DEGREE PROJECT

Virtual Reality In Architecture

TECHNICAL LIMITATIONS, SOLUTIONS AND FUTURE USE

Ahmad Al-Falahi

Architectural Engineering, master's level
2022

Luleå University of Technology
Department of Civil, Environmental and Natural Resources Engineering

LULEÅ UNIVERSITY OF TECHNOLOGY

Acknowledgment

This master's thesis has been written by Ahmad Al-falahi for the civil engineer in architecture program at Lulea university of technology, in the department of architecture and water. I would like to thank all the interview participants that have offered up their time to help me investigate the study questions. I would also like to thank my supervisor at Lulea university of technology that has helped with conducting this study guide.

Ahmad Al-falahi

Lulea, Sweden

LULEÅ UNIVERSITY OF TECHNOLOGY

Master of Science Thesis

Title	VR in architecture, technical limitations, solutions, and future use
Author	Ahmad Al-falahi
Department	Architecture and water
Supervisor	Gustav Jansson

Abstract

VR is a relatively new technology that has been shown to have potential to increase productivity and facilitate better decision making, both within the architecture role and in the broader building industry. However, there are many difficulties that stand in the way of this new technology. In this study, the researcher uses semi-structured interviews to interview six working architects from three cities in Sweden. This is an attempt to investigate what architects think are the technical difficulties that stand in the way of VR use within the architect role. Both software and hardware limitations are investigated. I additionally investigate what architects think are potential solutions to those problems, and how architects think VR can be used in the future in a way that would be useful and facilitate better communication. This study found that, according to the architects interviewed, the technical limitations are mainly the lack of portability, isolation from the outside world, the need for powerful hardware, motion sickness, movement restrictions and the setup process being generally inconvenient. The future use of VR that would be useful according to the architects interviewed are the ability to have virtual meetings, VR being used in conjunction with AR, the ability to design and sketch in VR and using VR as a communication tool to convey design ideas to the public.

Keywords: Virtual reality, augmented reality, Head mounted display

Förord

Detta är en masteruppsats som har skrivits av Ahmad Al-falahi för civilingenjör i arkitekturprogrammet vid Luleå tekniska universitet, vid arkitektur- och vattenavdelningen. Jag vill tacka alla intervjudeltagare som har erbjudit sig tid för att hjälpa mig att undersöka studiefrågorna. Jag vill också tacka min handledare vid Luleå tekniska universitet som har hjälpt till med att skriva denna studie som vägledning.

Ahmad Al-falahi

Luleå, Sverige

Examensarbete

Titel	Virtuell verklighet I arkitektur, tekniska hinder, åtgärder och framtida användning
Författare	Ahmad Al-falahi
Avdelning	arkitektur och vatten
Handledare	Gustav Jansson

Sammanfattning

Virtuell verklighet är en relativt ny teknik som har visat sig ha potentialen att öka produktiviteten och bidra till bättre beslutsfattande, både inom arkitektrollen och i den bredare byggbranschen. Det finns dock många svårigheter som står i vägen för denna nya teknik. I denna studie använder jag semistrukturerade intervjuer för att intervjua 6 arbetande arkitekter från 3 städer i Sverige. Detta för att försöka undersöka vad arkitekter anser att de tekniska svårigheterna är som står i vägen för virtuell verklighet-användning inom arkitekturrollen. Både mjukvaru- och hårdvarubegränsningar undersöks. Jag undersöker dessutom vad arkitekter tror är potentiella lösningar på dessa problem, och hur arkitekter tror att VR kan användas i framtiden på ett sätt som skulle vara användbart. Denna studie fann att enligt de intervjuade arkitekterna är de tekniska begränsningarna främst bristen på portabilitet, isolering från omvärlden, behovet av kraftfull hårdvara, åksjuka, rörelsebegränsningar och att installationsprocessen är allmänt obekväm. Den framtida användningen av VR som skulle vara användbar enligt de intervjuade arkitekterna är förmågan att ha virtuella möten, VR användning i samband med AR, förmågan att designa och skissa i VR och att använda VR som ett kommunikationsverktyg för att förmedla designidéer med allmänheten.

Nyckelord: Virtual reality, augmented reality, Head mounted display

Table of Contents

Definition of Terms

VR - Virtual reality

AR - Augmented reality

HMD - Head mounted display

BIM - Building information modelling

AEC - Architecture, engineering, and construction

VE - Virtual environment

1 Introduction

1.1 Background and motivation

The construction industry is especially inefficient compared to other industries (Thabet et al., 2002). The level of productivity has not seen an increase that is as big in relation to other industries, this can be seen by the flat productivity curve (Lavikka et al., 2018). One challenge that faces the traditional architectural design process, is that architects to some extent, have a difficult time understanding scale and other details from the traditional methods to represent architectural designs (Bergman, 2017). This lack of understanding applies more so to non-architects, and in turn makes communication difficult between architects and the rest of the project members/general public (Bergman, 2017). Another issue facing architects, is that the traditional presentation methods for customers are generally not interactive. This presents the issue of architects having to choose what the customer will see in a presentation and can pick the wrong parts of the design to show the customer (Edwards, et al., 2015).

VR can be used as a communication tool during the planning phase. The use of modern information communication technology tools including VR, has the potential to substantially increase the efficiency of the design and planning process within the architecture role as well as the AEC-industry in general (Woksepp, 2007). This increase in efficiency needs to be coupled with the correct methods and organisational structures to occur. VR in architecture has the potential to resolve the problem of low productivity (Woksepp, 2007). VR allows for the customer to explore and interact freely with the design presented by the architect, and this eliminates the need for the architects to curate the presentation and pick exactly what the customer is going to see (Edwards, et al., 2015). Another problem that VR can resolve is the communication between architects and other project members/public. This is because people generally have an easier time understanding scale and other details of design when viewing it in VR (Bergman, 2017). VR is not used in the industry to a significant extent (Dashti & Vasques, 2020). Some of the issues that make it so that VR is not used to any large extent is the managers lacking information and experience when it comes to VR. Other issues include the managers not thinking that the cost of implementing the technology is worth the perceived benefits and having the perception that VR has not matures enough as a technology (Dashti & Vasques, 2020). Other issues that hold back VR include the need for training new staff, buying new hardware and the possibility of motion sickness (Norlund & Rask, 2016)

1.2 Goals and aims

The aim of this study is to conduct interviews with Swedish architects to investigate the technical problems with existing VR systems that explain the low level of usage in that context. The problems investigated will be both hardware and software related. Another related aim is to investigate what the solutions are for the problems highlighted in the first aim of the study. The final aim is to figure out how architects think VR can be used in the future, in a way that would be useful and facilitate better communication.

The goal of this study is to serve as a guide for VR developers and manufacturers to help them design hardware and software that is easier to use and more appealing to architects during the design phase.

1.3 Research question

Research question 1

What do the architects generally think are the technical reasons that explain why VR is not used to a higher extent in the architect role?

Technical reasons refer to hardware and software specifications. The research question focuses on aspects like screen resolution, refresh rate, the ergonomics of the headsets and the accuracy of the hand tracking among other things for the hardware. And software related explanations are aspects like software availability and software compatibility.

Research question 2

What are the remedies and solutions to the problems highlighted in the first research question, that if implemented would result in an increase of usage of VR within the architect role?

This research question investigates what features architects think are missing from current hardware and software that will lead to increased usage by adding a new hardware or software functionality.

Research question 3

What do the interviewed respondents think are potential uses of VR in the near future that would lead to better internal communication, public communication, and increase work quality?

This study question investigates the potential uses for VR in the architecture role, that are not utilized today and that architects think would increase the work quality and lead to better communication.

1.4 Scope

This thesis is only going to rely on interviews with architects that volunteer to be interviewed and have some experience with using VR ay work in the past. The aim of this study is not to look at budgetary or organisational concerns and will instead only look at the technical explanations (hardware and software). The choice to only interview architects familiar with VR was done to get a sample that can answer the questions adequately. The choice to focus only on technical limitations and solutions was made to limit the scope of this study, otherwise the researcher runs the risk of the study being too unmanageable.

2 Theory

2.1 The architect role

The study will be conducted by interviewing building architects. The role of an architect is that of the designer, that is done by coming up with suggestions of how the different aspects of the building will look like, in the form of drawings texts and models (Nordstrand, 2008). Architects must adhere to the functionality, aesthetics and regulations when designing a building, as well as the demands of the person or organisation that commission the building (Nordstrand, 2008). Architects usually work in big groups where each person has a smaller responsibility, that later gets combined to finish the project (Nordstrand, 2008). Architects use many tools to communicate their ideas and designs to costumers, other architects, and other project group members. The tools that are often used for this by architects are methods like handmade sketches, computer-generated sketches, photos, perspective drawings, maps, descriptions in text and computer-generated models (see figure 2) (Saade, 2018). This represents a risk for the architect, because all those methods of representation involve the architect choosing what the consumer is going to see. This risk here is leaving out information that the customer could be interested in but will not be able to explore because the architect did not include it in the representations (Edwards, et al., 2015).

Figure 1: 3D model (Saade, 2018)

2.2 The architectural design process

The architectural design process is an iterative process, where the design ideas are suggested, represented, evaluated and then altered (Zikic, 2007). According to Révai (2013), architectural design can be divided into three phases, the design process, system design and detail design, those phases can run parallel (see figure 3). During the design phase, the general shape and dimensions of the building are decided (Bergman, 2017). The next phase is when the bearing construction system and other installations are designed (Nordstrand, 2008). In the last step the final details are decided on, those include colour choices and other small details (Révai, 2013). The concepts that the architect comes up with during the design phase are communicated through various means, and communication can take many forms, such as verbal representations, drawing text or small-scale

models (Zikic, 2007). Scale models are a good way to that the designers can convey their ideas, but the negative aspect with them is that they cannot offer a good understanding of scale, in virtue of them being smaller than the actual building (Henry, 1992). Another way that designers can convey their ideas are computer models, they are a relatively new way of presenting concepts and have the advantage over scale models in the ease of making modifications. However, computer models lag behind scale models by not offering depth perception in virtue of them being usually represented on Two-dimensional screens. (Henry, 1992). VR has the potential to resolve those issues.

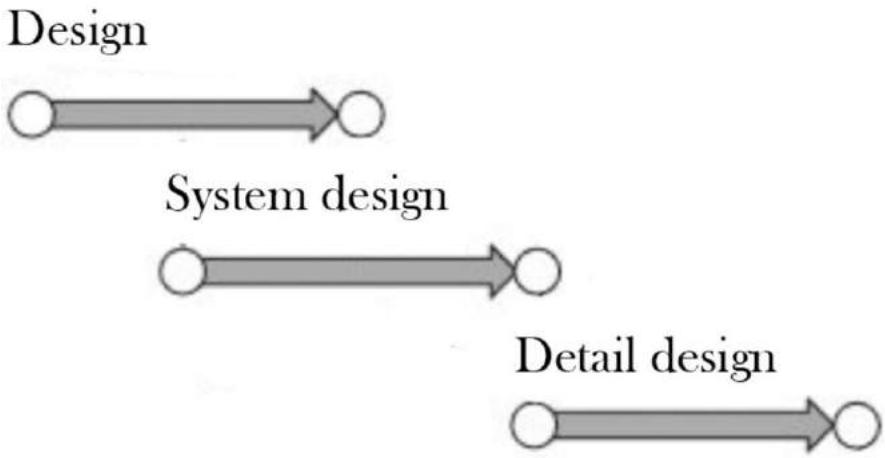

Figure 2: The design process, inspired by (Nordstrand, 2008)

2.3 VR

VR is a relatively new technology that has been used in a wide range of fields, such as education, design, and gaming, among other fields (Cipresso, 2018). VR first emerged in the 1960s and the first commercial tools started getting used in the 1980s. Modern VR equipment usually consists of an HMD (head mounted display) that uses stereoscopic head-tracking, sometimes in addition to hand tracking devices to simulate depth perception and the feeling of presence (Cipresso, 2018). See figure 1 for an example of modern VR equipment. This creates a more immersive experience for the person using the headset, compared to traditional two-dimensional methods of viewing media, such as paper, digital pictures, and videos (Radianti, 2020)

Figure 3: Example of VR equipment, HTC Vive (Borchert & Skoglund, 2017)

2.4 Application and benefits of VR in the design process

VR in architecture is used as a visualization tool (Woksepp, 2007). VR offers a deeper level of understanding and information, that help with the design process and more specifically decision making. VR is used during multiple phases of the design process. During the early stages of the design process, the technology is used inspect aspects like form and colour and gain an understanding in a better way compared to the traditional ways of representation (Bergman, 2017). The same applies for the later phases of design when details that are more minor are decided on. Another way that VR is used currently is conveying design ideas to co-workers and other project members (Bergman, 2017). There are several benefits that come with using the technology during the design phase. Among those benefits are gaining a better understanding of the end product. That in turn enables better decision making, saves time and money (Bergman, 2017). VR models can also be easily modified in addition to offering depth perception and scale understanding (Zikic, 2007).

2.5 VR creating depth perception

The basic way that VR devices create the illusion of depth is by having each eye see the same picture from a slightly different angle, this is called “stereoscopic display” (Jamiy et al., 2019). This can be done in many ways, but the most popular way and the one that this study is going to examine is by using an HMD (head mounted display). Where the viewer wears a headset that covers the eyes, and two screens show separate images to each eye. The headset also has magnifying lenses to magnify the screens. (Henry, 1992). This method reproduces some of the binocular vision cues. This method however is not perfect, as it does not accurately reproduce all the vision cues, and can lead to expertise feeling uncomfortable for the user (Jamiy et al., 2019)

2.6 Hardware and software requirements for using VR in architecture

VR is a technology that allows for users to freely navigate a virtual three-dimensional environment and interact with virtual objects in real time (Woksepp, 2007). According to Woksepp (2007), a virtual environment (VE) can be experienced by using different methods that come with varying degrees of immersion. This includes common computer monitors, a 3D stereoscopic display, and Head mounted displays in the case of what is called fully immersive experiences. This study will be focusing on HMD based virtual reality systems, because those are currently the most popular (Renganayagalu et al., 2021). The HMD based VR systems incorporate a headset that functions as both an input and output device at the same time. Inputs for the headset include head motion tracking sensors, gyroscopes, and accelerometers (Renganayagalu et al., 2021). The system also usually includes input devices such as gloves, or regular gaming controllers, and sensors that track the position of both the headset and the controllers. The simulation is ran by some type of computer that sends an output in the form of sounds and images to the two screens in the headset (see figure 4). (Renganayagalu et al., 2021).

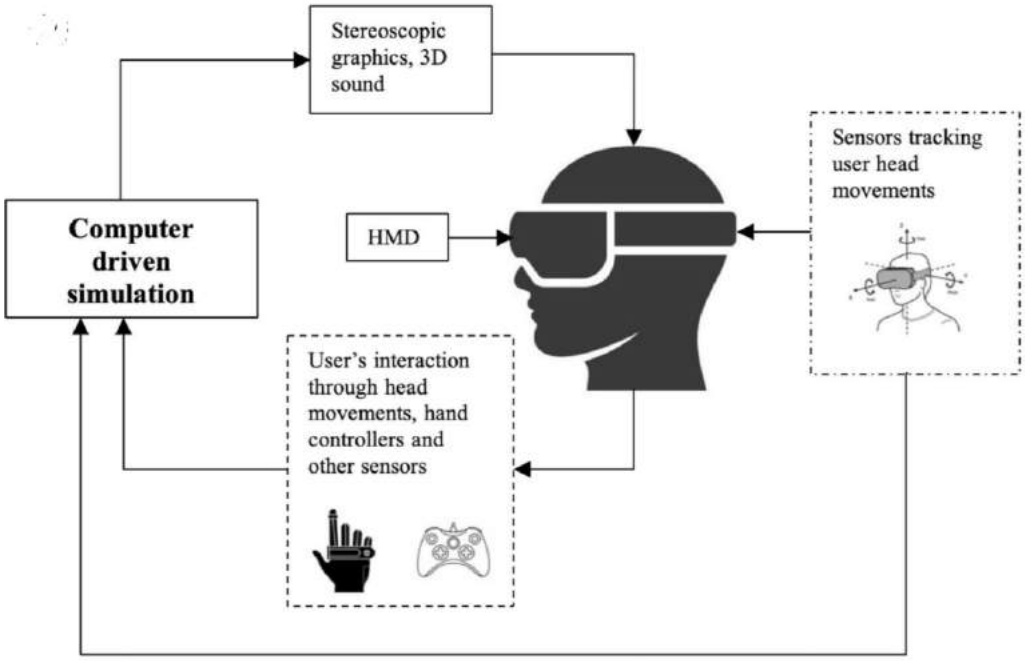

Figure 4: A sample VR HMD system (Renganayagalu et al., 2021)

2.7 Current challenges facing VR in architecture

According to Dashti & Vasques (2020), the problems facing VR in architecture and more broadly the AEC-industry mostly organisational and budgetary. The technology is generally viewed by managers as too expensive in addition to them lacking knowledge about VR. Managers also believe that the technology has not matured enough for wide use in those industries (Dashti & Vasques, 2020).

Because VR is not an established technology, its implementation requires new hardware and software to be invested in. This does not only include the Headset, controllers, and tracker, but also a computer powerful enough to run VR (Norlund & Rask, 2016). Other problems include the requirement to train staff to be able to use VR, and the risk of motion sickness. The strength and occurrence rate of motion sickness depends partially on the screens refresh rate and screen resolution (Norlund & Rask, 2016).

3 Method

3.1 The research approach

The approach this study takes is a combination between the deductive and inductive methods. Those two research methods are the opposite of each other (Yin, 2011). The deductive methods aims to extrapolate and work its way from theory to the correct data. In contrast to that is the inductive method, it works its way from correct data to a general theory (Yin, 2011).

This study uses a deductive approach to for a research method and strategy. The inductive approach is used to extrapolate generalizations from the data collected by the interviews.

3.1.1 The qualitative method

According to Buessto et al. (2020), qualitative research is formally defined as *"the study of the nature of phenomena, including their quality, different manifestations, the context in which they appear or the perspectives from which they can be perceived, but excluding their range, frequency and place in an objectively determined chain of cause and effect"*. The data used in qualitative research generally comes from words rather than numbers. According to that same paper, the reason that qualitative research is used is because quantitative research cannot answer some questions. The most common methods to do qualitative research are document studies, observations, semi-structured interviews and focus groups (Buessto et al., 2020).

3.2 Literature study

A literature study is a data gathering method in a subject (Björklund & Paulsson, 2012). To gain more information about the study subject, various studies were investigated. This was done by searching relevant terms on google scholar between the period 2021-10-05 and 2021-10-29. The reading of previous research served at first as a guide for directing the purposes and aims of this study, by looking into what questions have already been investigated and what is missing and needs further investigation (Björklund & Paulsson, 2012; Bryman, 2012). Another purpose for the literature study was to gather more understanding for the subject at hand, to be able to formulate the question in an effective and relevant way, thereby serving as a guide to direct the study (Björklund & Paulsson, 2012; Bryman, 2012). The details that were investigated are things like how VR works, hardware, and software trends. The final objective of the literature study was to look into what other studies have found when asking similar questions, to compare and get context on what to expect to get as a result for this study. The terms used to search for the studies on google scholar include *VR in architecture, Digitalization in architecture, the architect role, VR, VR AEC.*

3.3 Semi-structured interviews

Semi-structured interviews are a type of qualitative research that involves an exchange of a non-formal nature. Where the interview uses open ended questions for the sake of delving into the motivations and desires of the person interviewed (Buessto, 2020). In this type of interview, the pre-prepared questions serve as a guide for setting the topic. One advantage that this type of research style has over written questionnaires is the ability to delve into motivations on the part of the

person interviewed that the researcher did not anticipate (Buessto, 2020). That is a consequence of the back-and-forth nature of the interviews.

3.3.1 Choosing interview subjects

The selection for the interviews was done by contacting architecture companies located in various locations in Sweden through emails. The choice to use E-mail as the contact tool was due to convenience as the people to be interviewed lived far apart from each other, and the researcher. While in contact with those companies to obtain the interviews, the researchers inquired if the architects in the company generally had experience with VR at work. If the company employees generally had little or no experience with VR, no further pursuit was attempted to plan interviews. However, if they generally had some experience, then the researcher asked for the interviews. This selection process was done, because the type of respondent that were required for this study was the type with at least some experience with VR. If the respondent were not familiar with or had experience with VR at work, they would likely not be able to provide good answers for the study questions. In all cases the researchers had contact with one employee in the company that served as a representative and sent out the emails internally in the organisation. The people that were selected for the interviews volunteered to have the interview. They were contacted individually, and a date was set up for a digital meeting.

3.3.2 Performing the interviews

The interviews were done over the internet, using the computer program “zoom”. The interview method was chosen to be over the internet as opposed to in person because of two main reasons. The first reason being is the Covid-19 pandemic, the ideas was that performing interviews digitally would not expose the researcher or the interview subject to an additional risk factor for getting the infection. The pandemic also made it so that many of the interview subjects were working from home, so interviewing them would be much harder.

The other reason for performing the interviews over the internet was that the architects interviewed were from different cities, and not having to travel made the interviews much easier. The researcher started the interview off by introducing themselves and thanking the interview subjects for their time.

Then the purpose of the study was disclosed to help the architects being interviewed give good answers in virtue of them understanding the reasoning behind the questions. Later the researcher gave some examples of how VR can be useful in the context of the architecture role and sited some studies that show the usefulness. When it came to the interview questions, they were all open ended. The first few questions were warm up questions and asked the interview subjects to talk a little about their role and describe the level of familiarity they had with VR (see appendix 1) for the questions. All the scripted questions were asked and when the person being interviewed said something that the researcher thought would be interesting to delve deeper into the, the interviewer asked them to elaborate or give further explanation.

The interview subjects had ample time to answer after the question was asked, this is to ensure that they could reflect on the question and give a good answer (Doody & Noonan, 2013). All the interviews were done with architects working for white architecture in Örebro, Västerås and Umeå Sweden. There was a total of 6 interviews done (see table 1) for an overview of the interviews. All the interviews were recorded using a program called “open broadcast software”.

Respondent	Role	Interview type	Date	Office
R1	Administrative landscape architect	Digital	2021-10-18	Örebro
R2	Administrative residential architect	Digital	2021-10-18	Örebro
R3	Residential architect	Digital	2021-10-19	Örebro
R4	Administrative residential architect	Digital	2021-10-20	Västerås
R5	City planning architect	Digital	2021-10-20	Örebro
R6	Residential architect	Digital	2021-10-21	Umeå

Table 1: Respondent's role, office and date of the interview

3.4 Data analysis

The guideline followed to do the data analysis was based on Yin (2011). This method of analysis is called thematic analysis, and there are five main stages, compiling (1), disassembling (2), reassembling (3), interpreting (4) and concluding (5) (Yin, 2011). The process of going through those steps are not linear and is instead an iterative process, as indicated by the two way pointed arrows (see figure 5). This method of analysis is a flexible method that allows for understanding large amount of qualitative data, and combine data from sperate (Saunders, et al., 2016). A data base is firstly created by extracting chunks of information from the empirical data, and then sorting those chunks into different categories depending on the context (Yin, 2011). The data base of the sorted data chunks is looked through to identify themes and patterns, the chunks are also resorted if new patterns and themes are discovered (Yin, 2011). The data is later interpreted and from this, conclusions can be drawn to answer the research questions (Yin, 2011).

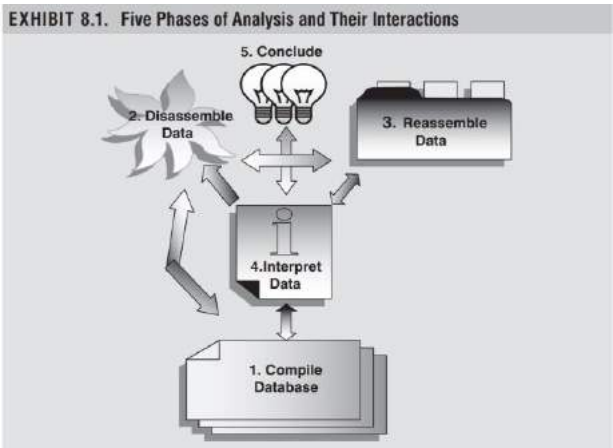

Figure 5: The stages of analysis (Yin, 2011)

The recordings were listened to multiple times and then notes were taken for each interview. The audio recordings were turned into a script, and what was included in the script are either parts of the interview that answered the research questions or offered some context understanding that was thought to be relevant to answering the research questions. The script was written by translating the Swedish audio to written English (see appendix 2).

Later the researcher went through the script and assigned codes to all the parts of the interview included in the script. Codes are brief description of what is being talked about in that part of the interview. An example of a code could be something like the word “headset weight” if the person being interviewed is talking about how the weight of headset makes it hard to use. This step included looking through the codes and establishing connections to find the different themes and patterns of what is being talked about. An example of a theme could be a category like “picture clarity” where all the codes that relate to the picture quality are put into that theme.

Themes are reviewed by the researcher. Things that were investigated are how the contents of the themes cohere together. If the contents of a single theme were too different, it meant that the theme was too broad and needed to be split into two or more themes. This was an iterative process where the researcher continuously tried to find all the possible connections and modifies them until the final order of the themes is settled on. Finally, with the help of the themes established, conclusions were drawn.

4 Findings

The hardware used for all the respondents is the HTC Vive from Valve

4.1 Hardware obstacles

4.1.1 Processing power requirement

An opinion that was held by some of the architects being interviewed, is that a major hindrance in using VR in architecture is that it requires a powerful and expensive computer to run. All the organisations interviewed, had one common room where the VR equipment was set up and that is where the shared computer was. This way the respondents could not use their own computers and that in their mind made it cumbersome to use VR daily.

"… Because we need to have a powerful computer that not everyone has access to, we have not gotten to the point where VR is used every day." (R1)

The main issue here seems to be that because a powerful computer is needed to run VR, and those tend to be both non-portable and expensive, they are not given to employees as personal computers. And this makes it so that viewing a model in VR requires additional steps, like exporting files between computers, starting, and updating the VR system on that separate computer and the person using VR having to leave their workspace and moving to where the stationary computer is. Those extra steps take time that can be spent doing other things. The other issue is that the headset could be taken home and used there, as they would also have to have a powerful computer at home.

"In the Future I see VR being very common, but it has to be convenient and easy to use, because everyone in the building industry is stressed out and does not have much time" (R4).

4.1.2 Motion sickness

Several of the respondents that were interviewed, expressed that an issue holding back the usage of VR in architecture is motion sickness. That is the feeling of disorientation, dizziness, or sickness. According to the respondents, motion sickness does not necessarily affect everyone, and that some people are more effected than others. The issue is that if a customer or a designer is prone to feeling sick while using VR, then they will be very averse to using it.

"You can sit down with a consumer and show them the house in VR, but if they feel ill, you have probably lost them, and they will not use VR anymore." (R5)

The respondents also expressed that the possibility of a person you are doing a presentation for will feel ill, must be considered. That is why it is hard to rely on VR as the only method of presentation, and other methods must be prepared.

4.1.3 The weight, size, and portability

Some respondents expressed that a big issue for them is the weight and the size of the headset. One of the respondents worked from home at the time of the interview and they thought that a big obstacle for her using VR is that she could not take a headset home.

"I could carry my computer home with me from work, but I would not want to do the same with a big headset and all the other equipment that are needed." (R2)

The things here expressed to be relevant were the headset size, that the shape and weight of the headset did not allow it to be stuffed in a bag or carried. Another problem was the all the additional components that would also have to be transported, namely the tracking sensors and the controllers.

"The lack of portability, the need for tracking cameras and everything else makes it not very useable." (R6)

The lack of portability also leads to the problem of not being able to have meetings with customers while using VR as a tool outside of the architecture office.

4.1.4 Isolation from the outside world

Some of the respondents mentioned that a problem for them is being isolated from the people around them when using VR. There are two main issue, the first one being that the headset blocking the user's vision such that they can not see and are less able to interact with people around them. This impedes the ability to have social interactions and communicate ideas to other people.

"You are also isolated because you can't see much of what is going on outside because the headset blocks you vision." (R2)

The other issue is that the design of the headset makes it so that usually, only one person can be present in the VR environment. This makes it so that if a model is being shown to multiple people, then they can not all experience the model and have a shared experience.

"… It feels like another huge major problem is that you are isolated when using VR. Other people to get the same experience when they are sitting next to you." (R2)

4.1.5 Movement restrictions and small spaces

The lack of space was a theme that was brought up multiple times. Some of the respondents expressed that being able to walk around naturally without running into a wall or other objects in the room was valuable to the experience. They thought that the possibility of running into objects and the lack of freedom in movement served as a hindrance for immersion. The alternative method used today according to the respondents was teleportation, that is changing position by teleporting the desired spot in the VR environment. This method of movement does not feel natural and serves as a hindrance for immersion. Another related issue that was brought up is that the people using VR in the VR room have to move out furniture and other objects and that could also be time consuming.

"Often a hindrance for us is not being able to walk and having to teleport instead because of the small room we are in." (R5)

4.1.6 Hardware setup and inconvenience

A problem that was brought up by the respondent was the set-up process hardware wise when starting the system. VR uses many components, and they must be connected to each other and the computer to use VR, this process can be time consuming and could potentially not work.

"Maybe you want to show something in a meeting that is an hour long, and if it takes 20 minutes to set up the hardware, you feel that it's not worth it." (R3)

Another issue that was brought up was the fact the controllers for the VR system had to be recharged often, and that people forget to charge them after use. This creates an additional hindrance for daily use, as the activity that was going to be done using VR would have to be halted until the controllers have recharged. This is a big issue if the activity has a rigid time frame and can easily be postponed, like a client meeting. One of the respondents mentioned that this issue is partly due to human error, as people forget to plug in the controllers after they are done. It is worth mentioning here that the headset that is used by all the architects interviewed had controllers that had to be recharged, and that there are other headsets that have swappable batteries.

4.2 Software obstacles

4.2.1 Programs that are not designed to facilitate social interaction

This issue is similar to the isolation problem that is brought up in the hardware section of the findings. The programs that the respondents have access to when viewing their models in VR are designed to be single player only. This again makes it so that only one person can view and interact with the VR environment, and other people cannot get the same experience.

"All the programs feel isolated, and you can't view the models with other people." (R6)

4.2.2 Model import

Although most of the respondents expressed that importing a model from a sketching program into VR was an easy and non-cumbersome process, some did not. Some of the respondents expressed that the model import process was somewhat of a hindrance, because often they could not successfully import the model and had to get help from someone more knowledgeable.

Another issue that was brought up was adding detail into the VR model, so it feels more realistic. That process was time consuming and was often not worth the effort because of the time it is expected to take.

"The importation process itself is easy, however adding a lot of detail to a VR model is very time consuming." (R1)

4.2.3 Updates, set up process, and convenience

Several issues were brought up that were related to the ease of use and convenience. One of the respondents expressed that a big issue for him and a major reason he did not use VR often was the time it took to update the software. Because VR was not used that often in the office, updates would accumulate and that's why it takes a long time.

"VR is not used that often, and that causes big updates every time you start the system, those updates take a lot of time." (R3)

Additionally that same respondent mentioned that another big problem is that every person in the office has their own login information and that it's not enough that the software gets updates by one person once. Each person with a login must download and install an update. The issue with the setup process being complicated was also brought up. Not everyone in the office knew how to set the system on the software side, and often they had to ask for help from someone more experienced.

4.3 Hardware related issues remedies

4.3.1 Feeling ill

Generally, most of the respondents that brought up motion sickness as a problem, did not have a solution. They clarified that they did not know enough about VR and how it works to know what causes the feeling of motion sickness. However, one of the respondents suggested having a button on the headset, that when pressed takes the user out of the experience immediately.

"Having button on the headset that takes you out of the experience immediately would be helpful with feeling ill." (R6)

4.3.2 The set-up process and convenience

On this front many suggestions were given by the participants. A general sentiment to deal the hassle of setting up the system was less parts. The respondents meant that if the system had less parts, then it would not take a lot of time to set up and additionally there is less that can go wrong or fail. Another suggestion that is related is to have less cables, the idea was that this as well would make the set-up process easier and would also increase the level of immersion because the user would not have to be concerned with tripping over the cable or pulling it out. On that note one suggestion was having the wired connected to the headset hang from the ceiling, so it would be less likely to trip over them.

"… It would help out a lot if setting up the equipment was much easier, less cables, and less parts." (R2)

When it came to the problem of charging the controllers, one of the respondents had an idea that involved having more wires. He suggested having the controller connected with wires, that way it would not have to be recharged. Another idea was having charging stations where controllers would be docked, and that way it would be easier to charge them.

4.3.3 Portability

Most of the respondent that brought up the issue of portability were united on the idea that the headset should not require a computer to run, instead they preferred a standalone headset. This would help with many issues, and among them the portability issue. The idea was that if the headsets were standalone, there would be the opportunity to use them from home in case the respondents were not at the office and were working from home. Standalone headsets would also allow the architects to take them with them when having a client meeting that is not in the office. A portable headset was also suggested as a solution to VR needing a powerful computer.

"… The headsets could get smaller and not need to be connected to a computer, that would make it much easier to move around." (R5)

Another solution to the portability problem was having the headsets be much lighter and smaller, this in turn would also help with the transportation.

4.3.4 Space restrictions

This issue of small spaces was another issue that the respondent generally did not offer a solution to. However, one of the respondents suggested the company they worked for renting a local where VR could be set up, and that in turn would offer more freedom in movement.

4.4 Software related issues remedies

4.4.1 Social interactivity

The solution suggested here was having viewing software that can be accessed by multiple users at the same time. This in the opinion of some of the respondents would help facilitate social interactions and make VR more usable in more situations.

4.4.2 Updates, set up process, and convenience

In this department many solutions were given. When it comes to update management, it was suggested to either have less updates, or having the updates apply to all the accounts. This way if one person updates their profile, everyone else gets the update and this would save a lot of time and make VR usable in situation where time is of the essence.

Other respondents suggested having the VR user interface be user friendly and easy to learn, that way architects would not have to consult other people to get help with their own project. This is related to the process of adding detail and importing the model so VR, automation of this task would make VR more usable.

"VR needs to be usable enough so that building a virtual environment is not a task that someone else has to do and it not becoming a project that cost money. Instead, it should be a thing where anyone can make that environment easily." (R1)

The idea was that by streamlining this process, it would feel less like a whole new project that has to be done by someone else. That would in turn make it more justifiable to use VR on daily tasks.

4.5 Potential future use for VR in architecture

4.5.1 Virtual meetings

Some of the respondents suggested that a way VR could be used in the future that would be useful, is conducting meetings. The idea there was that the architect could have virtual interviews with the other project members from all over the country. This would also help with meetings if someone were working from home.

"… a future use of VR could be having Virtual meetings with customers in other parts of the country and be able to explore the virtual building with them and talk in that virtual space." (R2)

Other respondent suggested the same idea and mentioned that having meetings with the whole project group in VR would help everyone be more involved and informed on the decisions and the progress of the project.

4.5.2 VR in conjunction with AR

Multiple respondents indicated that they wanted to see VR in the future being used in conjunction with AR. The idea that was expressed is being able to go to a physical place where building is planned and be able to see what the place would look like after the building has been built. This would according to some of the respondents be a very useful method to make better decisions and gain more understanding of the project. Another related idea that was suggested is the user being able manipulate the environment around them.

"A future use for VR is in combination with AR, you could be in a place and look through a headset to see what it would look like if we removed or added a building here." (R5)

Another idea that was suggested is being able to see in AR how the plant life evolved over time, when someone is in the planned building site.

"… a way that VR can be used in the future is to simulate and visualise change over time, where a person is standing there and can see how a place would develop, I can see that being useful to show how trees and plants develop well after the building process is over." (R1)

4.5.3 VR as a creative tool

Most of the architects interviewed wanted to see VR in the future being used as a creative sketching tool and not merely a viewing tool. A subset of the respondents that suggested adding sketching capability to VR also suggested the functionality of being able to sketch and work on the same model with other architects at the same time. The idea was that being able to cooperate in VR and work together has a similar effect to modifying a physical model, where more than one architect works on the physical model at the same time.

"… a way to use VR in the future would be to be able to design and view models together internally, that way everyone can be more involved." (R4)

4.5.4 VR a public communication tool

One of the respondents wanted to see VR in the future used as way to communicate to the public. The idea was that big crowds of citizens would all be able to participate and view the design plans being worked on by the architects. This could be done by either having many VR headsets distributed to the viewing audience or have a VR technology that does not require a headset. The respondent thought that this would make the design process, especially when it comes to city planning more democratic. Citizens would be able to participate in the design process and influence the architect's decisions. This would be a way that the general public would have an easier time understanding designs in comparison to the traditional ways that designs are conveyed to the general public, like drawings.

"One thing VR could be used for is convey ideas to the general public, where big crowds of people can see what a place would look like to make the process of change more inclusive, democratic and get citizens more involved." (R5)

5 Analysis

5.1 Recurring problems

A problem that every respondent mentioned in some way, is the inconvenience of using VR to help with daily tasks. This study heavily suggests, that for VR to be used in a larger capacity in the architecture role, then the issue of inconvenience must be resolved. From talking to the respondents, it seemed that the issue of VR being time consuming was the biggest hindrance, and that is what for the most part causes VR to be used so infrequently. The problem of inconvenience according to the respondents are caused by a plethora of issues. The issues that cause inconvenience are the lack of portability, hardware/software set up process, model creation, and import. All those problems are consistent with the findings of Dashti & Vasques (2020). That study suggests that managers found VR to be a technology that has not matured yet. What is meant by immature according to Dashti & Vasques (2020) is that the technology is too cumbersome, hard to use and time consuming. The need for a computer to use VR was also reiterated by the respondents and this is consistent with the findings from Norlund & Rask, (2016).

5.2 Problems without clear solutions

One issue that was revealed by some respondents but generally did not have a solution associated with it is the problem of motion sickness. This might be because the reason motion sickness occurs with some people is technical in nature and requires background knowledge in areas that the respondents are not familiar with. To find a solution for this a future study would have to be done or investigate previous research on the cause of the issue. The finding that motion sickness is viewed as a problem that holds back the use of VR in architecture agrees with the findings of Norlund & Rask (2016). That study did not offer a solution for the problem, but states that the issue is partially caused by the screen resolution and refresh rate.

Another issue was that creating the digital models that would be used in VR was a time-consuming process. This issue as well did not have a clear solution that was offered by the respondents. This issue could be related to the findings of Norlund & Rask (2016), the study found that one of the challenges for VR in that field is that it is challenging to train staff to be able to use virtual reality. This could lead to the staff being undertrained and in turn partially explain why creating VR models is so time consuming.

For the problem of space restriction, a solution was offered, but that involved the company building bigger VR rooms or renting big locals. No solution was given that could be addressed by VR developers or manufacturers. In addition to that the solution were not related directly to the software and hardware.

5.3 Future use in architecture

According to the respondents, most of the ways VR could be used in the future are ways that help make VR a more social experience. Using VR as a meeting tool, a creative tool and a public communication tool all involved making it easier to both work with and convey ideas to people. That being the co-workers and the public. Communication seems to be the strongest motivator that the

respondent had in mind when suggesting ways that VR can be used in the future. This is consistent with older research that suggests that VR can make communicating to the general public and other project members easier, compared to traditional design presentation methods (Bergman, 2017).

The other motivator seemed to be using VR to gain better understanding of the projects that are being worked on, both during the design process and before it starts. Using VR in conjunction with AR was suggested because the respondent thought that they would make better decisions if they saw what the building looked like in the actual building site before the design process started. The other future use, that was being able to work and edit models inside a virtual space was suggested because the respondent thought it would help them gain a better understanding of the model. They also thought it helped them see mistakes more easily and correct them while in VR. Better understanding of design and decision making is a finding by an older study (Woksepp, 2007).

5.4 VR and time consumption

The result of this study suggests that inconvenience in the set-up process was the most common issue with VR for architects. The researcher suspects that this finding falls in line with the fact that the architectural design process is an iterative process (Zikic, 2007). This is because during the design process, the models get drawn, reviewed, and then altered, and this process can happen multiple times. This means that if VR is used to review a model by an architect, then the user would have to import the model and set up the system multiple times. This could lead to VR being time consuming, and using it being not worth the time investment if the iterative process is implemented.

5.5 VR as a communication tool

The theme of communication was brought up multiple times in the results of this study. Communication was brought up firstly as an area in the use of VR that needed to be improved by solving several hardware and software issues. Communication was also somewhat of a motivator when architects suggested ways that VR can be used in the future. The researcher suspects that the reason that explains communication being a motivator for the interview respondents is that the architectural design process tends to be a highly cooperative process, that involves big groups of architects (Nordstrand, 2008). Architects working in big groups is suspected to be specifically that explains the respondents taking issue with the VR software not facilitating social interactions. That is because the isolation makes it harder to work in bigger groups, because of only one person being able to experience the virtual world at a time. The cooperative nature of the architectural design process design process could also explain why some of the respondents wanted to see VR be used as a tool to facilitate virtual meetings. This would make it easier to communicate ideas quickly with co-workers and other parties that are involved in the process, even when they are not physically in the same place.

Another way some of the respondents wanted to see VR used in the future is as a mass communication tool, to convey design ideas to the public. This could be a result of the difficulties for non-architects to understand the traditional presentation methods used by architects (Henry, 1992).

6 Discussion

6.1 Research limitations

A factor that introduced a major limitation in this research is the coronavirus pandemic. The pandemic made it so that, in person interviews were impractical and therefor caused the interviews to be conducted over the internet. The interviews being conducted over the internet could have an impact on the results of the research. Firstly, the digital interviews introduce a sense of impersonality and that could affect the results of the study, by affecting the responses of the respondents. Another way that the pandemic could have affected the research, is that the pandemic could have made it harder to plan interviews by making architects less likely to be willing to participate in those interviews. Another issue that this research ran into is some of the respondents not being prepared and could not answer questions because the respondents have not considered the question before, and they did not get enough time to consider and reflect on the question during the interview. This could make it so that the interviews did not reveal answers to the research question that the respondents could have given had they considered the question before.

Another relevant factor is that all the respondents worked for the same company (white architecture). This skews the results of the research in the case that other firms have different ways they use VR, and those different ways are different in such a way that it is relevant to the answers to the questions. The interview respondents were from three different white architecture offices from around Sweden, but a possible issue is that four of the six respondents were all from the same office (Örebro), that could have also potentially skewed the results of the study in the case that some problems are specific to the Örebro office and vice versa.

The background of the author of the study and earlier knowledge could have had an impact on the answers of the interviews and the results of the study. An example is the way that the questions were asked, and the way the question is further elaborated on when the respondents did not understand the question and wanted further explanation.

Another factor that needs to be considered is the age of the studies that are cited. The study by Norlund & Rask, (2016), is a study that is 8 years old at the time of writing this paper. This could mean that the results of this study Norlund & Rask, (2016), are not relevant to the findings of this study. This is because the technology is evolving all the time. However, the type of headset used in the Norlund & Rask, (2016) study is the same as the ones used by the respondents interviewed in this study, The headset is the HTC Vive from Valve. The software used in the two studies could be different and this could have an impact on the comparison between the studies.

Another study cited in this paper is by Woksepp, (2007). This study could be outdated, and the results of that study could not be used to draw accurate conclusions in this paper. This study was chosen due to a lack of research on the current topic, especially when looking at the Swedish AEC industry.

6.2 Improving the research methodology

A way to improve this research when it comes to the methodology is performing in person interviews instead of digital interviews. This would remove the factor of impersonality and possibly alter the research answers. It is not clear however if removing the sense of impersonality would affect the results in a positive or negative way. Another altercation to the methodology is having more respondents, interviewing respondents that work for more companies with varying firm sizes

and interview respondents from a varied set of offices around the country. All of those altercation would serve to make the results of the study more generalizable over the set of all architects in Sweden. An altercation to the methodology that could be change the results dramatically and give better research answers is having the respondents review the interview question before participating in the interview, that way they could have more time to reflect on the question and be more prepared.

6.3 Future research

One possible area of research in the future, is the specifics of how VR can be used in the future in the context of the architecture role. This study revealed some general ways it can be used, but no specifics. Future research can investigate logistics, budgetary and organisational concerns when it comes to all the suggested future uses of VR. This area includes the question of what the specifications and features of the VR headsets that architects think would be ideal for using in virtual meetings. Another research question that is relevant in this area would be the estimated cost that would be associated with using VR in the ways that were suggested and if it is financially viable for architect firms to employ those new technologies on that scale.

7 conclusions

The research questions this study investigates are:

RQ1: What do the architects generally think are the technical reasons that explain why VR is not used to a higher extent in the architect role?

RQ2: What are the remedies and solutions to the problems highlighted in the first research question, that if implemented would result in an increase of usage of VR within the architect role?

RQ3: What do the interviewed respondents think are potential uses of VR in the near future when the VR technology has matured, and the technical problems have been resolved?

For the first question, this study suggests that what architects generally find to be the technical difficulties are the computer hardware requirements being too high and requiring a powerful dedicated computer. VR inducing a feeling of motion sickness in some people was also mentioned as an issue. Another issue was that the headsets and the software used creating a feeling of isolation. The headset creates a sense of isolation because it covers the field of view of the user and therefor makes it hard to communicate. When it comes to the software, it creates a sense of isolation because the programs does not allow for collaboration with multiple participants in the virtual world at the same time. Another issue that was brought up was that the headset and the other VR equipment are too bulky, heavy and are hard to transport. The issue of inconvenience was brought up both in the context of hardware and software. When it comes to inconvenience in the context of the hardware, the issue was the setup process taking a long time, requiring experience that not all the architects have, and the possibility of failure. When it comes to inconvenience in the context of the software, the issues were the process of importing the model from the modelling software to VR required some experience, as well as the task of adding detail to models being time consuming and the software update process also being time consuming. The final issue is the space restrictions.

According to the participants the solution for the problems or VR requiring a powerful computer, portability and the lack of convenience is a portable headset that does not require a computer or tracking sensors. That way it can be moved around easily and makes the set-up process easier from a hardware perspective. When it came to the issue of motion sickness, most of the participants could not offer a solution because they did not know what the cause was for some people experiencing motion sickness. One solution that was offered to partially alleviate the sickness problem is a button on the headset that once pressed takes the user out of the virtual experience. The solution offered to the issue of space restriction is the company renting or buying big locals where the experience could be had, that way the user would have a greater freedom to move around. And finally, the solution suggested to the hindrance of lacking social interactivity was viewing programs that are multiplayer enabled, that allow for multiple users to be in the virtual environment at the same time.

Many suggestions were given by the participants on how VR could be used in the future in a way that would be useful. One suggestion was VR being used as a long-distance tool for meeting and viewing designs. Another way was VR being used as a creative tool, to edit and design models while in the virtual space, some participants even suggested having the ability to create models in the with other users simultaneously. VR being used in conjunction with AR was also suggested, where the user could visit a place be able to add or subtract buildings from the environment and see how the environment changes. And finally, a suggestion was using VR as a mass communication tool, to help designers communicate with the general public.

The Goal of this study was to serve as a guide for the manufacturers and developers of VR to help optimize the technology an make it more usable in the context of the architect role.

The Aim of the study is considered by the researcher to be reached. This is because the study succeeded in establishing several technical problems that cause the low usage of VR in architecture, according to the architects interviewed. Those problems related to both the hardware and software of VR. Clear solutions to some of those problems were also established, as well as ways that VR can be used in the future according to architects.

The aim of this study is also considered to have been reached by the researcher. Because a clear set of problems, solution, and ways that VR can be used in the future has been presented in this study. That information could be used by manufacturers and developers of VR to further optimize the technology for that specific field. The hardware issues, solution and suggestions can be specifically used by VR manufacturers. The software related issues, solution and suggestion can be used by the software developers.

Most of the changes, that are suggested in this study will likely not have the potential to be implemented with the hardware and software being used in that field currently. Instead to implement those changes new hardware and software will likely be required.

8 References

Bergman, E. (2017). Framtidens teknik för arkitekter. En studie om hur VR kan integreras på arkitektkontoret. [Bachelor's thesis, Mid Sweden University]. DiVA. https://www.diva-portal.org/smash/get/diva2:1392016/FULLTEXT01.pdf

Björklund, M. & Paulsson, U. (2012). Seminarieboken - att skriva, presentera och opponera (2nd ed). Studentlitteratur AB.

BORCHERT, L., & SKOGLUND, S. (2017). Virtuell verklighet för att förbättra arkitekturen-En rapport om VR som verktyg på arkitektkontor. [Bachelor's thesis, Chalmers Technical University]. Chalmers open digital repository. https://odr.chalmers.se/handle/20.500.12380/251474

Busetto, L., Wick, W., & Gumbinger, C. (2020). How to use and assess qualitative research methods. Neurological Research and Practice, 2(1). https://doi.org/10.1186/s42466-020-00059-z

Cipresso, P., Giglioli, I. A., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and Augmented Reality Research: A network and cluster analysis of the literature. Frontiers in Psychology, 9. https://doi.org/10.3389/fpsyg.2018.02086

Dashti, B. Roberto, V. (2020). Exploring use and perception of augmented and VR in the Swedish AEC industry. [Bachelor's thesis, Royal institute of technology.]. DiVA. http://kth.diva-portal.org/smash/get/diva2:1458295/FULLTEXT01.pdf

Doody, O., & Noonan, M. (2013). Preparing and conducting interviews to collect data. Nurse Researcher, 20(5), 28–32. https://doi.org/10.7748/nr2013.05.20.5.28.e327

Edwards, G., Li, H., & Wang, B. (2015). Bim based collaborative and interactive design process using computer game engine for general end-users. Visualization in Engineering, 3(1). https://doi.org/10.1186/s40327-015-0018-2

Virtual reality market size & share report, 2022-2030. Virtual Reality Market Size & Share Report, 2022-2030. (2021). Retrieved January 21, 2022, from https://www.grandviewresearch.com/industry-analysis/virtual-reality-vr-market

Teklemariam, H. G., Kakati, V., & Das, A. K. (2014). Application of VR technology in design education. In DS 78: Proceedings of the 16th International conference on Engineering and Product Design Education (E&PDE14), Design Education and Human Technology Relations, University of Twente, The Netherlands, 04-05.09. 2014. https://scholar.googleusercontent.com /scholar?q=cache:yCr8geJ71akJ:scholar.google.com/+Application+of+VR+technology+in+design+education.+&hl=sv&as_sdt=0,5

Henry, D., & Furness, T. (1992). Spatial perception in Virtual Environments: Evaluating an architectural application. Proceedings of IEEE Virtual Reality Annual International Symposium. https://doi.org/10.1109/vrais.1993.380801

El Jamiy, F., & Marsh, R. (2019). Survey on depth perception in head mounted displays: Distance estimation in virtual reality, augmented reality, and mixed reality. IET Image Processing, 13(5), 707–712. https://doi.org/10.1049/iet-ipr.2018.5920

Lavikka, R., Kallio, J., Casey, T., & Airaksinen, M. (2018). Digital Disruption of the AEC industry: Technology-oriented scenarios for possible future development paths. Construction Management and Economics, 36(11), 635–650. https://doi.org/10.1080/01446193.2018.1476729

Nordstrand, U. (2008). Byggprocessen (4th ed). Liber.

Norlund, A., Rask, Lisa. (2016). Virtual reality som presentationsverktyg för arkitekter. [Bachelor's thesis, Lunds University]. Libris. http://libris.kb.se/bib/19931733

Renganayagalu, S. kumar, Mallam, S. C., & Nazir, S. (2021). Effectiveness of VR head mounted displays in professional training: A systematic review. Technology, Knowledge, and Learning, 26(4), 999–1041. https://doi.org/10.1007/s10758-020-09489-9

Révai Ervin. (2012). Byggstyrning (4th ed). Liber.

Roupé, M. (2013). Planera verkligheten i Virtual Reality. Kort rapport om forskning, nr 3 Chalmers technical University. https://www.cmb-chalmers.se/wp-content/uploads/2015/10/Roupe_2013_ webb.pdf

Saade, A. (2018). VR som arkitektoniskt kommunikationsverktyg, Realtidsvisualisering i designprocessen. [Master's thesis, Lulea University of Technology]. DiVA. http://www.diva-portal.se/smash/get/diva2:1199247/FULLTEXT01.pdf

Saunders, M., Lewis, P. and Thornhill, A. (2016). Research methods for business students (7th ed). Pearson Education.

Thabet, W., Shiratuddin, M. F., & Bowman, D. (2002). VR in construction: a review. Engineering computational technology, 25-52. http://doi.org/10.4203/csets.8.2

Vienne, C., Masfrand, S., Bourdin, C., & Vercher, J.-L. (2020). Depth perception in virtual reality systems: Effect of screen distance, environment richness and display factors. IEEE Access, 8, 29099–29110. https://doi.org/10.1109/access.2020.2972122

Woksepp, S. (2007). Virtual reality in construction. Tools, methods and process. [Doctoral thesis, Lulea technical University]. DiVA. http://www.diva-portal.org/smash/get/diva2:999878/FULLTEX T01.pdf

Yin, R. K. (2016). Qualitative research from start to finish (1st ed). Guilford Press.

Zikic, N. (2007). Evaluating relative impact of VR components screen size, stereoscopy and field of view on spatial comprehension and presence in architecture (Doctoral dissertation, Pennsylvania State University). http://citeseerx.ist.psu.edu/viewdoc/download?doi=1 0.1.1.527.607&rep=rep1 &type=pdf

Yessios, C. I. (1987). The computability of void architectural modeling. New York, pp. 141-172. http://papers.cumincad.org/cgi-bin/works/Show&_id=caadria2010_039/paper/65d7

Appendix

Appendix 1- interview questions

Warmup questions:

In Swedish- Hur skulle du beskriva din arbetas roll?

Translation- How would you describe your work role?

In Swedish- Hur mycket kontakt har du haft med VR utanför jobbet?

Translation- How much contact have you had with VR outside of work?

In Swedish- Hur mycket kontakt har du haft med VR på jobbet?

Translation- How much contact have you had with VR on the job?

Study questions:

In Swedish- Vilka Hårdvara relaterade hinder tror du finns idag för VR i arkitekturrollen?

Translation- What are the hardware related hindrances do you think exist today for VR in the architect role?

In Swedish- Vad tror du är de bästa lösningarna till de problemen?

Translation- What do you think are the best solutions to those problems?

In Swedish- Vilka mjukvara relaterade hinder tror du finns idag för VR i arkitekturrollen?

Translation- What are the software related hindrances do you think exist today for VR in the architect role?

In Swedish- Vilka Hårdvara relaterade hinder tror du finns idag för VR i arkitekturrollen?

Translation- What are the hardware related hindrances do you think exist today for VR in the architect role?

In Swedish- Vad tror du är de bästa lösningarna till de problemen?

Translation- What do you think are the best solutions to those problems?

In Swedish- Hur används VR i arkitekturrollen idag?

Translation- How is VR used in the architecture role today?

In Swedish- På vilka sätt kan VR användas i framtiden på ett sätt som skulle vara användbart inom arkitekturrollen?

Translation- What are some ways VR can be used in the future in a way that would be useful within the architecture role?

Appendix 2- interview summery

R1

“We stopped using VR for a while, maybe the reason is covid sense we could not meet”

“From my perspective we have not used VR extensively”

“I have not had much contact with VR outside of work, because to run VR, you need a powerful computer”

“It takes a lot of computer power to run VR and that is a big drawback”

“Because we need to have a powerful computer that not everyone has access to, we have not gotten to the point where VR is used everyday”

“In our office we have a small room that does not allow for free movement, where u feel like you are going to fall over a chair when using VR”

“The space is a major hindrance at my office”

“A way to fix the space issue is to have dedicated rooms, where u can be more free when moving around”

“Another major hindrance is people feeling ill, when using VR”

“Not everyone can use VR because of the problem with feeling ill”

“I don’t know how to fix the problem with feeling ill”

“Enscape makes it really easy to import and export models from sketching programs to VR”

“The importation process itself is easy, however adding a lot of detail to a VR model is very time consuming”

“VR is used a lot in analyses, you can experience the feeling of thing you sketched. You can feel the scale how”

“VR is useful for shadow analysis, to see how shadows and light interact. VR make give you a much better feel compared to traditional viewing methods”

“VR is very good at conveying the idea to the consumer, because many people can’t understand drawings.

“a way that VR can be used in the future is to simulate and visualise change over time, where a person is standing the and can see how a place would develop, I can see that being useful to show how trees and plants develop well after the building process is over”

“a development that would be exiting is if VR is less specialised, where anyone can pick up a program and build whatever they want t in a simple way and later view it in VR”

“a future use of VR could be taking the headset to a place where building is planned and be able to scan the environment and see what a building in that place would look like”

“VR needs to be usable enough so that building a virtual environment is not a task that someone else has to do and it not becoming a project that cost money. Instead, it should be a thong where anyone can make that environment easily”

“VR does not offer that much when viewing things on a large scale, it feels like VR offers most of its value when viewing things in a realistic scale. You might as well use a computer monitor to view the big scale and it would not make much of a difference”

“Me and my co-workers have talked a a lot of about using VR in a way where multiple people can sit together to edit and sketch together in VR, and viewing, I think that this idea has a lot of potential”

“Traditionally many architects can work together on a physical model. Being able to do that in VR seems to have a lot of potential”

R2

“I am an administrative architect and I work on projects”

“I have had some contact for with VR, not too much contact”

“Now that I am working from home the most obvious problem is the weight and a size of the VR equipment that u have to move around”

“I could carry my computer home with me from work, but I would not want to do the same with a big headset and all the other equipment that are needed”

“The price for headset seems to be too much if everyone started using it”

“It feels like another major problem is that you are isolated when using VR. Other people to get the same experience when they are sitting next to you”

“You are also isolated because you can’t see much of what is going on outside because the headset blocks you vision”

“You need a very powerful computer to Run the headset”

“You can’t easily show the consumers what you are designing, because they would always have to come to the office where we have out VR set up. We can’t show them out work if we are at any other place”

“We can’t demand that our customers buy the same equipment, so idea communication becomes hard”

“Having to go a specific room is an issue because the tracking equipment and the computer is required”

“a hindrance is that when a problem arises with setting up the headset and the equipment is that you have one person who knows how to fix it, and it becomes hard for other that are not as experienced to use it”

“It would help out a lot if setting up the equipment was much easier, less cables, and less parts”

“It would also help out a lot of the headset was made much lighter for the ease of transport”

“Having headsets that do not require a computer or tracking stations would solve a lot of issues”

“Its really easy to import and export models from Revit to VR, but it just takes some time to learn how to do it. It only takes a few clicks”

“VR is usually used to check if we have made any mistakes in our designs”

“It’s also used as a communication tool for the customer”

“VR is used to find the best angles to use in a presentation”

“a future use of VR could be having Virtual meetings with customers in other parts of the country, and be able to explore the virtual building with them and talk in that virtual space”

“It would be really cool and exiting if we could sketch together in a VR environment”

R3

“I play more of a supporting role because I’m new, I don’t have much responsibility”

“I have not used VR much outside of work”

“I don’t use VR at work on a daily basis, because setting the whole thing up is annoying”

“a hindrance is that it just does not work”

“Maybe you want to show something in a meeting that is an hour long, and if it takes 20 minutes to set up the hardware, you feel that it’s not worth it”

“There are just so many steps that take a lot of time, you have to update the system and I won’t connect. That takes a lot of effort”

“The hand tracking controllers run out of battery because people forget to charge them”

“I would like to see everything connect with wires, that way it works directly, and you don’t have to charge the controllers”

“I would also like to see the wires connected to the ceiling, that way you don’t trip over the wires, and we won’t have battery problems, because now it’s based-on people not forgetting to charge the controllers”

“Another solution to the battery issue could be a charging station, so you can easily charge the controllers instead of connecting them to wires.

“VR is not used that often, and that causes big updates every time you start the system, those updates take a lot of time”

“Each person has their own account, and each account has to update separately”

“VR is mostly use to relate a building to its context, that helps with understanding the building in a better way”

“VR is also used to costumer communication, it’s easier for them to understand rather than paper or computer monitors”

“If VR is connected to every computer, there is the potential to use it all the time during the design phase”

“It would be interesting to use VR as a modelling tool instead of just using it to view models that were design in a non-VR environment”

“Being able to model with other people in a VR environment would also be useful”

R4

“I have had no contact at all with VR outside of work”

“The problem with the hardware is that it is bound, you can’t take it with you”

“If you want to use VR then you have to invite the whole group to the VR room and that is cumbersome”

“You have to move out all the furniture from a room if you have many people. The meetings become a hassle and not convenient at all”

“a problem is converting the models into something the VR system can handle”

“A solution is having headsets that are light, and don’t need to be installed with trackers or bound to a computer that can be given out to all the participants”

“a hindrance is that when viewing a model, we have to take turns. One person is using VR and the other people just sit there and watch him”

“a way to solve this would be a multiplayer experience where multiple people can interact with each other and view the model at the same time”

“a way to solve the importing exporting problem would be some kind of a plug in, where the headset can view the model with a click of a button”

“We have used VR mainly as a way to generate interest for the customers”

“a way to use VR in the future would be to be able to design and view models together internally, that way everyone can be more involved”

“for the future I can see the whole project group having meeting in VR, in the planned building. That way the whole group would be informed and can make better decisions. That would be valuable”

“It would be ideal if you could edit the model while viewing it in VR. That’s where I want to see go. To be able to move walls and other design elements and see how the feeling changes”

“in the Future I see VR being very common but it has to be convenient, and easy to use, because everyone in the building industry is stressed out and does not have much time”

R5

“I have contact with VR on the job, but not much outside of work”

“The challenge is having to the get the customer at the office to show them the model, and not being able to do that remotely”

“Some people feel scared to put on the headset and being in that environment”

“Some people also feel ill when wearing the VR headset”

“You can sit down with a consumer and show them the house in VR, but if they feel ill, you have probably lost them, and they will not use VR anymore”

“You can’t really interact with the people you are sitting with and that creates some kind of a barrier”

“Often a hindrance for us is not being able to walk and having to teleport instead because of the small room we are in”

“Renting or buying a big local would allow for more interactivity and allowed for more interaction by being able to walk around”

“The isolation issue would be somewhat resolved if we could interact with each other in the VR environment”

“Moving the VR setup is a big challenge, because you have to movie the computer and all that comes with the headset, tracking cameras and controllers”

“The headsets could get smaller and not need to be connected to a computer, that would make it much easier to move around”

“The setup process, both hardware and software are complicated, and I need to get help from other people to help me set it up”

“VR is very useful for me to get an intuitive understanding of the scale”

“Another use for VR is giving the consumers understanding of the building”

“A future use for VR is in combination with AR, you could be in a place and look through a headset to see what ot would look like if we removed or added a building here”

“It would also be useful if we could change the places we are physically in, in VR”

“One thing VR could be used for is convey ideas to the general public, where big crowds of people can see what a place would look like to make the process of change more inclusive, democratic and get citizens more involved”

R6

“I have had some interaction with VR on the job”

“I have also had a bit of interaction with VR outside of work”

“The lack of portability, the need for tracking cameras and everything else makes it not very useable”

“A lot of people feel ill using VR”

“You need to be in a specific room that is small and does not allow for much interactivity”

“Having button on the headset that takes you out of the experience immediately would be helpful with feel ill”

“a portable headset that is wireless and does not require a computer would make it more usable in my eye”

“All the programs feel isolated, and you can’t view the models with other people”

“Having a program where you can see the other people viewing the model with you would make the experience more social”

“Making the model feel like real life is very time consuming and is a project on its own that we don’t have the time for”

“Having the process of adding detail more automated would save us time”

“In the future, I can see VR being Useful as a meeting tool, where the consumer and the architects can have long distance interviews in a virtual world, while at the same time showing them the project”

“Being able to sketch and edit a model in VR would be useful”