 lecturers through a questionnaire. All participants were asked to fill out the questionnaire by checking responses on a Likert-type 5-point scale after they manipulated the system.

As shown in Table 1, 75% lecturers felt that the system is convenient for organizing a teaching material. Moreover, half of the lecturers agreed that the automatic course generation system can facilitate them to produce a teaching material. Furthermore, approximately 41.67% thought that the proposed system can organize a teaching material according to their requirements. In addition, 50% of the lecturers claimed that they enjoyed using the system to administer a re-organization for particular teaching material.

Table 1. The lecturers' perceptions on using automatic course generation system

#	Question	SA & A (%)	Neutral (%)	D & DS (%)	Mean
1	Automatic course generation system is convenient for organizing a teaching material	75	16.67	2.08	4
2	Automatic course generation system facilitates the production of a teaching material	50	33.33	16.67	3.5
3	Automatic course generation system organizes a teaching material according to my requirements	41.67	33.33	25	3.08
4	I enjoyed using automatic course generation system to organize a teaching material	50	25	25	3.5

Following that, we surveyed the 12 lecturers to understand their thoughts in depth via an interview. In light of the interview result, most lectures indicated that the results always have to make some minor revisions. Moreover, some lecturers said that they sometimes feel like peers to talk over how to revise the teaching material. Furthermore, some lecturers suggested that the system should develop a function to search outside learning objects because that can enable the system to offer more resources to users.

6 Conclusions and Further Works

In this paper, the proposed system can model the composition of a set of learning objects according to multi-criteria specified by users. To evaluate the usability of the system, a questionnaire has been conducted to capture the attitude of 12 lecturers. The results revealed that the proposed system can facilitate the lecturers to produce a new teaching material efficiently through re-organizing existing learning objects according to the multi-criteria.

Finally, based on the lecturers' feedback from the interview, we will develop collaborative function to extend the system to serve peer revision. Moreover, grid technology will be embedded in the system to support resource-sharing.

Acknowledgments. This work was supported in part by the National Science Council (NSC), Taiwan, ROC, under Grants NSC 97-2511-S-006-001-MY3, 97-2511-S-130 - 002 -MY3, and 97-2511-S-218-003-MY3.

References

1. Frederick, B.K., Michael, F.Y., Kelly, D.R., Schrader, P.G.: Defining distance learning and distance education. Educational Technology Review 9, 1–14 (2001)
2. Advanced Distributed Learning, `http://www.adlnet.gov/downloads/311.cfm`
3. Shih, W.C., Tseng, S.S., Yang, C.T.: Wiki-based rapid prototyping for teaching-material design in e-Learning grids. Computers & Education 51, 1037–1057 (2008)
4. Eberhart, E., Kennedy, J.: A new optimizer using particle swarm theory. In: 6th International Symposium on Micromachine and Human Science, pp. 39–43. IEEE Service Center, New York (1995)
5. Kennedy, J., Eberhart, R.C.: Particle swarm optimization. In: IEEE International Conference on Neural Networks, pp. 1942–1948. IEEE Service Center, New York (1995)
6. Kennedy, J., Eberhart, R.C.: A discrete binary version of the particle swarm algorithm. In: IEEE International Conference on Systems, Man, and Cybernetics, pp. 4104–4108 (1997)
7. Yin, P.Y., Chang, K.C., Hwang, G.J., Hwang, G.H., Chan, Y.: A particle swarm optimization approach to composing serial test sheets for multiple assessment criteria. Educational Technology & Society 9, 3–15 (2006)

The Experience of Adopting Game-Based Learning in Library Instruction

Sheng-Hui Hsu[1], Shu-Chen Cheng[2], and Yueh-Min Huang[1]

[1] Department of Engineering Science, National Cheng Kung University
[2] Department of Computer Science and Information Engineering, Southern Taiwan University of Technology
obs945@easylearn.org, kittyc@mail.stut.edu.tw, huang@mail.ncku.edu.tw

Abstract. The research is based on the course of library instruction and also a pilot study before adopting game-based learning into real library instruction course. The difficulty of the research is how we can make the original course like a game but with educational function. And another challenge is how to create a game which is executing in the silent library. After the trial experiment we have some findings and suggestions. These data will be useful to the further researches and helpful to make this educational game becoming a real course in the school.

Keywords: Game-based learning, educational game, library instruction.

1 Introduction

In Taiwan, there are library instruction courses for the freshman in some schools. The purpose of library instruction is to help these people be familiar with the library in their school and to know how to use equipments in the library. However internet is thought as a common skill for the people nowadays and the result is that young people think library is unnecessary. Another reason of why library is not popular for young people is that library is solemn. They cannot freely move inside, and young people cannot find something interesting in it. Even the school policy stipulated that the freshman should take the library instruction course but most of the students are forced to participate in the course unwillingly.

Although the library is not interesting enough for the young, but it is really useful for people to search for information and gain knowledge. Maybe it is not as convenient as internet search engine, but with the bibliography and related management method the old library still keeps its value. And not all the information is digitalized already, as long as the information is not digitalized and you cannot find it on web. The most powerful part of library should be mentioned about is that there are lots of copyright books in it. Copyright law provides that publications with copyright are under the protection of law and people cannot disseminate with permission. For the reason that these publications can only been looked up in the library if you did not have these publications.

M. Chang et al. (Eds.): Edutainment 2009, LNCS 5670, pp. 571–576, 2009.

2 Educational Game

There is no clear definition about educational game or serious game [1], but it is been known as a game have been specifically design for education purpose. Why a successful educational game is hard to be created? The reason is that it is hard to strike the balance of the proportion of game and education. A successful educational game can make players feel they are playing a game and learning things unconsciously. If the proportion of education is more than game, players will feel the game is a different type of curriculum or a computer assisted instruction software. On contrary if the proportion of game is more than education, the players will not learn almost nothings from the game.

Game design can be broken down into separated into three specific areas: core mechanics, storytelling and narrative, and interactivity. Each is a distinct, complementary element of a game, and each makes up one part of a larger whole [2]. The core mechanics of educational game are the contents that you want to teach and the pedagogy used in the learning activity. Storytelling and narrative is the story that the game wants to tell the player, and also the decoration of the educational content. The last but not the least part is interactivity. Interactivity is the bridge connecting the game, player, and the play environment.

3 Design a Game for Library Instruction

There are some previous related researches can be good examples for us to emulate to design a game for library instruction. The museum guidance system is a location-based system. People who visit the museum can be guided by the guidance system. There is a machine with chip inside. Once you press the button and the guidance starts. The new trend of museum guidance system is to adopt IrDA device or RFID tag on the target [3] and becoming a context awareness education environment [4]. The system can enhance visitors or learner's experience and have more interactivity in the museum or exhibition hall [5]. The idea from mobile learning is to use mobile computing devices such as PDA or Smartphone to learn. The mobility and lite computing power is just fitting the need of the person who has to move himself or herself to other places [6]. Another good example is a board game for library instruction [7]. This game indicates many learning material for researchers work for in the same domain. We can take advantages from these researches and adopt them in the game.

4 Library Instruction Game: Library Escape

4.1 Core Mechanics

The content for the game is based on the original library instruction course. The traditional course is lectured with a teacher centered style. But this type of lecturing method in library instruction course can due to the problem that learners are only listening and have no chance to experience the real situation by themselves. Due to this reason, we adopt the pedagogy of "learning by doing" as the pedagogy in this

learning activity [8]. In order to coordinate with the pedagogy, the content of the library instruction course is separate into several of questions and clues in the game.

4.2 Storytelling and Narrative

The story of the game is referred from popular flash game in the internet. The type of these flash games is called as room escape game [9]. The general idea of escape room game is that one day you are imprisoned in a room and you can find some clues or tools to help you to escape from the space. The library instruction game is the same as room escape game. The story of the game is that one night you are imprisoned in the library but there is no one here to help you to open the library gate. You have to use your wisdom to find clues in the library to escape from the building.

4.3 Interactivity

The interactivity in tradition library instruction course is a one way situation, that the teacher lecturing to the students. But this situation will not happen again in the game. First the learning activity is without the teacher. All the students have to do is concentrate and enjoy the library instruction game. Second, besides the content of the game, the students have also to find clues in the library. We had set some hints in the library. These hints are the key to the next question. Third, the students should use their PDA to get the clues in the library. Therefore, players will have good interaction with the whole game environment.

4.4 Game Design

Library Escape is a mixed reality game. The game is operated on PDA. In this version of game, wireless roaming network is not a necessary condition of the research. For the reason, we can free from the restriction of power consuming problem of PDA. The students only operate a PDA with RFID reader to read the tag hidden in somewhere of the library. Students should watch out for any clues from the PDA monitor and the library. And another advantage of using PDA in the research is that students can use earphone to hear the background music of the game without unnecessary noise.

The game type of library instruction game is adventure game (AVG). The characteristic of AVG is the structure of story. We redesign the curriculum of original library instruction course and separate it into several chapters. Every chapter is transformed into a question in the game. The game map is in the seven-floor library. Players can move to these seven floors to find the clues. Once the players solve a riddle, the story will keep on moving to the next stage and cannot be reversed. This also means that if the player did not solve the riddle and they will have no chance to move to the next stage.

Another part to increase the interactivity of the game is that the game is played in the first person point of view. When players play the game they can bring the PDA to the place where the same as the scene on the PDA screen. The background pictures are taken in the library. Although this game is not 3D virtual reality game but we try our best to make the players feel themselves are really in the actual spot.

Fig. 1. This figure is one screenshot of the game. Players can press the arrow button to decide their next move (upstairs, downstairs, move to the right or left scene). The user interface is all graphical. Via the graphic user interface players can easily control their movement in game with a PDA pen.

5 Experiment

We separately choose 17 college freshmen (13 male, 4 female) major in different department to play the game. Before they play, the only thing we ask them is to enjoy the game and they have two hours to play the game. For sure that if they finish the game or want to quit, they can send back the PDA before the end of these two hours.

After the game the participants are told that they will have an hour of interview three day after. But we do not tell them that they will also have a post-test to test if they learn the knowledge or not. We designed four categories with twenty questions in the post-test. The complete rate of the post-test is 87.94% (S.D. value: 1.278) and two of the students get full scores.

6 Discussion

6.1 Game Design

The content for the game is based on the original library instruction course and also the kernel of the game. According to the result of the experiment we can found that the students are with a high complete rate of the game. But most of the students answered wrong answers in the questions of library policy. Students who play the game can learn the skill to find books in the library but they do not pay much attention on the library policy or rules. The result also means that we still have much room for designing the content of game which can promote library policy. In next version of Library Escape game, we will put more effort on promoting library policy and adopt it in the game.

Some students had indicated that the game is with too many riddles to solve but with too less time to play. The library building is not a small place so that they have to pay much time in moving and seeking hints hidden in the library. They feel interesting to the game but it is a pity that they have to play in a rush but not enjoy the content of the game. As to this issue, we have decided to downsize the game. The scale of the game is certainly big to the students. In next version of game, we will separate the game into chapters or adopt the game saving mechanism in the game. Hence, students can focus on the content of the game instead of time consuming.

6.2 Storytelling and Narrative

Almost all the students agree that the game is success because they had devoted themselves in the game due to the narrative of the game. But there is still a problem in this game. Students can feel the narrative which designed by us but there is one thing they cannot feel: time. We did not design a clock or a counter on the screen. For the reason, students can only watch their watch to know how much time they spend in the game. This is inconvenient for the players and will also distract players' attention from the game. The students suggested us that it will be better to add the time mechanism in the game and they can control their tempo of playing the game.

6.3 Interactivity

The interface is easy for player to use. In order to complete the game, the students have to interact alternately between the real library and the library in the game. This is the most skillful and successful part in this game. In some of the riddles, students have to use the RFID reader to search the RFID tag. The information coded in the tags will lead them to the next place. We also arrange questions that students need to use the computers in the library to find related clues to solve. Without this mechanism, students will feel they are using a traditional library guidance system. And with this mechanism students can feel the sense of participation. After complete the game, students will learn things from the game and adopt these skills in the real situation.

7 Conclusion

Overall, the concept of Library Escape game is feasible for the real library instruction course. However there are still various things need to be improved in next version of game. The content of curriculum should be reorganized to avoid the situation that students feel the content are too prolix. The official library instruction course is separated into different levels and contents. Therefore we can ask for advices from the specialist and try to integrate other library service courses into the new game. The wireless roaming environment in the library is also a resource for us but we did not use it in this version. This research is not a perfect one, but we can get some experience from it. The experience will help us to make next research more perfect.

Acknowledgments. The authors would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract No. NSC97-2511-S-218-003-MY3.

References

1. Wikipedia, Educational game, http://en.wikipedia.org/wiki/Educational_game (retrieved on February 9, 2009)
2. Andrew, R., Emest, A.: Andrew Rollings and Ernest Adams on Game Design. New Riders (2003)
3. Yatani, K., Sugimoto, M., Kusunoki, F.: Musex: A System for Supporting Children's Collaborative Learning in a Museum with PDAs. Wireless and Mobile Technologies in Education (2004)
4. Want, R., Fishkin, K.P., Gujar, A., Harrison, B.L.: Bridging Physical and Virtual Worlds with Electronis Tags. In: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 370–377 (1999)
5. Fleck, M., Frid, M., Kindberg, T., O'Brien-Strain, E., Rajani, R., Spasojevic, M.: From informing to remembering: ubiquitous systems in interactive museums. Pervasive computing 1(2), 13–22 (2002)
6. Liu, T.C., Wang, H.Y., Liang, J.K., Chan, T.W., Ko, H.W., Yang, J.C.: Wireless and mobile technologies to enhance teaching and learning. Journal of Computer Assisted Learning 19(3), 371–382 (2003)
7. Fletcher Library Game Project, http://www.west.asu.edu/libcontrib/game/website
8. Prensky, M.: Digital Game-Based Learning. McGraw-Hill, New York (2004)
9. Room escap games, http://www.escapegames24.com

Author Index