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Driving Automotive User Interface Research

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Cars are very close to many working definitions of *pervasive computing*. They contain numerous (100 or more) networked processors; their processors and applications are often linked to physical input and output; they take contextual information into account; and they offer interfaces that allow networking with other cars, the surrounding infrastructure, and mobile devices such as information, entertainment, and communication systems.. Many recently proposed ideas for smart spaces and intelligent environments are already a reality in this domain. Thus, many researchers have discovered that cars offer an interesting but challenging microcosm for pervasive computing research and in particular for interaction with pervasive computing systems. However, cars are far from a "research playground" as there could be severe—literally fatal—consequences if things go wrong.

In recent years, exploring means for car-to-car and car-to-infrastructure communication has driven the focus on pervasive computing's technical aspects in the automotive domain. With many of the basic communication problems solved and increasingly more computing resources available in the car, the questions inevitably move toward new applications and interaction with these systems, for example, warnings about a localized danger or an upcoming, dangerous intersection. Increasingly, researchers are looking at interactive applications in the car and investigating human-car interaction from a computer science— rather than an ergonomics or mechanical engineering—perspective. This interest, demonstrated by papers submitted to various conferences related to the subject, motivated us to initiate a conference that brings together researchers concerned with user interfaces and interactive applications in the car. This field offers many challenging research questions while providing the opportunity to show that new solutions can affect people's lives. We quickly learned that research questions don't heed the traditional borders between disciplines, such as computer science, engineering, design, and psychology; the conference and program committee also reflected this diversity.

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Traditionally, research in this field has been carried out in automotive companies' labs and was often very secretive. In the past few years, however, we've seen a more open and cooperative research approach as many companies, research labs, and universities started numerous projects to tackle emerging challenges that arise from pervasive computing technologies. With the International Conference on Automotive User Interfaces and Interactive Vehicular Applications (Automotive UI), we aim to establish a new platform for the research community on automotive user interfaces. We share some of the presentations and discussions that took place at the first conference in Essen, Germany, in September 2009. The proceedings and papers are available in full text on the Web site (http://auto-ui.org).

KEYNOTE: THE NEW MINI—AMPLIFYING THE ORIGINAL

Gerd Hildebrand, head of design at Mini (BMW Group) and creator of the new Mini launched in 2001, presented the conference keynote. Under the title "Mini Design: From the Original to the Original. The Path from Center Speedo to Center Globe," he discussed his design philosophy and showed how his team realized this philosophy in the design of the center globe, a new interaction device in one of the recent Mini concept cars. Technically, the center globe is a multitouch sphere that supports multiple projection layers. The globe is located on the dashboard between the driver and

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the passenger and offers a unified user interface for access to information and entertainment functions. It has separate hemispheres for the driver and the passenger and links via tangible tokens to information on the World Wide Web. If you're curious about the center globe, a video (www.youtube.com/watch?v=aSWr_Craqos; the center globe is introduced at timestamp 2:08) and a Web page (www.coolgadgetconcept.com/mini-center-globe-concept) present the concept.

Besides classical design strategies, such as using consistently circular forms, Hildebrand discussed the importance of likeability and aesthetics, especially in the context of automotive user interfaces, which are typically driven by efficiency and concern for safety. The audience no doubt regarded the center globe's design as revolutionary—it incorporated many current design trends such as tangible interfaces and layered interaction, and at the same time spurred several controversial discussions. To mention just a few: Should we sacrifice efficiency for aesthetics? And, has aesthesis the potential to increase safety, even if it needs more attention? Overall, the keynote was inspirational and provided the basis for a fruitful discussion.

RESEARCH TRENDS IN AUTOMOTIVE USER INTERFACES

The conference program featured a set of topics and papers that represent trends in automotive user interface research.

Design Space, Techniques, and Tools

Looking at user interfaces in today's cars, it's clear that most manufacturers pursue a pragmatic and function-driven approach to deploying user-interface elements as systems and functions become available, which often results in a seemingly generic design. Two of us, Dagmar Kern and Albrecht Schmidt (University of Duisburg-Essen) proposed a design space for driver-based automotive user interfaces as a methodical approach to analyzing and comparing in-vehicle user interfaces. We developed a categorization scheme for easily comparing interaction modality, type, and position of user interface elements across different models and manufacturers. This design space is intended to provide a formal basis for analyzing and discussing different automotive user-interface arrangements, compare alternative user-interface setups, and identify new opportunities for interaction and placement of controls and output devices.

Anna Schieben and colleagues at the German Aerospace Center presented a more user-centered approach of designing in-car interaction. Their "theatre" technique is a Wizard-of-Oz-like interaction method that facilitates agile system design and testing. Through a coupled set of identical input devices, user and wizard (which represents the system) can communicate with each other in a direct and intuitive way.

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In the research community, many people seem to build driving simulators that are designed to aid their research in a specific way. Garrett Weinberg and Bret Harsham (Mitsubishi Electric Research Labs) presented their experience with developing a low-cost driving simulator—including hardware and software—for evaluating in-vehicle technologies. During the conference, Benjamin Hesse and colleagues (University of Duisburg-Essen, mercatronics GmbH) gave participants the opportunity to try out their Drivassist simulator. In addition, several open source projects provided basic software components for driving simulation studies such as the Configurable Automotive Research Simulator (CARS; http://cars.pcuie.uni-due.de). Throughout several talks, it became apparent that the community would benefit from a set of assessment tools and common measures to make their work comparable.

Know Thy Driver

Sensors, cameras, control units, and onboard computers collect and process an enormous amount of real-time information about a car and its environment, such as speed, fuel consumption, weather information, distance to other vehicles on the road, and lane position. Electronic control units also detect the driver's interaction with in-car user-interface elements, such as turning the steering wheel, pressing the gas pedal, or pushing radio buttons. Matthias Kranz and colleagues (Technische Universität München, German Aerospace Center, University of Duisburg-Essen) showed examples of using the available data for various context-dependent applications.

However, we know relatively little about the drivers themselves. Both Andreas Riener and colleagues (University of Linz, International School of Informatics Hagenberg) and Bryan Reimer and colleagues (Massachusetts Institute of Technology) presented work on measuring physiological data, such as heart rate, heart variability, and skin conductance, in real-world driving situations. They showed these measures' sensitivity to the driver's affective state and in reaction to cognitive workload. So far their research doesn't have a specific application; one possible domain is assistance for elderly drivers that require monitoring of their vital parameters or the control of autonomous driving functions. In the not-too-distant future, 50 percent of drivers in Germany will be older than 60. In this context, Andry Rakotonirainy (Queensland University) explored age-related issues of older drivers. He presented functional impairments, an analysis of older drivers' crashes, and

a conceptualization of relevant technology based on crash patterns.

Interaction and Distraction

Many years ago, the automobile's only purpose was transporting people between locations. Today, cars have numerous information and entertainment functionalities that people are supposed to operate while driving, but which shouldn't affect the safety of the car's occupants or those in cars around them. As a result, we've seen a lot of research that investigates the design of easy-to-use information and entertainment applications. Ronald Ecker and colleagues (BMW Group Research and Technology and Stanford University) and Tuomo Kujala (University of Jyväskylä) focused on finding efficient ways to select single points of interest from a large set in navigation systems.

Visual distraction is still one of the primary problems of in-car infotainment systems. Speech dialogue systems replace the visual aspect with auditory menus to reduce glancing at in-car displays. Jackie Chang and colleagues (Volkswagen Group of America) presented their work on speech dialogue systems' usability, and Andrew Kun and colleagues (University of New Hampshire, Microsoft Research) found that auditory output in navigation leads to fewer glances away from the road and results in less variance in driving-performance measures than visual information.

Multimodal Feedback

While driving, people must process many information bits and, based on that, make decisions—all in a very short time period. We know from cognitive psychology research that using more than a single human perception channel for information transport can support information processing. Several authors showed their work on using multimodal feedback for in-car interaction in different application areas. Yujia Cao and colleagues (University of Twente and German Research Center for Artificial Intelligence) experimented with multimodal presentation of local danger warnings to identify the fastest and easiest comprehensible design. Research results from Annie Rydström and colleagues (Luleå University of Technology) indicate that people can perceive visual information faster than haptic information. But naturally, visual information is likely to induce distraction when used with secondary tasks. Myounghoon Jeon and colleagues (Georgia Institute of Technology) showed that providing auditory cues while users scroll through text lists has a positive

effect. Gary Burnett and Ainojie Irune (University of Nottingham) assessed drivers' perception of in-car user interface elements' quality through vision, hearing, and touch. They found that touch seems to have the greatest influence on quality perception.

Some authors also focused mainly on haptic feedback. Matthew Pitts and colleagues (University of Warwick) explored subjective response to haptic feedback on in-car touchscreens and found a user preference for multimodal over single-modal feedback. Martin Kienle and colleagues (Technische Universität München and the German Aerospace Centre) used haptic feedback in assisted driving with an active side stick instead of a steering wheel, providing differently designed haptic feedback about the automation function's current behavior. This work addresses a challenging question that will become more important in the future: how will a user cooperate with a smart or semiautonomous system? This question is relevant in the automotive domain as well as smart environments and intelligent spaces.

TOWARD THE FUTURE

In society as well as in the car industry, eco-friendly cars and more generally sustainable transport are major issues, but it seems that the discussion focuses more on the technologies and less on the user. Interaction with the car, automotive user interfaces, and interactive applications in the car also seem able to contribute significantly to efficient driving. Alexander Meschtscherjakov and colleagues (University of Salzburg) presented their work on acceptance of future persuasive in-car interfaces toward a more fuel-efficient driving behavior at the conference. Given the potential for saving energy by changing drivers' behavior, such as less, shared, and more fuel-efficient driving, we were surprised how little current research has considered this topic.

Safety is still the central topic, and researchers are rightly unwilling to compromise on it. During the conference dinner, we visited the Zeche Zollverein, a United Nations Educational, Scientific and Cultural Organization (UNESCO) world heritage site, sometimes called the most beautiful coal mine in the world. The outside is stunning with truly impressive architecture, but the inside, while it was in operation, included much hardship and many accidents. Just 100 years ago, it was normal that, in such a mine, on average one person per day got seriously injured and one person per week died while working. It seemed inevitable, and people accepted it because energy was necessary. Nowadays, we don't consider such working conditions acceptable. However, with current cars and personal transport, it's somehow acceptable that more than 4,000 people per year are killed in road accidents in Germany alone (and we seem happy that this number has decreased significantly over the past few years). But looking at the research in the automotive domain, and in particular on user interfaces, we have to ask—what will people in 50 or 100 years say about us allowing this to happen? Research in computer science and pervasive computing can offer much toward a goal of zero accidents on the road. However, this might restrict the way we use transportation and could call for a radical rethinking of personal transportation.

The conference facilitated exciting discussions, and participants saw great value in this exchange of ideas. The Automotive UI Conference 2010 will be held in Pittsburgh. Conference proceedings are online on the conference Web site at http://auto-ui.org.

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