A Tour of the Past, Using Augmented Reality for a Story

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Abstrakt

Augmented Reality (AR) är på uppgång och många företag lägger miljontals dollar i branschen. Både Google och Apple har nyligen släppt sina egna AR SDK’er som kommer att köras på miljontals enheter inom en snar framtid. AR är verkligen fascinerande och har sagts vara nästa miljard-industri. Målet med denna avhandling är att undersöka vad som är möjligt med dagens AR för mobila enheter och undersöka vilka begränsningar det finns. Det är också intressant att få insikt om hur framtiden ser ut för AR. Dessutom vill jag veta vad är viktigt ur användares synvinkel när man utvecklar en AR-applikation.

För att utforska nuvarande mobil AR-teknik utvecklades en prototypapplikation för Malmö Stadsteater. De gav mig olika scenarier som de ville ha under en rundvandring och jag undersökte vad som var möjligt att uppnå relaterat till AR. Applikationen utvärderades sedan, efter utforskning och utveckling av ett scenario, för att få kunskap om en användarens synvinkel. Utvärderingen kombinerade observationsdata med korta intervjuer och ett frågeformulär.

Det har visade sig att det är ganska lätt att skapa en arbetsmiljö för AR-utveckling men det finns vissa problem med AR idag. Till exempel fann jag att spårningen inte är optimal, generering av realistiskt innehåll i den verkliga världen är svår och prestandaproblem uppstod på grund av att hårdvaran inte är tillräckligt avancerad.

När det gäller användarna är det viktigt att generera realistiskt innehåll med bra placering, ha tydliga indikationer på hur man använder applikationen och hur man placerar sig vid användning. Det har också visat sig vara viktigt att det konstant händer saker i applikationen för att hålla användarnas uppmärksamhet.

Abstract

Augmented Reality (AR) is on the rise and a lot of companies put millions of dollars into the industry. Both Google and Apple have recently released their own AR SDKs that will run on millions of devices in the near future. AR is really fascinating and have been said to be the next multi-billion-dollar industry. The goal of this thesis is to explore what is possible with today's AR and what are the limitations? It is also interesting to get an insight in what the future holds. Furthermore, what is important from a user's point of view when developing an AR application?

To explore current AR technology a prototype application was developed for Malmö Stadsteater. They provided me with different scenarios that they wanted to have during a tour and I explored what was possible to achieve in regards to AR. The application was evaluated after the exploration and development of one scenario to provide knowledge from a user's point of view. The evaluation combined observational data with short interviews and a questionnaire.

It was found that it is quite easy to set up a working environment for AR development but there are some problems with AR today. For example, I found that the tracking is not optimal, generation of realistic content on the real world is hard and performance issues due to hardware not being advanced enough.

When regarding the users it is important to have generate realistic content with good alignment, have clear indications of how to use the application and how to locate when using it. It was also found to be important to have things happening to keep the users attention.

Keywords: Augmented Reality, Mixed Reality, Vuforia, limitations, user experience.

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Thank you.

Malmö, April 2018

Johan Brantberg

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1 Introduction

In this first chapter I introduce the reader as to why I decided to do this report and what my goals were. Furthermore, the structure of the report is presented.

1.1 Background

A theater, *Malmö Stadsteater*, wanted to have a tour of the theater building and its history. The story was going to be narrated with the basis through the creator of the theater and combine storytelling with the experience of reality as it was during that time. The target audience is primarily younger people and in order for an enhanced experience they want to have certain scenarios (see appendix B), were the real world is combined with computer generated imagery, and is experienced primarily through hand-held devices, e.g. smart phones. Combining the real world with digitally generated augmentations of the surroundings is called *Augmented Reality* (AR). Seeing a person jump from the roof into a pool, putting make-up on or seeing the audience from the stage are examples of scenarios that Malmö Stadsteater want to be able to experience through AR during the tour.

Malmö Stadsteater contacted *Softhouse Consulting AB* in order to see if it was possible to develop the software. Softhouse did not have any earlier AR experience and Malmö Stadsteater did not acquire the money from its investors for the project and could not develop a full application. This thesis is conducted with the basis for getting Malmö Stadsteater some an example of AR for the future and getting interest from its investors while Softhouse got one step inside the door of AR development.

Augmented Reality is a subject that has exploded during recent years and is now available for development for everyone with a computer and web camera. It is interesting if there is any difference in developing applications for AR considering the end users compared to other software.

Having no prior experience in the area, I explore the possibilities of developing AR functionality for hand-held devices in this report. I also examine how user interaction is best achieved during development of such software.

1.2 Goals

The goal of this project is to explore AR and its limitations when developing on mobile phones, making a small prototype. I am wondering what is possible to accomplish with augmented reality today? Another goal is to use the knowledge of current AR technology to develop a prototype mobile application with AR functionality for hand-held devices with Android. In other words, what are the limitations and problems that is encountered during development?

I am also wondering how satisfying feedback is achieved for the end user? What are the other concerns related to augmented reality when maximizing user experience?

1.3 Previous Work

Earlier there have been several papers on the theme of virtual storytelling with focus on AR. Showing archeological sites or having guided tours in e.g. museums are the some of the more common ones. G. Papagiannakis et al. (2005) published a paper that is using AR with markerless tracking and generated 3D models in Pompeii [1]. Additionally, A.A. Nauman and T. Asghar (2010) have used AR to improve the experience of a guided tour at a museum [2]. Furthermore, J. Billock (2017) has listed five AR experiences that can be experienced in different museums [3].

These examples have been found looking only at AR but there are many more, especially if the search is widened to include Mixed Reality.

1.4 Structure of Report

The structure of the report is divided into the following sections:

- ***Introduction***

  The introduction contains the background description, what is the cause and why this report was written. Additionally, the goals of the thesis and previous work are presented as well as the structure of the report.

- ***Theoretical Background***

  The theoretical background describes the related terminology to Augmented Reality, how it works and the theory behind it. It also contains the theory behind evaluation of Augmented Reality applications.

- ***Tools and Hardware***

In this section I first describes the tools used for this thesis. I begin with describing Vuforia which is a SDK for Unity. I then shortly describe Unity. At last the hardware that was used is detailed.

- ***Method***

  The method chapter describes the methods used during the process of finding relevant literature and the methods used to achieve the resulting prototype mobile application and how it was evaluated.

- ***Results***

  The results chapter presents the findings regarding augmented reality possibilities discovered during the brainstorming phase, the resulting prototype and the results from the scenario evaluation.

- ***Discussion***

  The discussion chapter provides the reader with the approach taken for developing a part of an augmented reality application and the results from a technical point of view and the user evaluation. I also discuss further development and the future of AR.

- ***Conclusion***

  The conclusion chapter summarizes the results and evaluates if the goals was met.

2 Theoretical Background

In this section I describe the relevant terminology related to this thesis.

2.1 Augmented Reality

Augmented Reality (AR) is the technology through which the real world can be experienced with computer generated images and/or sounds in coalition with the real world. It is not to be confused with *Virtual Environment*, more commonly called *Virtual Reality* (VR), which is an exclusively computer-generated reality. Objects can be added or removed from the real environment in AR, thus augmenting the reality and creating a different experience for the user, compared to only seeing the real world. One example could be that a person took his or her phone and looked at an empty space in a room through the camera and seeing a sofa placed on the floor. The popularity of AR has been increasing substantially in the last couple of years. AR is used in different fields such as medical, educational, entertainment and advertising.

The most common definition of AR is made by R. Azuma who defined augmented reality systems as having the following three characteristics [4]:

1. *mixture of real and virtual reality*
2. *run in real time*
3. *registered in 3D.*

Registration is the accurate alignment of virtual objects in the real world [5]. With this definition AR is not locked to the visual sensation but also feeling, hearing, etc. This paper will focus on the visual part of AR from here on.

Mixed Reality is a collection name for both AR and VR defined by Milgram (1994) as the *Virtuality Continuum* [6] (see Figure 1), where VR is closer to a pure virtual environment and AR is closer to the real environment.

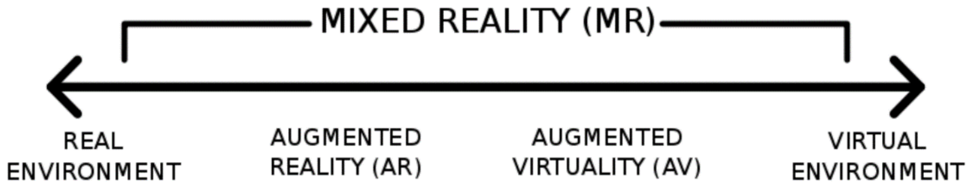


Figure 1. Milgram's Reality-Virtuality Continuum.

Source: http://www.offeo.com/wp-content/uploads/2017/07/mr_Fotor.png

To provide an effective AR experience there are several factors that need to be considered according to Zho et al. (2008) [7]:

- *Graphic rendering hardware and software that can create virtual content for overlaying the virtual world.*
- *Tracking techniques so that the changes in the viewer's position can be properly reflected in the rendered graphics.*
- *Tracking calibration and registration tools for aligning real and virtual views.*
- *Display hardware.*
- *Computer processing hardware for running AR simulation and supporting input and output devices.*
- *Interaction techniques specifying how the user can manipulate the AR virtual content.*

Tracking in AR is the ability to recognize the environment in order to present the computer-generated scenery in a realistic position, compared to the user, in the real world. Without sturdy and accurate *registration,* the AR will not be convincing and that is one of the main problems today. If it is not convincing it will not be used [8].

Furthermore R. Azuma (2016) identifies the main problems to be [9]:

- *Precise tracking in large environments with pixel-accurate registration during both day and at night.*
- *Wide field-of-view optical see-through near-eye displays.*
- *Innovative interfaces to control AR systems without keyboard or mouse.*
- *Semantic understanding of real-world objects in large scale environments without emplaced infrastructure.*

2.1.1 **Tracking techniques**

The most common way of tracking is using computer vision. For other means and an in-depth analysis of tracking I recommend reading *A Survey of Tracking Technologies for Virtual Environments* [10].

In computer vision-based tracking there are two different categories, *marker-based* and *markerless* tracking.

Marker-based tracking can be used when the environment is known and tracking is done through either known markers, images or objects. Distinctive shapes or patterns are recognized by image processing and the computer can calculate where to put the generated material based on those calculations [11].

Figure 2 is showing an example of a marker being tracked by the software and a tea kettle being generated relative to the tracked marker.

Figure 2. Example of marker-based tracking. Source: https://vuforialibrarycontent.vuforia.com/Images/devGuide_ImageTargets.jpg

Markerless tracking is used when the environment is unknown beforehand and the use of natural features in the surroundings helps calculate realistic registration. Techniques of this type requires a lot more computational power and has been insufficient for personal computers and mobile devices until recently but are starting to be more common [12]. There are companies like Magic Leap [13] and Microsoft that have invested millions of dollars into head-mounted AR displays in the last years that use markerless tracking techniques.

One of the most common markerless tracking techniques is *Simultaneous Localization and Mapping* (SLAM). In order to achieve SLAM there are five parts that have to be taken into consideration [14]:

1. ***Landmark extraction*** *– Extracting features from the environment for each frame that can be used by the system to localize.*
2. ***Data association*** *– The matching between landmark extraction frames.*
3. ***State estimation*** *– Updating of current position with the use of odometry data and landmark observations.*
4. ***State update*** *– Updates the estimated state by re-observing landmarks.*
5. ***Landmark update*** *– Add new landmarks to current state.*

Odometry data is data collected from sensors to estimate change in position over time [15].

2.2 Software Development Models

Software development is the process of developing software. There are different models that can be considered when deciding how this process is done. R. Pressman describes a generic process model to have five different activities [16]:

- *Communication*
- *Planning*
- *Modeling*
- *Construction*
- *Deployment*

A *process flow* characterizes how these activities are organized in respect to sequence and time [16]. Different models have different process flows and below are short descriptions of the most common models.

Traditional process models

Traditional process models (also known as prescriptive process models) strives for structure and order when developing software [16]. The tasks and activities of the process flow occur sequentially. The most common example of traditional process models is the waterfall model.

Incremental process models

Incremental process models focus on delivering a series of releases, called increments [17]. Typically, it starts with a core product and then each increment adds more functionality to the product. The process flow is both linear and parallel.

Evolutionary process models

A straight-line approach, like the traditional process models, are mostly unsuitable when developing software because product and business requirements often change over time. Evolutionary process models' counters this by being iterative and enables developing of increasingly more complete software [16]. Two of the most common evolutionary process models are prototyping and the spiral model.

Prototyping is preferable when the customer has general objectives of software but no detailed requirements or when the developer is unsure of the best approach. It is mostly combined with any of the other process models.

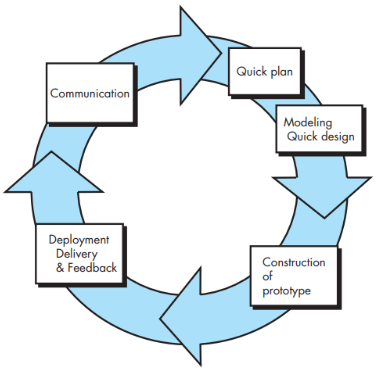


Figure 3. Overview of the prototype model [16].

Prototyping starts with communication with the stakeholders to define the overall objectives for the software. A quick plan and design is made which focuses on showing the aspects of the software that are visible to the end-users. A prototype is made from the quick design and is then given feedback by the stakeholders [16].

2.3 Evaluating Augmented Reality Systems

Evaluating AR systems and interaction with these systems is very different from traditional software evaluations. Even if such systems are developed with Azuma's definitions in mind they can be very different considering e.g. interfaces, multimodal output and manipulating objects in 3D-space.

Swan and Gabbard (2005) presented a meta-study which evaluated all research papers and publications based on augmented reality released between 1992 and 2004. They found total of 1104 publications of which only 21 described a formal user study [18].

Dünser et al. (2008) presented another study which was broader and between 1993 and 2007. They found that roughly 10 % of the AR papers published in ACM and IEEE included some user evaluation [19]. Although during recent years there is an upwards trend regarding the publication of papers related to user evaluation and AR, see figure 4.

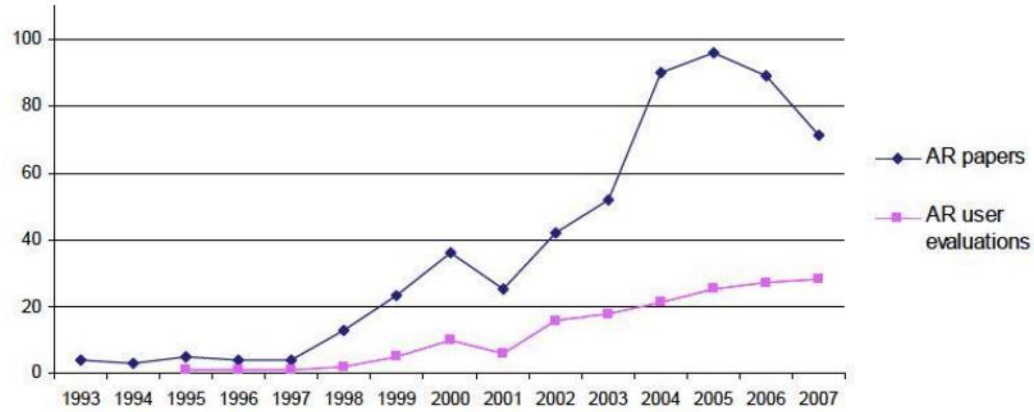


Figure 4. Number of papers related to AR and those that contain a user evaluation [19].

Dünser et al. identified five types of evaluation techniques used in AR papers:

1. *Objective measurements*, e.g. task completion times, positions, number of actions etc.
2. *Subjective measurements*, e.g. user questionnaires, user ratings.
3. *Qualitative analysis*, e.g. formal user observations, formal interviews.
4. *Usability evaluation techniques*, e.g. heuristic evaluation, task analysis, think-aloud methods.
5. *Informal evaluations*, e.g. informal user observations or informal collection of user feedback.

Albeit, the usability evaluation techniques were rarely used. It is common most of these techniques are used in combination to explore different aspects of the user experience.

There have been some attempts to create design methodologies which applies these evaluation techniques. Gabbard (1999) created a model with focus on Virtual Environment Systems which was then later used by Hix et al. (2004) but applied to AR Systems [20]. The model iteratively moves through the stages of:

1. *User Task Analysis*
2. *Expert Guidelines-Based Evaluation*
3. *Formative User-Centered Evaluation*
4. *Summative Comparative Evaluation.*

J. Gould and C. Lewis (1985) presented three key principles when designing for usability in respect of traditional software: Early focus on users and tasks, empirical measurements and iterative design [21]. Those principles are closely connected to the model created by Hix et al. Although there has not been much research in the area relating to AR systems these principles are still important when developing AR software.

3 Tools and Hardware

In this section I first describes the tools used for this thesis. I begin with describing Vuforia which is a SDK for Unity. I then shortly describe Unity. At last the hardware that was used is detailed.

3.1 Vuforia

Vuforia, developed by Qualcomm, is one of the largest AR software development kits and is integrated with Unity3D (see below) [22]. With the use of computer vision, it supports placement of virtual objects with different trackable targets (also referred to as *trackables*) as [23]:

- *Model targets. Recognition of objects shape.*
- *Image targets. Recognition of images.*
- *Object targets. Created by scanning objects, like toys.*
- *Multi targets. Posters, murals and product packaging makes good multi targets.*

The software also supports:

- *Background effects*
- *Video playback*
- *Virtual buttons*
- *Occlusion management*
- *Support for both Android and iOS*
- *Extended tracking*
- *Masking*

Extended Tracking allows for keeping the augmentation in view even after the a trackable has been lost [24].

Vuforia was chosen as the tool for developing the AR application since it is the most used (in the time of writing) software and have extensive documentation on its webpage. Furthermore, it also comes integrated into Unity3D.

3.2 Unity3D

Unity3D is a multi-platform game creation engine developed by Unity Technologies. The extensive IDE and the ability to deploy to numerous platforms where the deciding factors when choosing this software. Also, since it is one of the most popular game engines today it also has considerable support and good documentation [25].

Figure 5. Unity3D working environment

In Unity there are scenes working as the different parts of the game that is being developed, similar to scenes in a play. Each scene is made out of objects and those objects usually have scripts to behave in a certain way. A scene with a camera and a light source can be seen in figure 5. The scene and its objects are listed in the left panel, the configuration of the marked object to the right and a file explorer in the bottom.

Different languages are supported when scripting like JavaScript, C# and Boo. Vuforia uses C# for its scripts.

Peters (2016) conducted a study showing that Unity3D is the most cost-effective, flexible and sustainable software to develop AR applications [26].

3.3 Hardware

The software was implemented on a modern and powerful laptop with an Intel i7 processor and 8gb RAM.

A Samsung Galaxy S7 Edge 32gb, model number SM-G935F, smart phone with Android version 7.0 was used when testing the application on a hand-held device.

4 Method

In this section I describe the methods used during the process of finding relevant literature and the methods used to achieve the resulting prototype mobile application and how it was evaluated.

4.1 Literature

I searched for publications using *Google Scholar* [27] and *Lovisa* (the library catalog of Lund's University) [28]. I primarily used different combinations of the following keywords: *Mixed reality, augmented reality, archeology, museum, tour, tracking, user, evaluation, experience, usability, software, development, models, approaches*.

It began with searching for augmented reality. After finding the most popular and most cited papers and reading them, other keywords related to augmented reality was found, e.g. tracking. To get more information on specific topics and keywords I combined those keywords with augmented reality or mixed reality. Since I was looking to develop an application involving a tour I also searched for augmented reality or mixed reality in combination with archeology, museum and tour.

4.2 Workflow

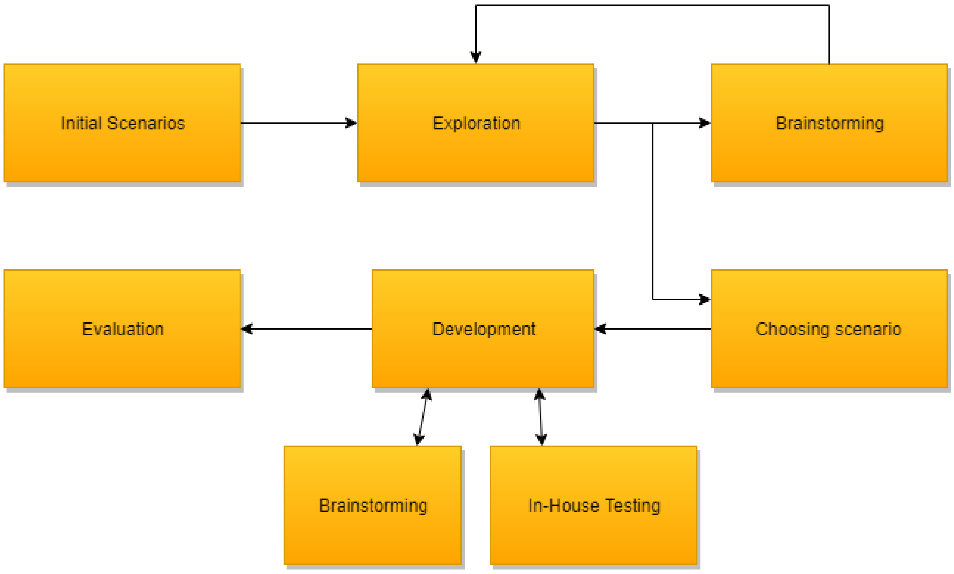


Figure 6. Workflow

The workflow I used when creating the prototype application is seen in figure 6. Malmö Stadsteater initially proposed nine different scenarios that were to take place during the tour (see appendix A).

4.3 Exploration and brainstorming

With no prior knowledge of augmented reality development, I wanted to explore what was achievable with current technology, in Unity using Vuforia. A combination of brainstorming [29] ideas and exploring solutions were done in iterations.

The exploration phase consisted of using different markers, different videos and/or pictures and different scripts to change the scene during run-time. The markers, in this case, consisted of distinct patterns on different paper sizes to test the image recognition. The different videos and/or pictures were to calculate performance differences on the hardware during run-time and the scripts to try and manipulate the generated imagery.

The brainstorming was done in parallel with the exploration of technical possibilities. The brainstorming was unstructured and consisted mainly of trying augmented reality functionality and discussing with my supervisor how to do things differently. It also consisted of using pen and paper to write down the ideas generated.

This was repeated until I had thorough understanding of the augmented reality possibilities and problems in Vuforia. It was during this phase I found the initial problems and possibilities of AR related to the different scenarios.

4.4 Choosing scenario

After gaining knowledge of how AR worked and what was achievable I had another meeting with Malmö Stadsteater to discuss my results and to conclude what scenario to develop in the prototype. Because lack of time and money we decided that I should focus on the following scenario for the prototype: *En loge, bild 1* (See appendix A).

En loge, bild 1 is a scenario that takes place in a make-up room where an actor can be seen putting make-up on and preparing mentally for the upcoming scene on the stage.

4.5 Development

The development process began with obtaining the right material from Malmö Stadsteater. For this we recorded a video related to the scenario at the theatre. Then the implementation was done in *Unity* using the *Vuforia* SDK. The development phase involved small iterations of developing the AR functionality and then testing in-house.

I chose to work with *Vuforia* because of the ease of use, cost free, masking and extended tracking as well as the support for both Android and iOS. It is simple to create an AR camera that automatically takes the camera feed from the device, add trackables that the camera registers and then generates the virtual content based on the orientation of the user.

4.6 Evaluation

The purpose of the test was to see if the user understands how to navigate the application by themselves and if they understand the augmented reality aspect. I also wanted know what the users thought about the different scenarios, if the scenarios made the tour more interesting and if they were immersive enough to be satisfying?

Bach and Scapin (2004) studied the main issues with the ergonomic evaluation Mixed Reality Systems and found three categories of methods to be suitable for testing these systems [30]:

- *Questionnaires and interviews*

  Important for gathering of subjective data for evaluating e.g. user preferences and missing functionality.

- *Inspection methods*

  To find ergonomic issues since the knowledge of such issues is limited in Mixed Reality systems.

- *User testing*

  Which has been the main method of testing in other systems.

Considering the above and the theoretical background, in order to do an exploratory test on an AR application in its early stages I proposed using a think-aloud method combined with objectively observing and documenting the test subjects when experiencing the scenario. Then end the evaluation with a subjective semi-open questionnaire [31].

4.6.1 **Target group**

The testing was supposed to be done on the intended end-user, primarily younger people up to 15-16 years of age. But the tour could also include other ages and in order to have a larger test sample I tested it on the personnel at Malmö Stadsteater. The test was conducted with 12 test subjects in the ages between 25 to 60, all non-technical people.

4.6.2 **Techniques**

4.6.2.1 Objective observations

- What are the limitations of the marker? Does it go out of scope a lot? Is it easy for the test subject to restart the scenario?
- How does the user try to interact with the augmentation?
- How is the user positioning?
- How long does it take for the user to understand how to start the scenario?
- What errors does the user do?
- Other miscellaneous observations.

4.6.2.2 Questionnaire

With the questionnaire I wanted to answer questions relating to the user experience and how realistic and easy or hard the users thought it was. It was also interesting to see what functionality that was lacking and other thoughts or suggestions. For further information, see table 1 below.

Question	**Answer**
How realistic did you think the augmentation was?	Range from 1 to 5. 1 is not at all realistic and 5 is very realistic.
How easy did you think it was to use the application?	Range from 1 to 5. 1 is not easy at all and 5 is very easy.
How much would you like to have AR as a part of the tour?	Range from 1 to 5. 1 is a resounding no and 5 is a resounding yes.
On a scale, do you think AR will contribute to make the tour more entertaining?	Range from 1 to 5. 1 not at all entertaining and 5 is very entertaining.
Was there any functionality that you missed?	Open question.
Any other thoughts or suggestions?	Open question.

Table 1. Questionnaire.

4.6.3 **Setup**

The test was set up in the same environment that was going to be used in the resulting application, see figure 7. All testing was done on the same hardware that was used when developing the application.

Figure 7. Set up of test environment

An introduction was made before the conduction of the test. The introduction contained a short description of the product and what was to be tested. The test person was encouraged to use the think-aloud technique [32] and it was made clear that notes were going to be taken during the test. It was also pointed out that it was the application that was to be tested and not the person.

After the introduction, a scenario was presented and the test person carried out the scenario while observations was made. At last, the test person was asked to fill out the questionnaire.

5 Results

Here I present my findings regarding augmented reality possibilities discovered during the brainstorming phase, the final prototype and the results from the scenario evaluation.

5.1 Exploration and brainstorming

Initially, the goal was to augment the surroundings in real time without the use of markers. After the exploration and brainstorming I found that *markerless tracking* was hard to achieve on mobile devices without a lot of processing power [32]. Vuforia does not support it either. After reviewing the scenario, I determined that it will be sufficient with *marker-based tracking* since the environment is known beforehand.

5.1.1 **First scene**

The first scenario I decided to explore was scenario *En loge, bild 2* (See appendix A). The scenario describes a woman trying on a dress while telling about how nervous she is and how uncomfortable the dress is. The first idea was to make a person fade in with the dress on, on top of the physical dress in the room. To simulate this, I tried having a face emerge on a jacket (see figure 8). A video was shot with a green screen background of a person's face and then I made that video start playing on the marker when Vuforia recognized the marker.

Figure 8. Exploration of first scene

It looked surprisingly good but it was obvious that it was a video on top of the jacket and not a realistic augmentation of the jacket as an object. Another problem was that the marker (A4-sized paper) was not recognized if standing further away than approximately 3 meters from the object during good light conditions.

Since the face did not look like a realistic augmentation of the jacket I decided to explore other solutions. Instead of having a face emerge on the jacket, a person could step out of the jacket, while fading in, with the complete outfit. For the resulting augmentation, see figure 9.

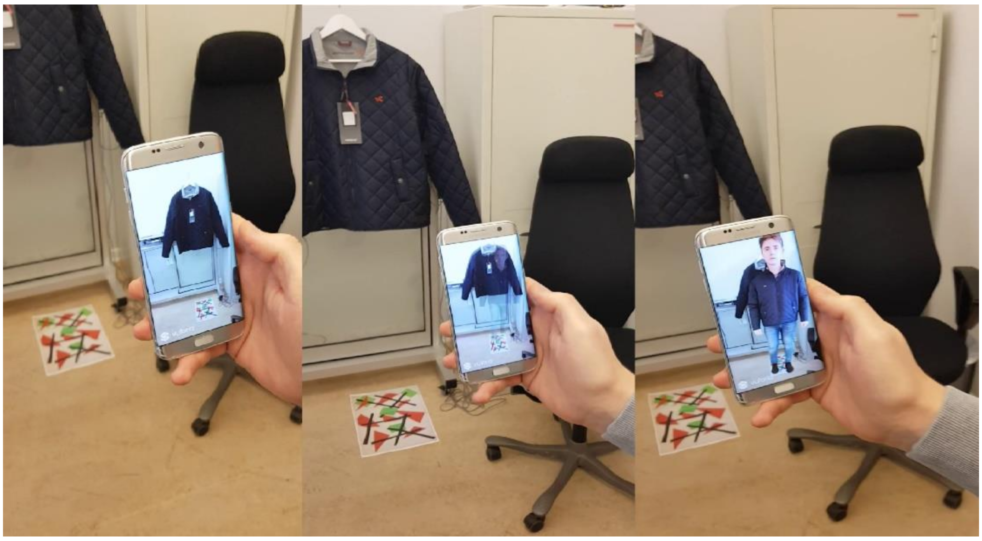


Figure 9. Person emerging from jacket.

The issue with having a person emerge from the jacket is that the camera need to have the marker in-scope the whole time, or else the augmentation will disappear. With a model that is this large it requires the user to point the camera away from the marker to see the whole model. Vuforia offers a solution for this with *Extended Tracking*.

Extended Tracking allows the tracking to continue once the image target has been detected. Vuforia uses information from the environment to keep track of target position. It assumes that both the environment and the target is mostly static.

5.1.2 Second scene

The second scenario I wanted to explore was *Trapphuset, bild 3* (See appendix A). This scenario describes a person walking down a set of stairs. It was interesting to see how well a dynamic augmentation would look. In order to do this, a person's legs and feet was filmed while walking down a set of stairs with a green screen behind to remove the background afterwards, see figure 10 for the result.

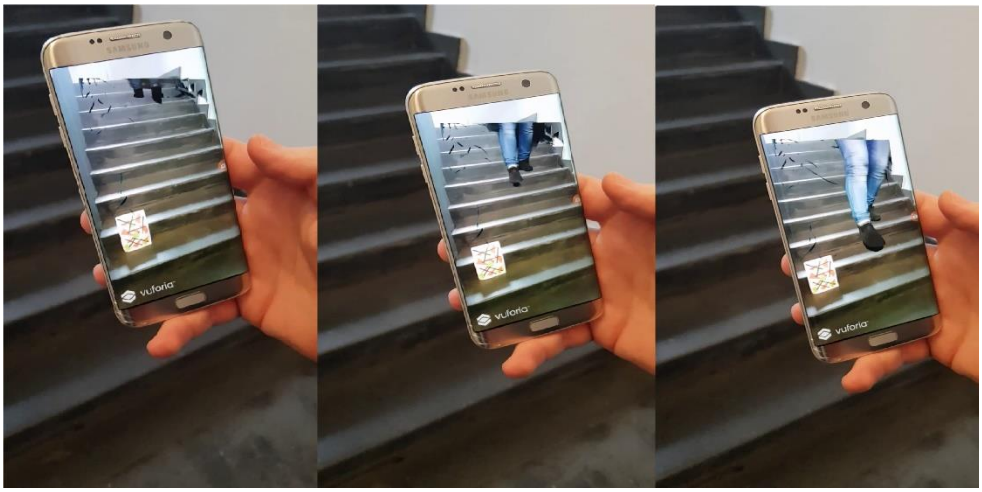


Figure 10. Person walking down stairs.

Here I was met with challenges because the model had to align perfectly with each step down the stairs. I was also met with performance issues, having the video stuttering while playing. Furthermore, the lightning conditions were not optimal, making it hard to detect the marker.

5.1.3 Mirror scene

Next, scenario that was explored was *En loge, bild 1* (see appendix A). *En loge, bild 1* is a scenario with a person sitting in front of a mirror and putting make-up on, preparing for a performance.

Having a person sit in a chair and make it look realistic from behind while at the same time seeing the same person in the mirror proved too difficult with the limited resources. To get a sense of the past the mirror could function as a way to look into the past without a person being physically augmented in front of it.

A video of a person putting make up on was filmed. This was done with filming the mirror from a slight angle behind the person, as to not see the camera in the mirror (see figure 11). Afterwards, the video was fitted onto a mirror with a marker attached to it.

Figure 11. Recording of person putting make-up on in mirror.

To have a realistic mirror-looking effect, different parts of the video (in this case representing the mirror in the past) should be showing depending on the angle and position of the camera. To not render the whole video Vuforia offers a technique called *Masking*. If you add a *mask* to an object, the masked part of the object will not be rendered when playing the scenario.

The idea was to have a smaller part of the video showing for the user while playing and move the video around depending on how the user moves. With the use of masks on top of the video in Unity and using a script to move the video-object during run-time a mirror-looking effect was achieved. In figure 12, the green rectangles represent the masks and the smaller grid underneath represents the video frame.

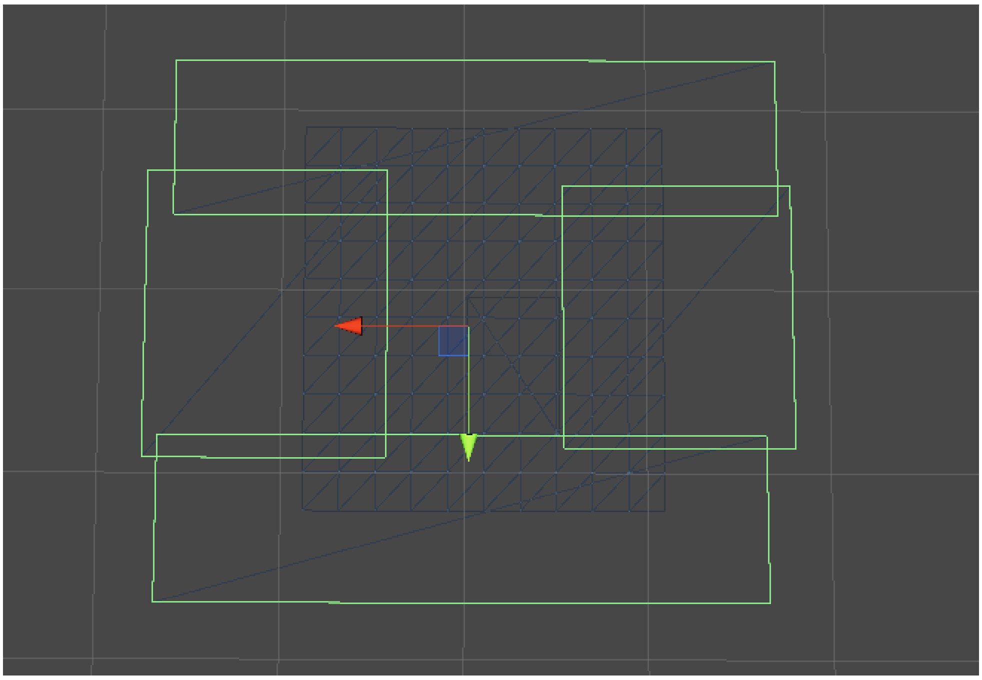


Figure 12. Masking the video.

The results when playing the scenario through the phone looked decent. The problems I had was that it did not look very good because it was filmed from an angle behind. It was also hard to get the angle between the camera and mirror during run-time and move the video accordingly.

But I still got a lot of understanding of what is achievable with the limited resources available and after another meeting with Malmö Stadsteater we decided to focus on the scenario were an actor puts make-up on in a dynamic mirror.

5.2 Scenario in-depth

To develop sound and realistic AR you need acceptable immersion. Immersion is defined by how much a user is captivated by an experience [34]. In order to achieve high immersion, the generated computer material need to exist similar to how it would exist in the real world. The user should be able to view it from different angles and distances while the material stays consisted with the real world.

In order to make the scenario realistic, the user should be able to look in the mirror from different positions and see different parts of the room, as it would behave in real life. The room and person in the mirror should be decorated to represent that time period. To achieve this, it was suggested that a video playback was put on the mirror when the camera detected some marker. After brainstorming (using pen and paper) how to make a realistic mirror I decided that:

- *The video should be filmed from the mirror's point of view*
- *The video scene should be larger than the mirror*
- *When looking into the mirror the only show part of the video related to the position of the user's camera*

The filming of the video took place at Malmö Stadsteater with a real actor, see figure 13.

Figure 13. Recording material for mirror scenario.

The video from the recordings was added to the scene in Unity with masks like the figure 10. The video played when detecting the marker but the marker had to be on the mirror. The next challenge was to make the marker a neutral part of the environment, ideally not on the mirror nor visible to the user. The marker was put next to the mirror to begin with. This resulted in the video playing on the mirror as expected but when moving the camera around to see different parts of the video the camera lost focus of the marker and the movement was limited. The marker had to be on the mirror.

The next idea was to have the frame of the mirror as a marker. Vuforia used to have frame markers as a part of the software but the support was removed. A regular image target with a frame as a marker was investigated instead, see figure 14.

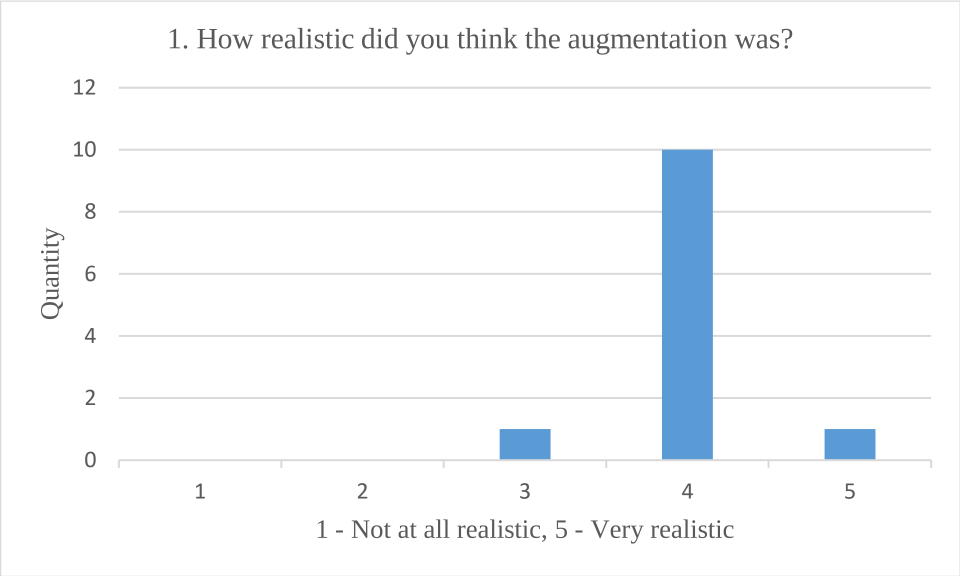
Figure 14. A frame as a marker.

The camera had a hard time detecting the frame and when moving around it easily lost the tracking, making it very unstable and unreliable. It was not surprising since Vuforia recommends an even distribution of the features in the marker [39]. In the end, it was decided to have a marker with the same theme as the scene on a part of the mirror. The marker can be seen in figure 6 at the bottom right of the mirror.

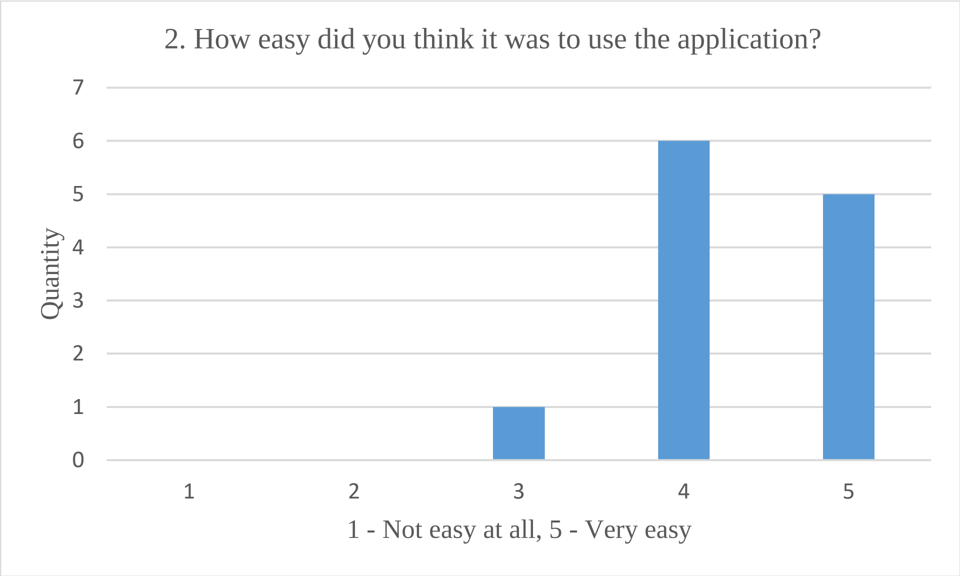
5.3 Evaluation

In this chapter, the results from the questionnaire answers are presented first and then the observations that were made. There were 12 test persons who answered the questionnaire.

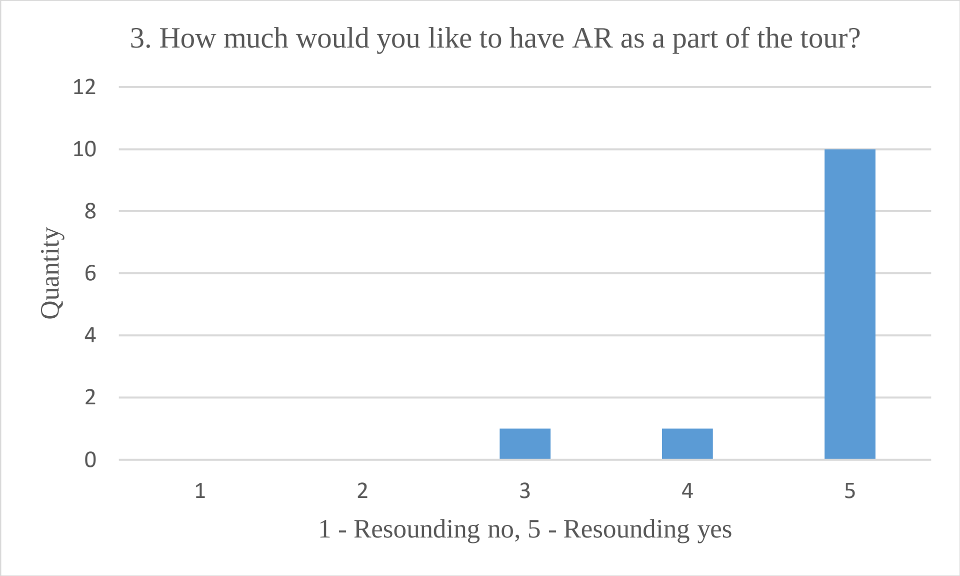
5.3.1 Questionnaire answers



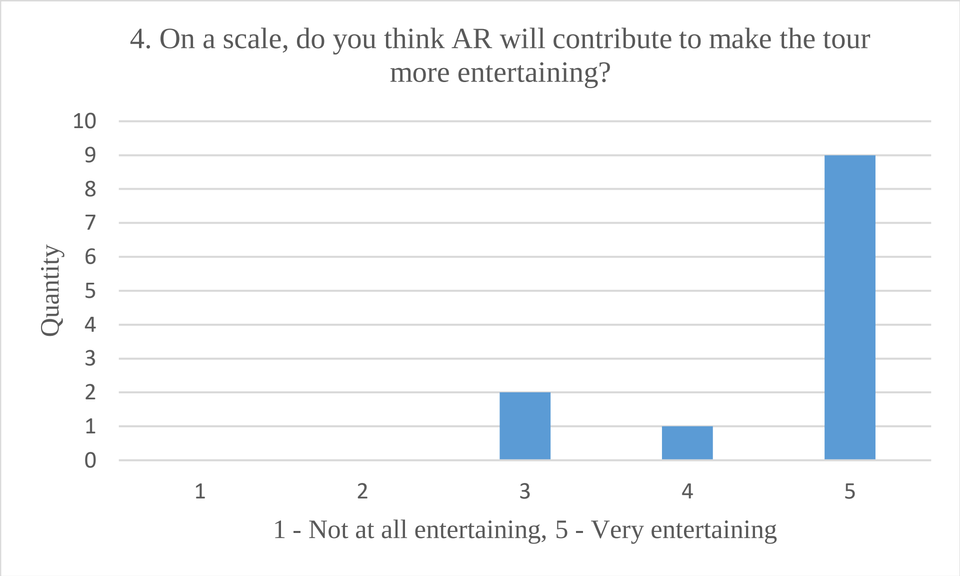
Almost all test subjects found the augmentation to be realistic. Some commented that the fitting of the video to the mirror was good and that was what made it realistic.



Almost everyone thought it was very easy to use.



Almost everyone was excited about having augmented reality as part of the tour in the future.



17 % of the test subjects thought AR would contribute to make it a bit more entertaining but overwhelmingly many subjects thought it would make the tour very entertaining in the future. No one thought it was unentertaining.

Was there any functionality what you missed?

- *Better sound quality*
- *Sound coming from external speakers in the surroundings*
- *Indication on where to stand since you have to be close to the marker*
- *More things happening in the background*
- *A scenario where movement is included, e.g. following a person through a room*
- *More things to trigger in the surroundings*
- *Keep the augmentation running even when the marker goes out of scope*

Other thoughts?

- *Music in the background*
- *Fun with a mixture of AR and real events*

5.3.2 **Observations**

What are the limitations of the marker? Does it go out of scope a lot? Is it easy for the test subject to restart the scenario?

The initial observations I made was that the light was not very good in the room so I had to get an extra lamp to shine light on the marker. Once the users found the marker and starting the tracker they kept the augmentation running without any problems. Almost everyone looked around the room for more augmentations and lost the initial scenario and restarted it without any problem.

How does the user try to interact with the augmentation?

I also found that almost all users wanted to look around for other things happening, losing the tracking of the marker and ending the augmentation.

How is the user positioning?

The users had to be close to the marker in order to start the scenario. It was not clear that this was the case and I had to guide most people, telling them that you had to stand pretty close to the marker.

How long does it take for the user to understand how to start the scenario?

Some test subjects looked at the marker through the phone up to 10 seconds before I had to tell them that you had to be closer, since the test subjects did not know that you had to stand close to the marker in order for the phone to register it.

What errors does the user do?

I did not observe any special errors that were made.

Other miscellaneous observations.

Something showing the users were to locate in order to start the augmentation would be preferable and having more augmentation to keep their interest.

6 Discussion

In this chapter I discuss the approach taken for developing a part of an augmented reality application and the results from a technical point of view and the user evaluation. I also discuss further development and the future of AR.

6.1 Method

The decision to use Unity with the integrated Vuforia SDK was based purely on popularity and availability. A better approach would have been to test a couple of different augmented reality software before making the decision to use Vuforia.

The software development model that was used was an evolutionary process model. This model was used with an unstructured end-user approach for creating a small prototype. The AR field is still in a fairly early phase and the approach seemed like a good idea since [35]:

- *Non-formal*
- *Shorter development time*
- *Small scale project*
- *No budget*
- *Focus on end-user*
- *Gives feedback for future development*

Since the resulting software is heavily dependent on user experience it might have been more suitable to have a more iterative approach similar to agile development with shorter iterations and more user testing. Although, the approach used gave some insight in development for augmented reality applications and the user experience based on using such software.

During the exploration of technical possibilities related to the scenarios it would be preferable to have had more in-depth brainstorming using real brainstorming techniques along with bodystorming in the environment that the product was going to be used, at the theater. Although the availability of the theater was limited and it was not possible to develop on site.

6.2 AR and the prototype

6.2.1 **Technical results**

A goal of this project was to develop a prototype mobile application with AR functionality for Android. I wanted to explore what is possible to accomplish from a technical point of view and what the limitations are.

I found that it is effortless to set up a working environment for creating small augmented reality related applications using Unity and Vuforia. The hardest part, in the beginning, was the creation of realistic content to use in the application and how the tracking was going to be achieved in a satisfiable manner. The tracking was concluded to only be made by markers instead of using markerless tracking since the environment was known beforehand and Vuforia had no support for markerless tracking.

The first problems that were encountered during the initial testing of scenarios were related to the tracking of the marker. In order for the software to recognize the marker, the user had to stand within a couple of meters of the marker. Furthermore, the augmented content was stuttering if the marker did not have sufficient lighting.

The use of markers instead of markerless tracking provided a problem when having large augmented reality content because it was hard to explore the surroundings without losing track of the marker and ending the augmentation. This was partially solved by having extended tracking enabled in Vuforia. This was doable because the augmentation was a video with static location in relation to the marker.

Additionally, real-time AR calculations are expensive. It requires good hardware and the hardware on mobile phones is restricted. It has to be taken into account when developing software for hand-held devices. I encountered some stuttering problems when having high-quality video playing at the same time as the phone were trying to calculate were to put the content in the real world.

6.2.2 **Results from the evaluation**

Another goal was to examine how users interact when faced with an AR application to understand what is important from a user point of view. How do you maximize user experience and give valuable feedback?

Considering the questionnaire answers I found that most users found the augmentation of the mirror to be realistic but not very realistic. The main why it was realistic was that the augmentation aligned almost perfectly with the mirror in the real world. Another reason was the movement of the video depending on the movement of the camera. Furthermore, I found that almost all users thought it was easy to use and were excited about having augmented reality as a part of the tour in the future.

When talking to the users, looking at the observations and examining the open questions on the questionnaire it was established that clear indications of user positioning to start the scenario was needed, largely due to the marker not being recognized if not standing close enough, and the users stood in front of it waiting for something to happen.

The users also examined the surroundings for other augmentations and scenario happenings. One reason for this was that the video in the mirror was 30 seconds long and even if the users thought it was interesting they soon lost interest and wanted to further explore the technology. Another reason was that the sound quality was not satisfactory so it was hard to hear what the actor in the mirror was saying.

When the users wanted to explore the surroundings, the marker got out of scope and the augmentation stopped. This was not ideal since they had to restart the scenario and start from beginning. The scenario should keep running after being started to let the users explore the environment without interruption.

All test subjects had no prior experience in using AR applications and all were non-technical. These characteristics represents the lower end of the spectrum of how easy the users might think it is to use the application in the future. However, the test was conducted on only 12 persons, all of whom did not represent the age of the primary final users.

The test was conducted in an informal manner were the almost all the test subjects showed up at the same time. This may have affected the results since some persons saw the testing of other persons. Furthermore, most subjects had no time to stay and discuss their thoughts for more than a couple of minutes. If the testing was to be re-done it would be preferable to have a more formal testing environment and isolate each test subject.

There should have been a question on the questionnaire to conclude if they had used AR before and to what extent. This was done orally when interviewing the test subjects before and after experiencing the scenario.

6.3 Further development

If further development of the application is to be undertaken there are several considerations to be made. Some of the considerations that I thought of and derived from the evaluation are presented here.

- *Other devices*

The development of the prototype was limited to an Android phone. In the future it would be interesting to not only test on other operating systems such as iOS but also having other display techniques. Mixed Reality glasses are very expensive today but a lot of research and development is being made. Those glasses could provide a more immersive experience and give the users more room for exploration and interaction when the hands are free.

- *Markerless tracking*

  With the rapid advancements that are being in made regarding augmented reality software and better hardware it could be interesting to see if markerless tracking could be achieved in an efficient manner.

- *3D-Model creation*

  Having 3D-models instead of filmed material that are being played to show the different scenarios opens up for further exploration. I.e. if the users wanted to see an actor on the scene they could walk around the model and more precisely see the attire.

- *Clear indications of how to use the application*

  From the interviews and observations during the evaluation it was found that the users need clear indications how to use the application and experience the different scenarios. This could either be done in the environment through directions or maybe in some clever way in the application, having an AR interface.

- *Collective start of scenarios*

  The tour in future would be guided and there was some interest in having groups of people using the application at the same time and starting the different scenarios simultaneously.

- *External sound*

  If starting a scenario simultaneously on all devices during the tour it would be preferable to have an external audio source. It would provide better sound quality and the group could experience the scenarios collectively.

- *Interaction*

  In order to have higher immersion and keep the interest of the users it would be more entertaining if they could interact with the environment in some cases.

6.4 Future of Augmented Reality

Azuma et al. (2001) found that the major limitations of AR today fall into three categories [5]:

1. *Technological Limitations*
2. *User Interface Limitations*
3. *Social Acceptance Issues*

Furthermore, Martinéz et al. (2014) found the limitations to be in [36]:

- *No AR standards*
- *Limited computational power in AR devices*
- *Tracking inaccuracy*
- *Social acceptance*
- *Information overload*

Considering the technological limitations, e.g. tracking, displays and computational power. Tracking has come a long way but much research is needed to have reliable tracking that does not care about if you are inside or outside.

When considering displays, the most advanced display technique of today is the head-mounted displays like Microsoft HoloLens. The disadvantages of such displays are that they have a narrow field of view or true occlusion of the world. There is ongoing research to solve those problems but more research is needed. In the more distant future we might just have a contact lens.

A social acceptance problem that must be solved is that the use of AR hardware in public setting today can make a user look silly. The glasses or headsets of today are quite large and heavy.

To have realistic real time anywhere augmentation there is much research to be done and the computational power has to get much better. Although some of the reasons for AR to keep expanding are:

Interaction possibilities

Imagine being in your home and looking through your fridge and finding additional information about your groceries, having visual feedback while talking to the Apple device Siri or other smart home apparatus or having a holographic tour guide at the museum.

Advertising

When people will be using AR glasses or lenses there is opportunity for companies to advertise on location, in real time and very personalized to the user.

Social

Having AR systems to share what we are seeing, hearing and feeling with others in real time will revolutionize the social aspects of our lives but might come at the expense of privacy.

There are of course many other aspects of our lives that will be affected by the advancements of AR but it will probably take a couple of years before the really cool things start to happen. As Tim Cook, the current CEO of Apple, said [37]:

> "I'm excited about Augmented Reality because unlike Virtual Reality which closes the world out, AR allows individuals to be present in the world but hopefully allows an improvement on what's happening presently." - *Tim Cook*

7 Conclusion

In the following subsections I try to answer my goals to see if they were fulfilled based on the results I got.

7.1 Technical

A goal of this project was to develop a prototype mobile application with AR functionality for Android. I wanted to explore what is possible to accomplish from a technical point of view and what the limitations are.

In conclusion, the main problems found were:

- *Recognizing the marker during bad lightning conditions*
- *Distance to marker had to be close*
- *Camera focus and resolution*
- *Having realistic augmentation of real world objects*
- *Keeping the marker in-view while looking at the model*
- *Calculating the environment when trying to change augmentation during run-time*
- *Performance issues on hand-held devices*

7.2 Evaluation

Another goal was to examine how users interact when faced with an AR application to understand what is important from a user point of view. How do you maximize user experience and give valuable feedback?

The results from the evaluation gave insight in how the application was used and what the users thought about when using it. It also gave Malmö Stadsteater an example of AR for future development.

In conclusion the user evaluation provided the following aspects for future development in regard to maximizing the user experience and giving the right feedback:

- *Important with good alignment*
- *Clear indications on positioning*
- *More things to explore*
- *Keep scenarios running even when going out of scope*

References

[1] Papagiannakis, G., Schertenleib, S., O'Kennedy, B., Arevalo-Poizat, M., Magnenat-Thalmann, N., Stoddart, A. and Thalmann, D. (2005). "*Mixing virtual and real scenes in the site of ancient Pompeii"*. Computer Animation and Virtual Worlds, 16(1), pp.11-24.

[2] A.A. Nauman, T. Asghar. "*Augmented Reality in Museum Environments*". Master Thesis. Division of ergonomics and aerosol technology. Dpt. of Design Sciences, Lund University, 2010.

[3] J. Billock. "*Five Augmented Reality Experiences That Bring Museum Exhibits to Life*". June, 2017. Available 2018-05-28 at: https://www.smithsonianmag.com/travel/expanding-exhibits-augmented-reality-180963810/.

[4] R. Azuma. "*A Survey of Augmented Reality"*. In Presence: Teleoperators and Virtual Environments 6, 4, August 1997, pp. 355-385. Available 2018-01-03 at: http://www.cs.unc.edu/~azuma/ARpresence.pdf.

[5] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, B. MacIntyre. "*Recent advances in Augmented Reality"*. Computer & Graphics, November 2001. Available 2018-04-02 at: https://www.cc.gatech.edu/~blair/papers/ARsurveyCGA.pdf

[6] P. Milgram and A.F. Kishino. "*Taxonomy of Mixed Reality Visual Displays*". IEICE transactions on Information Systems, E77-D (12), 1994, pp. 1321–1329. Available 2018-01-03 at: http://etclab.mie.utoronto.ca/people/paul_dir/IEICE94/ieice.html

[7] F. Zhou, H. Been-Lirn Duh, M. Billinghurst. *"Trends in Augmented Reality Tracking, Interaction and Display: A Review of Ten Years of ISMAR".* 7th IEEE/ACM International Symposium on Mixed and Augmented Reality, Sept. 2008. Available 2018-04-02 at: https://pdfs.semanticscholar.org/d1ba/a7bf1dd81422c86954447b8ad570539f93be.pdf

[8] G. Klein. *"Visual Tracking for Augmented Reality"*. University of Cambridge, Department of Engineering, Jan. 2006, pp. 2-3. Available 2018-04-02 at: https://pdfs.semanticscholar.org/093c/f4c7cf2779cf5f5d8fa2215774d443c2ff21.pdf

[9] R. Azuma. *"The Most Important Challenge Facing Augmented Reality"*. Presence Vol. 25, No. 3, 2016, pp. 234-238. Available 2018-04-02 at: http://ronaldazuma.com/papers/Presence_AR_challenge.pdf.

[10] J.P. Rolland, L.D. Davis, Y. Baillot. "*A Survey of Tracking Technologies for Virtual Environments, Fundamentals of Wearable Computers and Augmented Reality*", W. Barfield, T. Caudell, eds., Lawrence Erlbaum, Mahwah, NJ, 2001, pp. 67-112. Available 2018-01-04 at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.89.8135&rep=rep1&type=pdf.

[11] G. Klein. *"Visual Tracking for Augmented Reality"*. University of Cambridge, Department of Engineering, Jan. 2006, pp. 21-22. Available 2018-04-02 at: https://pdfs.semanticscholar.org/093c/f4c7cf2779cf5f5d8fa2215774d443c2ff21.pdf.

[12] G. Klein. *"Visual Tracking for Augmented Reality"*. University of Cambridge, Department of Engineering, Jan. 2006, pp. 10-16. Available 2018-04-02 at: https://pdfs.semanticscholar.org/093c/f4c7cf2779cf5f5d8fa2215774d443c2ff21.pdf.

[13] https://en.wikipedia.org/wiki/Magic_Leap. Available 2018-04-02.

[14] Araujo, T., Roberto, R., Teixeira, J., Simoes, F., Teichrieb, V., Lima, J. and Arruda, E. *"Life Cycle of a SLAM System: Implementation, Evaluation and Port to the Project Tango Device".* 2016 XVIII Symposium on Virtual and Augmented Reality (SVR). June 2016.

[15] https://en.wikipedia.org/wiki/Odometry. Available 2018-01-09.

[16] R. Pressman and B. Maxim. "*Software Engineering A Practitioner's Approach 8th edition*". New York: McGraw-Hill Education, 2015, pp. 29-86.

[17] J. McDermid and P. Rook, "*Software Development Process Models*" in Software Engineer's Reference Book, CRC Press, 1993, pp. 15/26–15/28.

[18] J. Edward Swan II, J. Gabbard. "*Survey of User-Based Experimentation in Augmented Reality"*. Proceedings 1st International Conference on Virtual Reality, Las Vegas, 2005. Available 2018-04-02 at: http://web.cse.msstate.edu/~swan/publications/papers/2005_Swan-Gabbard_Survey-AR-Experimentation_HCI-International.pdf.

[19] A. Dünser, R. Grasset, and M. Billinghurst, "*A survey of evaluation techniques used in augmented reality studies*," ACM SIGGRAPH ASIA 2008 courses on - SIGGRAPH Asia '08, 2008, pp. 1-27.

[20] D. Hix, J. Gabbard, J. Swan II, M. Livingston, T. Höllerer, S. Julier, Y. Baillot, D. Brown. "*A Cost-Effective Usability Evaluation Progression for Novel Interactive Systems*". HICSS-37, Jan. 2004.

[21] Gould, J. and Lewis, C. (1985). *"Designing for usability: key principles and what designers think"*. Communications of the ACM, 28(3), pp.300-311.

[22] https://www.vuforia.com/. Available 2018-04-02.

[23] https://vuforia.com/features. Available 2018-04-02.

[24] https://library.vuforia.com/articles/Training/Extended-Tracking. Available 2018-04-02.

[25] https://unity3d.com/unity

[26] E. Peters, B. Heijligers, J. de Kievith, X. Razafindrakoto, R. van Oosterhout, C. Santos, I. Mayer, and M. Louwerse. "*Design for collaboration in mixed reality: Technical challenges and solutions"*. In 2016 8th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), pp. 1–7, Sept 2016. doi: 10.1109/VS-GAMES .2016.7590343

[27] https://scholar.google.se/. Available 2017-12-11.

[28] Lovisa. Bibliotekskatalogen vid Lunds universitet. https://lovisa2.lub.lu.se/search/advanced?theme=systema. Available 2017-12-11.

[29] https://sv.wikipedia.org/wiki/Brainstorming. Available 2018-04-02.

[30] C. Bach and D. L. Scapin, "*Obstacles and Perspectives for Evaluating Mixed Reality Systems Usability*". Presented at Workshop MIXER "Exploring the Design and Engineering of MR system", IUI-CADUI 2004, Funchal, Island of Madeira, Portugal, 2004. Available 2018-04-02 at: https://pdfs.semanticscholar.org/95fe/0f3204ada37b018c034e205017d1341d446e.pdf

[31] Rubin, J. and Chisnell, D. "*Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests*". Wiley Publishing Inc., Indianapolis, 2nd edition, 2008.

[32] https://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/. Available 2018-04-02.

[33] R. A. Newcombe, S. Izadi, O. Hilliges, D. Molyneaux, D. Kim, A. J. Davison, P. Kohi, J. Shotton, S. Hodges, and A. Fitzgibbon, "*Kinectfusion: Real-time dense surface mapping and tracking*". In Mixed and Augmented Reality (ISMAR), 2011 10th IEEE International Symposium on, Oct 2011, pp. 127–136. Available 2018-04-02 at: https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/ismar2011.pdf.

[34] http://www.dictionary.com/browse/immersion. Available 2018-04-02.

[35] N. Biddle, "*Software Development Approaches".* Available 2018-04-02 at: https://www.purplezeus.com/software-development-approaches.html.

[36] H. Martínez, D. Skournetou, J. Hyppölä, S. Laukkanen, and A. Heikkilä. "*Drivers and Bottlenecks in the Adoption of Augmented Reality Applications*". Journal of Multimedia Theory and Application, 2(1), 2014.

[37] D. Phelan. "*Apple CEO Tim Cook: As Brexit Hangs Over UK*". independent.co.uk, Feb. 2017. Available 2018-04-02 at: https://www.independent.co.uk/life-style/gadgets-and-tech/features/apple-tim-cook-boss-brexit-uk-theresa-may-number-10-interview-ustwo-a7574086.html.

Appendix A Scenarion för rundvandring

Introduktion

Rundvandringen leds av en av Unga teaterns pedagoger som berättar om teatern och dess historia med utgångspunkt i cirkusartisten Orlando som vågade hoppa från Hipps kupol ner i en pool under Hipps scengolv. Berättelserna kommer varva mellan fakta och upplevelser av att våga stå på scen, scenskräck och mod. Berättelsen kommer kombineras med att publiken tittar i sin IPad eller mobil och då kan se en förstärkt verklighet över den reella. Detta kombineras med ljudinspelningar som styrs digitalt och andra effekter så som rök, vindmaskiner, dofter och rekvisita. Idén är att kombinera teaterns mer beprövade effekter med ny teknik.

Rundvandringen kommer gå från teaterns loger, bakom scenen, på scenen och ut genom foajén.

A.1 Scenarion

A.1.1 En loge

A.1.1.1 Bild 1

Här sminkar sig skådespelarna i dag, får kostymen på och samlar kraft och mod. I appen kan du se hur Orlando förbereder sig och hur man sminkade sig på den tiden, hur oljelamporna lyste och hur viktigt det var att förbereda sig mentalt.

Du kan också lukta oljelamporna och kritan från sminket.

(Viktigast här är att se en person som sitter i en stol och talar till publiken, helst 3D)

A.1.1.2 Bild 2

I logen hänger även en klänning som Cecilia Lindqvist, en av stadsteaterns skådespelerskor, använde i föreställningen ”Elisabeth den förste”. I appen kan du se hur det ser ut när Cecilia tar på klänningen och höra henne berätta om nervositeten inför rollen och hur klänningen skavde.

(Här ska alltså en person dyka upp i en befintlig kostym. Vi befinner oss i samma loge som förra bilden).

A.1.2 Trapphuset

A.1.2.1 Bild 3

I appen kan du se hur Orlando går mot scenen. Du får följa honom nerför alla trappor och höra hur han tänker och förbereder sig mentalt. Oljelamporna kastar skuggor på väggarna.

(Här ser vi hur en person passerar oss samtidigt som han pratar).

A.1.2.2 Bild 4

I appen kan du också se teaterdirektören Oscar Winge glida förbi innan han ska in och regissera en av teaterns kända revyer på 20-talet. Från scenen kan man höra Edvard Persson sjunga.

(En annan person passerar oss i trapphuset).

A.1.3 Foajé

A.1.3.1 Bild 5

Här får du veta hur det såg ut när teatern var en cirkus och gångarna runt scenen användes av djur och hästar. När du använder appen kan du på riktigt se hur hästarna rider förbi, du kan höra ljudet av hovar och känna lukten av hästhalm och djur.

(Här kanske man klippa in 2d bilder i filmen. Behövs ju inte att man filmar verkliga hästar i 3D utan vi få försöka hitta en annan enklare form).

A.1.4 Kulissen

Du får berättat hur det går till att vänta på sitt stick och hur man ska förhålla sig innan man går in på scen. Du kan se delar av en föreställning från kulissen.

A.1.4.1 Bild 6

I appen kan du först se och höra en skådespelare som berättar om hur det känns att vänta på sitt stick, sedan ser du hur skådespelaren träder in på scen Du känner ljuset i ansiktet och lukten av kalk.

(Ja här vill man gärna se en skådespelare först i kulissen och sedan inne på scenen från kulissen. Har man råd skulle man kunna modellera rummet så man också har möjlighet att se en hel dekor. Man kan också göra det väldigt enkelt med att man bara ser ljuset, skuggor i 2D och ljudet från föreställningen).

A.1.5 På scenen

Du får själv känna hur det känns att kliva ut på stora scenen. I appen kan du se en publik som jublar. Du känner strålkastarna i ansiktet. Du kan också få prova att känna på hur det kändes för en skådespelerska 1932 som blev utbuad av sin publik.

A.1.5.1 Bild 7

I appen kan du se publiken från 1910.

(Det här kan göras enkelt med att bara lägga en bild av en publik ovanpå salongen. Mer avancerat om man filmar en hel publik och lägger filmen ovanpå salongen i 2D).

A.1.6 Kupolen

Publiken går ut på en brygga, ovanför scenen. Publiken får höra Orlando tala om hur det känns precis innan hoppet, rädslan och beslutet.

A.1.6.1 Bild 8

(I appen ser du poolen från Orlandos perspektiv. Du ser en pool på scenen som inte finns i verkligheten. Det här kan klart göras mer eller mindre avancerat.)

A.1.7 På gatan

A.1.7.1 Bild 9

Du tittar in i restaurangen från gatan. I din app kan du se en av teaterns skådespelare sitta och ta ett glas efter föreställningen 1943. Eller är det Orlando som nu pustar ut efter att han klarat sitt hopp.

A.2 Sammanfattning

Det handlar alltså om 9 st bilder/filmer. Alla kan göras mer eller mindre avancerade beroende på budget och tekniska förutsättningar. De flesta bilder/filmer är en person som sätts in i en befintlig miljö. Oftast ska personen kunna förflytta sig och du ska kunna följa efter personen en bit med mobilen/applikationen. Drömmen är att på vissa ställen även skapa större rum som i foajén (hästar rider förbi) på scenen (du ser en hel publik) eller från bryggan (du ser en pool på scenen). Men dessa kan självklart också göras mer eller mindre enkelt.