Martin Storødegård
Per Axel Mathias Jørnsen

Creating an Immersive Experience of Historical Manuscripts using Mixed Reality

Helping the Gunnerus library create engaging and educational library visits with virtual reality and augmented reality

Master's thesis in Informatics
Supervisor: Theoharis Theoharis, Ekaterina Prasolova-Forland and Alexandra Angeletaki
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◼ NTNU
Norwegian University of
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Martin Storødegård
Per Axel Mathias Jørnsen

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NTNU
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<div align="right">Martin Storødegård and Per Axel Mathias Jørnsen</div>

Abstract

The Gunnerus library is the oldest scientific library in Norway. The library's collection includes specialist literature from Norway and Europe. The library also contains a smaller library called "Knudtzonsalen", which is a collection made by Broder Lysholm Knudtzon. The Knudtzon Hall itself is of great historical value, but the content is old and fragile and is therefore mostly unavailable to the public. The purpose of this project was to create immersive experiences around the manuscripts found in the Knudtzon Hall using virtual- and augmented reality. These immersive experiences should engage and educate a primarily younger audience. Our solution for this was to create two immersive applications, one in AR and one in VR were both present manuscripts from the library digitally, in an immersive manner. This way, the originals in the library are kept safe, and the general public can still access the content. In addition to this, we wanted to examine the strengths and weaknesses of AR and VR and compare the two, in the context of immersive manuscripts. Our findings, combined with theory, show that AR and VR can be helpful tools when creating such immersive experiences. There are, however, key differences between AR and VR that make them suitable for different aspects of such a task. Through our testing, we have proposed requirements for creating immersive manuscripts, and the differences between using AR and VR for this.

Keywords: *Virtual Reality, Augmented Reality, Mixed Reality, Immersive manuscripts, Educational, Engagement, Virtual Heritage, Immersion, Presence, Immersive headsets, HoloLens.*

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Abbreviations

VR	=	Virtual Reality
AR	=	Augmented Reality
MR	=	Mixed Reality
VE	=	Virtual Environment
HMD	=	Head-mounted Display
FPS	=	Frames Per Second
FOV	=	Field of View
GPU	=	Graphics Processing Unit
CPU	=	Central Processing Unit

Chapter 1

Introduction

This project is about the use virtual- and augmented reality in creating immersive experiences for manuscripts, how this can be used for education, and comparing the two technologies to each other. In this chapter we will present the context, motivation and research questions of the project.

1.1 Context

This project was part of a master's program in Informatics at the Norwegian University of Science and Technology (NTNU) in Trondheim. It was a collaboration between the Department of Computer Science (IDI), the Department of Education and Lifelong Learning (Innovative Immersive Technologies for Learning, IMTEL) and the Gunnerus Library at Kalvskinnet, NTNU. In addition, we have worked with Experts in Teams (EiT) students and the high school "Lucas VGS" to perform user tests.

The project's duration was September 2018 - May 2019. During the course of the project, we have developed, researched, and tested immersive manuscripts through the use of virtual- and augmented reality technology. The findings will be presented in this paper.

1.2 Motivation

Virtual- and augmented reality technologies have existed for many years but has recently become more accessible through products such as the Oculus Rift [29], HTC Vive [43], and smartphones. Augmented reality applications such as Pokemon Go[12] have also demonstrated to the general public that there is great potential for such technologies. While virtual reality (VR) and the head-mounted displays are slowly becoming a household appliance, many are still not familiar with augmented reality (AR), where the virtual and real world is blended with the use of a see-through display. The market for VR and AR technologies has been proliferating, and technologies that used to look like it was taken from a science fiction movie are now starting to be available to a reasonable price. The power

these technologies have to immerse users in a different reality can not only change how we look at entertainment, but can also change how we educate, and the way we experience everyday objects.

The concept of VR can be related back to the 1960s, and the first commercially available products were available already in the late 1980s[27]. Since then, VR has been used in various professional settings such as the first flight simulator developed in 1966 and the VR entertainment system "virtuality" in 1991[4]. Traditionally, VR and AR have been far too expensive to buy for the single consumer, but with the recent advancements in technology in addition to the increased investment from global companies like Facebook and Microsoft, these technologies are starting to become something that most people can afford[27].

In addition to lower prices, the technology behind VR and AR has gradually evolved to allow more immersive experiences such as improved graphics and more realistic sensors allowing users to feel a stronger presence in the environment. Immersion is one of the most important factors where VR and AR has an advantage compared to traditional desktop applications[15], so it might be a good idea to explore the uses of such technology. By being able to immerse users in a different reality, either it being an augmented version of reality or a completely virtual reality, a range of new possibilities for providing both entertainment and education can be explored.

Although entertainment might be an essential driver for these technologies, recent projects like the NAV fiskeoppdrett[30] application or Equinor's use of the HoloLens for maintaining oil rigs[9] have proved that it can be successful for other purposes as well. Not only can it be used to train personnel for potentially dangerous situations from a safe virtual environment, but it may also improve efficiency in the workplace by giving employees direct access to information not present in the real world. Real life scenarios can be reproduced in virtual reality or improved upon with augmented reality, which can be used to grant the user a more efficient way to learn, completely risk-free.

Another use-case of VR/AR is the preservation of history, which is an ongoing challenge where technology plays a central role. However, just as it is essential to preserve history, it is also important to show and educate about it. Modern technology has its own way of drawing people's attention and has already been used for educating about history in exciting ways. Several museums have already started using augmented reality apps for smartphones which makes exhibitions come to life [24] when pointing smartphones towards them, and virtual reality applications have been made for exploring historical sites often inaccessible to people in the real world[44]. These sites can either be explored from anywhere in the world through the use of VR glasses. Because of this, it might be beneficial to research how modern technology can be used to create a better way of experiencing various historical artifacts.

This project is done in cooperation with the Gunnerus Library at Kalvskinnet Campus. The library contains many important historical artifacts such as old manuscripts, some of which are unavailable to the general public. It is in their interest to attract people to the library in order to spread knowledge and educate about what the library has to offer, but over the last years, the number of people visiting the library has decreased. In order to change this, the library wishes to use virtual and augmented reality to attract more visitors, especially young ones. Their goal is to make manuscripts contained in the library

both more exciting and educational by using VR and AR to create a more immersive way of experiencing these manuscripts.

In relation to VR and AR, the term Mixed Reality (MR) is also central. According to Microsoft, Mixed reality is the result of blending the physical world with the digital world. This will be described more in-depth in section 2.2. To keep it simple, when describing VR or AR together, they will be referred to as Mixed Reality applications as they both fall under this category according to this definition.

1.3 Problem Description

Both virtual and augmented reality applications have already been used extensively for virtual heritage [16][24][44]. For this project, the focus is shifted to develop and evaluate educational mixed reality visualizations for manuscripts and archaeological collections at the Gunnerus library. The primary goal of these visualizations is to achieve a more exciting and immersive experience for the library's visitors, with a primary focus on the younger visitors. The library has several older objects and manuscripts that are too old and rare to be displayed to the public in their original form, which may also be visualized in the mixed reality applications.

During the project, we will also examine and compare the differences between using augmented reality and virtual reality for this type of educational applications.

1.4 Research Questions

The research questions focus on finding out how mixed reality can improve how users experience historical manuscripts, and compare the advantages and disadvantages of virtual reality and augmented reality for this purpose. The research questions are as follows:

RQ1: How can mixed reality be used to create an immersive experience of historical manuscripts?

RQ2: How can this experience be used to educate about history?

RQ3: What are the differences between VR and AR for these applications?

Chapter 2

Background

2.1 The Gunnerus Library

The Gunnerus library is the oldest scientific library in Norway[25], founded in 1768. Today it is a part of NTNU's university library, with a focus on specialist literature from Norway, the Nordic countries and Europe. The library's collection includes fiction and specialist literature dating back to the 1500s from Norway, and also includes literature in archaeology, biology, genealogy, and local history.

Because of the amount of valuable historical material the library contains, an essential goal for the library is to make this material available to the general public and allow people to learn about its historical value. Most of the library is therefore open to visitors, and the library regularly reaches out to institutions such as schools in order to help people, especially students, to learn more about the library and its content. The library has also carried out several projects where the goal has been to make it more exciting for visitors to learn about what they have to offer [1].

Inside the Gunnerus library is a smaller library called "Knudtzonsalen", which is a collection made by Broder Lysholm Knudtzon of approximately 2000 different volumes, as well as several original art pieces that are only available here. The room itself is of great historical value, but because the content kept in this room is both very fragile and valuable, the room is mostly unavailable to the public, and a special appointment must be made to visit the room.

2.2 Concepts

This section explains some of the essential concepts for this thesis.

Virtual Reality

In an article by Milgram et al. [26] virtual reality (VR) has been described as a headset that completely removes any view the user has of the real world and substitutes it with a

virtual world instead. The virtual world may or may not follow the properties of the real world, such as realistic physics and gravity. The goal of this virtual world is to immerse the user as much as possible into it and give the user a certain experience depending on what the given VR experience is designed to do. Some examples are games, storytelling, and simulation.

Augmented Reality

Augmented reality (AR) is when digital imaging is overlaid on top of the real world view [26]. This is often achieved using a see-through display, one example of this being Microsoft's HoloLens where transparent "holograms" can be seen on a transparent display allowing you to see both the holograms and the real world at the same time. Another example of AR can be a closed off headset that completely blocks the vision of the real world like how a VR headset does it, but has a camera in the front which displays the real world in real time through the display inside the headset.

Reality-virtuality Continuum

Milgram et al. [26] describes real- and virtual environments in the context of the continuum as *"Rather than regarding the two concepts simply as antitheses, however, it is more convenient to view them as lying at opposite ends of a continuum, which we refer to as the Reality-virtuality continuum"*. As such, the reality-virtuality continuum can be regarded as a spectrum used to describe how the concepts mentioned earlier relate to real and virtual environments. In Figure 2.1 shown below, we can see that the real environment and virtual environment are on opposite ends of the spectrum, while AR can be found somewhere in the middle of the two. VR would be to the far right of this spectrum, as it is based around a completely virtual environment. Augmented virtuality is the opposite of AR, such that the virtual environment contains real-world objects placed into it.
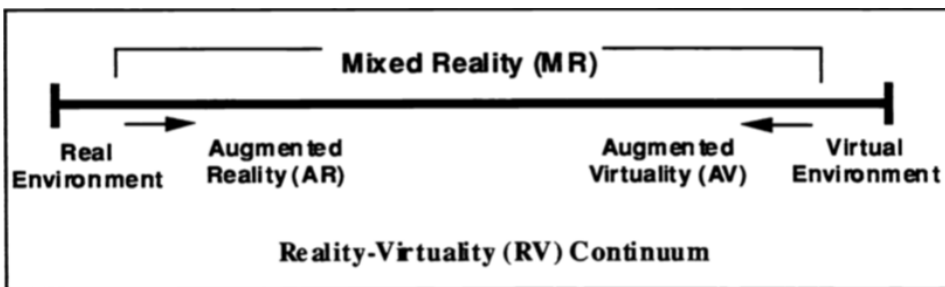
Figure 2.1: Reality-virtuality continuum

Mixed Reality

The mixed reality concept has changed quite a bit since the original introduction of the term in the paper by Milgram et al. [26] which published in 1995, where it was described as *"Within this framework it is straightforward to define a generic Mixed Reality (MR)*

environment as in which real world and virtual world objects are presented together within a single display, that is, anywhere between the extrema of the RV continuum"[26]. Since then Microsoft has picked up the concept of Mixed Reality, and use it to describe both their VR headsets (or immersive headsets, as Microsoft names then) and AR headsets.

Microsoft describes mixed reality in their article "What is mixed reality?" as *"Mixed reality is the result of blending the physical world with the digital world"*[20], it is also described as *"Augmented reality, Virtual reality and everything in between"* on the sales pages for the MR headsets [22]. Similar to the original definition, Microsoft looks at mixed reality as a spectrum since it concerns the blending of two different concepts. This spectrum can be seen in figure 2.2.
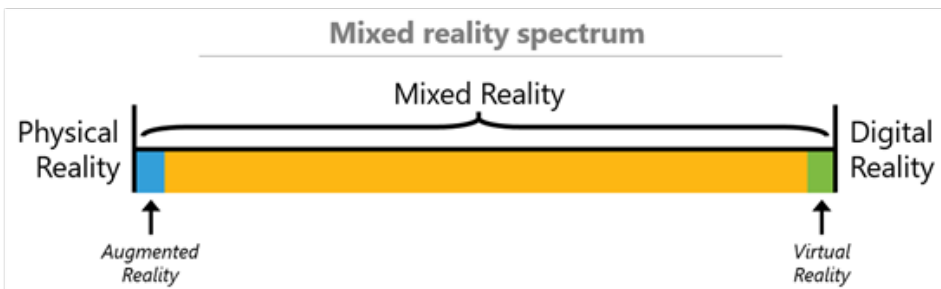
Figure 2.2: Mixed reality spectrum [20]

Here it is clear to see that AR and VR are on opposite sides of the spectrum, and are the closest thing to physical- and virtual reality inside the MR spectrum, respectively. Contrary to Milgram et al. Microsoft includes their immersive headsets (VR) in the MR spectrum, even though there is not necessarily included any part of the real world in them. In Figure 2.3, it is shown which part of the MR spectrum holographic devices and immersive devices can be a part of.
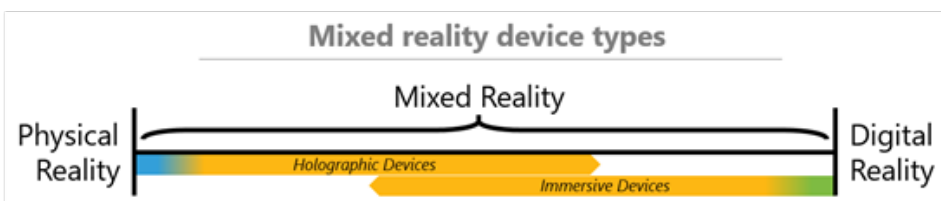
Figure 2.3: Mixed reality device types [20]

Immersion and presence

Achieving a high level of immersion through a VR application is essential, as it is necessary to complete the goal of most VR applications: replace real senses by computer generated ones. It is possible to achieve this in VR because our visual sense will mostly scan certain key points in our vision and then let the brain fill in the rest between these key points. In the case of VR, it is mostly the visual sense that is replaced. M. Slater describes

an immersive VR system as *"...one that delivers the ability to perceive through natural sensorimotor contingencies. This is entirely determined by the technology. Whether you can turn around 360 degrees, all the while seeing a very low-latency continuous update of your visual field in correspondence with your gaze direction,..."*[33]. This is also supported by Usoh et al. [34] in an article published in 2000, stating the different technological properties of a virtual environment that is important for a high level of immersion. So immersion is the objective technological properties of a virtual environment. Examples of such properties can be screen refresh rate, field of view, tracking capabilities, and representation of movement. It is also important to note that these properties will vary a lot based on what kind of system and technology is used, for example, a head-mounted display or a TV-screen require different properties to be seen as immersive. According to Slater, different immersive systems can be compared to each other in degree of immersiveness based on whether one of the systems can emulate the other system's immersive properties, and thus provide the same level of immersiveness as the other system but not the other way around.

Presence is the illusion of actually being in the virtual environment the user experiences, and is easier to achieve if the environment has a high grade of immersion. Even though the user knows she is not actually in the virtual environment, if it feels natural enough, the easiest solution for the brain's perceptual system is to infer the virtual environment as a real one [33]. Where immersion is a very technical and objective measurement of a system, presence is more subjective to the user. Presence is somewhat similar to how a reader can be absorbed into the storytelling of a book. Although text and images may be used to immerse the reader in the world described in a book, the world she imagines is a subjective experience. Often presence builds on top of a system's immersion level, as it is hard to feel like one is actually in a virtual world if the technology used to perceive that world is sub-par even if the virtual world itself is excellent.

Virtual Heritage

Stone and Ojika define virtual heritage as *"... the use of computer-based interactive technologies to record, preserve, or recreate artifacts, sites and actors of historic, artistic, religious, and cultural significance and to deliver the results openly to a global audience in such a way as to provide formative educational experiences through electronic manipulations of time and space"*[37]. By this definition, virtual heritage is not only the process of preserving ancient artifacts but also to make these artifacts available to the general public. Although it is crucial to ensure that critical historical artifacts are preserved while it is still possible, this effort has little value if the result is hidden from the general public. The part of virtual heritage concerning the delivery of such artifacts to a global audience might, therefore, be just as important as the preservation of them. The purpose of this thesis is not to research cultural heritage, but it is important to research virtual heritage as creating immersive manuscripts is a way of presenting cultural heritage to people. It may also be beneficial to research how this can be done in a way that interests and engages the user, as the effect of making historical artifacts available to the public has little value if people are not interested in it. Thus it might be a good idea to combine virtual heritage with immersive techniques to create something which is both educational and engaging.

Historical Manuscripts

The Gunnerus library has an extensive collection of books from various ages, and a lot of these books are what can be called manuscripts. A manuscript can be defined as *any document that is written by hand - or, once practical typewriters became available, typewritten - as opposed to being mechanically printed or reproduced in some indirect or automated way* [18]. Nowadays, it can have different meanings, but it is this definition which is relevant for the thesis. A historical manuscript is in the case of this thesis a manuscript which has historical value, such as a manuscript depicting instructions for an alchemy experiment, or the journey of a particular person.

2.2.1 Immersive manuscripts

An immersive manuscript can be explained as a manuscript that can give the user a high level of immersion in the manuscript's content through methods such as stimulating the user's senses like vision, sound, and touch. Such a manuscript can immerse the user in a different reality, and this effect could be used for both educational and entertainment purposes. If done correctly, this could make the user feel a stronger presence in the reality of the manuscript, and would, for instance, be beneficial when trying to tell a story and helping the user feel what it would be like to be present in the world of that story.

There are examples of existing applications for immersive manuscripts [1], but the level of immersion is often limited by the hardware chosen for the application. As Slater describes, the level of immersion that is delivered varies entirely by the technology[34]. These applications are often made to be available to as many as possible, and because holographic devices like the HoloLens are still too expensive for consumers, the target device is in most cases smartphones.

2.2.2 Education in MR

Predecessors of VR has been used in different capacities for training since the middle of the 1950s [3], although the term "virtual reality" was not coined until later. The most commonly known utilization is the training of pilots. Using VR in this case can be essential in saving lives and expensive equipment that could otherwise be lost in training. This is an example of where VR can be a great tool to combine with education. According to M. Slater's paper "Implicit learning through embodiment in immersive virtual reality" [32], there are at least five situations where VR might contribute to learning: *(i) Transforming the abstract to concrete; (ii) Doing rather than only observing; (iii) The infeasible or impossible becomes practical; (iv) explore manipulations of reality; (v) go beyond reality to positive advantage*. Some of these applications of education through VR is more obvious than others. The first situation (*i*) is for cases where abstract concepts can be exemplified through different scenarios. One example of this is Roussou's Virtual Playground that was used to teach young kids mathematics using a virtual playground and an interactive robot in VR [31]. The second situation (*ii*), doing rather than observing is central for education that requires practical training, e.g., surgeries, operating machinery, etc. Training for such activities can be costly and can often provide moral dilemmas that are not present when the training is done in VR. The third situation (*iii*), making the infeasible or impossible

a possibility. Examples of this can be virtual field trips to places far away, that can be experienced virtually. The fourth situation (*iv*), is to manipulate reality in such a way that the user can experience changes to it. How would the world be with lower gravity is such an example. This type of education is being used to teach about environmental changes such as rising water levels [7]. The last situation Slater describes (*v*), is situations that go beyond reality, such as recreating old historical sites. Common for all of these situations is the first-hand experience provided by VR, either through allowing the user to experience something or to try their hand at performing a task which can be beneficial for the learning output.

2.3 Technologies

This section briefly explains some of the main technologies and frameworks that were used during the development of the applications.

2.3.1 Unity

Unity is primarily a game engine for 2D, 3D, mobile, HTML5, and VR games. It provides several helpful out of the box features for developing games, such as physics, rendering, lighting and shadows, materials, shaders, etc. Unity also provides a standalone editor to build scenes and games efficiently. A massive API for further development is also provided, making coding your own custom features much easier than building a game engine from the ground up yourself. A pipeline to deploy to virtually any platform is also inherently provided in Unity, which eases the process of deploying an application across multiple platforms. [41]

2.3.2 Microsoft Immersive headset

Immersive headsets are more similar to traditional VR headsets than holographic headsets. They operate on the right side (towards virtual environments) of the mixed reality spectrum and are provided by several different retailers that have developed their own product within the mixed reality category. They use an opaque display with no see-through but can utilize several sensors, for example, cameras and motion sensors to react to the physical environment if necessary.

Figure 2.4: Example of an immersive headset produced by HP

2.3.3   Microsoft HoloLens

The HoloLens, unlike the immersive headsets, use a transparent display and is a holographic device. Therefore it operates on the left side of the mixed reality spectrum. They are also produced by Microsoft themselves, and not by external retailers.

Figure 2.5: Microsoft HoloLens

2.3.4   Mixed reality toolkit

The mixed reality toolkit, developed by Microsoft specifically for their immersive and holographic devices, is in their words *"The Mixed Reality Toolkit is a collection of scripts and components intended to accelerate development of applications targeting Microsoft HoloLens and Windows Mixed Reality headsets."*[19]. The mixed reality toolkit is built upon Microsoft's Universal Windows Platform (UWP), which allows us to reuse some of the functionality between our immersive application and our holographic application[21].

2.3.5   Vuforia

Vuforia provides software solutions to various aspects of the AR development process. Most known is the "Vuforia Engine" that provides easy to use image recognition and tracking functionality to mobile and AR devices. Using Vuforia, it is possible to anchor virtual objects to physical objects in the real world. Vuforia supports both Unity and HoloLens out of the box.

Chapter 3

Related Work

There exists many applications with various goals and purposes for the different MR headsets and devices on the market. Although there is very little research done on the field of immersive manuscripts in MR, there are some examples of research and applications which are relevant to this thesis. These will be discussed in depth in this chapter, and then compared to evaluate which of their features that are relevant for our applications.

3.1 M.A.R.T.S

MR has gradually become something that most people have access to some extent due to smartphones, and several museums have recently taken advantage of this by using MR to enhance its exhibitions. The paper "Mobile Augmented Reality in Museums" presents the system "Mobile Augmented Reality Touring System" (M.A.R.T.S), an AR application for exploring augmented museum exhibitions with smartphones. While this is not an example of MR used for manuscripts, it is still relevant as it shares many similarities to the goals for creating an immersive manuscript both by the tools that are used to achieve this and the goals. The paper compares two widely used systems for using mixed reality in museums and discusses how they can be improved with the M.A.R.T.S system [24]. By using a smartphone application, users can explore the different exhibitions at the museum and use the camera on their smartphone to get additional information laid on top of the video feed by centering the camera on the exhibitions. Augments such as text descriptions, voice overlays, 3D-models, and animations are then laid on top of the exhibitions, creating a blend between real life exhibitions and a virtual world. Other features such as virtual guides, reconstructions of deteriorated museum objects and markers to point out essential parts of exhibitions are also features of this system. This can give users an improved experience of the exhibitions and can help increase the learning outcome by providing additional information interestingly and understandably by using three dimensions.

This system does not allow for interacting with the augmented elements [24]. An important reason for this is that it is run on smartphones, and no extra hardware such as handheld controllers are used. VR and AR headsets usually have more sophisticated sensors,

and more powerful hardware has screens which can cover a larger part of the user's view and ways for interacting with the environment such as handheld controllers. This makes it easier to create more immersive applications compared to when using smartphones.

Figure 3.1: The M.A.R.T.S project

3.2 Crayola Color Alive AR-Book

An augmented book can be explained as a traditional book that is enhanced by displaying holographic objects on top of the pages, and is an example of an immersive book. Most of the augmented books that we have found at this moment are marketed towards children, and one such example is the "Crayola Color Alive" augmented book[8]. This application allows users to color figures in an included book, and then have these figures come to life as a 3D-model through the use of a smartphone application. This 3D-model then has the same colors as the drawing it represents. Although the application does not teach about history, it is a good example of how an immersive manuscript can be created. Features such as how the 3D-models are displayed in the book, and the use of a real physical book to merge the real world with the virtual world are highly relevant for how one can create an immersive manuscript in AR.

Figure 3.2: Crayola Color Alive

3.3 The Mubil Project

The Gunnerus library has previously created a "digital book" as a part of the Mubil project [1]. This book is enriched with 3D objects, additional explanatory content in pictures, drawings, videos, audio, and text in both Norwegian and English. This is a desktop application consisting of an interactable manuscript where users can flip through pages with a mouse cursor, and interact with the pages to reveal additional information. The images can be viewed in greater detail as 3D-models by clicking on the images, and sound clips are played to provide additional information about the manuscript. The environment for the application is modeled to represent the time era the book is from and contributes to the immersive experience delivered by the application by attempting to give the user the feeling of being there. The application is also possible to use with a projector and a Kinect camera, allowing for a more immersive experience through projecting the application on a large wall and allowing the user to interact with the application through hand gestures. The results from testing the application provided mixed results, as most users were not that engaged in the application [1].

Although the application does not use immersive headsets, the concept is still relevant for creating an immersive manuscript in MR. As it is an augmented book, the way of displaying augmented information on top of the book could be done similarly in MR. These objects contribute to enhance the book and grants additional information to users and give them more control by enabling them to interact with the book in ways not possible in a regular book such as by using virtual buttons. A similar application created with MR technology could enable users to experience the same quality of educational material as in the Mubil application, but also create a more immersive experience for the user which may improve the overall learning outcome and encourage interest.

Figure 3.3: An augmented book from the Mubil project

3.4 Comparison

Table 3.1 is an overview of the key features in the three applications. It compares whether the applications are created for VR or AR, if they have augmented text or augmented 3D-models, if the user can interact with this augmented content, if the application is centered around a manuscript, and if the applications' content is historical content. The intended applications for this thesis will focus on including all the points in this table.

The Mubil project has a large amount of functionality compared to the two other applications, but as it is a desktop application, it does not have as many immersive features as the other applications. The possibilities for interaction are also limited to interacting with a computer mouse, but the research is still useful as most of the features are quite relevant to this thesis. The other two applications are relevant as they are examples of how mixed reality can be used for creating immersive experiences, either it being historical content or fiction.

	M.A.R.T.S	AR-book	Mubil
VR			
AR	X	X	
3D-models	X	X	X
Text	X		X
Interactions			X
Manuscript			X
Historical content	X		X

Table 3.1: Comparison of the three applications, and relevant features for each of them

Chapter 4

Research Design and Methodology

4.1 Development methodology

During the first phase of development, a simplified version of the waterfall model [36] was used for developing the prototypes. This was done because two working prototypes had to be created before testing could begin, so the waterfall process of creating requirements, designing, implementing and then testing the applications at the end was the most suitable model for this phase. At the start of the second phase, we decided to switch to an agile development method [2], mostly because the applications were now testable so it was possible to iterate on these to gather regular feedback and make quick changes based on what users meant was important. An important reason to why this was necessary was the high uncertainty for the project, as neither of us were very experienced with MR development. Because phase 2 was the longest phase with the most uncertainty, three separate user tests were conducted throughout this phase to get feedback on features quickly after implementation in order to improve, change, or remove them without having to wait until the end of the phase. Although we decided to use an agile development methodology, we had not set specific sprints[2] due to uncertainties with the timeline of the project.

Throughout the phases, it also became clear that the VR application required more work to achieve the same features compared to AR. This is partly because, in VR, you also have to create the entire environment around the core application while in AR, you can focus on the core application itself (e.g., the library). In Table 4.1, we have shown how we divided our development time between VR and AR through the phases because of this.

Time spent on	VR	AR
Phase 1	50%	50%
Phase 2	60%	40%
Phase 3	80%	20%

Table 4.1: How the workload was divided between AR and VR throughout the phases.

In phase 1, we only had one user test, which was performed at the Gunnerus library on Experts in Teams (EiT) students. In total, 14 students tested the applications and responded to the survey during this test. As mentioned, in phase 2, it was decided to change to an agile development methodology, and instead of one user test, we had three in this phase. Across the three tests, 11 users responded to the survey. In addition to these respondents, we also received verbal feedback from an additional 8 users, as these users did not have time to answer the survey. A total of 19 users tested the applications during phase 2. In the third and final phase most of the requirements had been decided and there were few uncertainties, so similar to phase 1, only one user tests was required. 10 students responded to this survey, verbal feedback was gathered from 6 additional students, and expert feedback was gathered from a user interface (UI) expert through an open interview. Phase 3 ended up gathering feedback from a total of 17 users. After phase 3, a final user test was conducted. This test was first done on 10 high school students at Lukus VGS, and then on 5 librarians from the Gunnerus library. In total, 15 users responded to this survey.

For all the user tests combined, there were a total of 50 respondents to the survey, 14 cases where feedback was gathered orally, and one interview with a UI expert. In total, the feedback was gathered from 65 users.

We did not require our testers to sign a consent form from Norsk Senter for Forskningsdata (NSD) since all of the users who took part in the user tests were 18 years or older and no personally identifiable information was gathered. The testers also answered the survey on the same computer, leaving no technical trace such as IP addresses from the users. The data gathered is in accordance with NSD's non-identifiable data[10][11].

4.2 User testing

4.2.1 How the tests were performed

Throughout the project, we had several sessions of user testing on a range of different audiences. As the users we tested on usually had limited knowledge about both the Gunnerus library and VR/AR technology, we started all user testing with explaining this to our users. After this, we explained what our two applications were and what our goal for the project is, and how far we are in the development so that the users could know what to expect for the test session. As we had two separate applications, we were able to test on two users at once, and swapping them between the applications after half of the allotted time. The testing itself usually required around 10 minutes per user for each of the applications, a total of 20 minutes. After a user had experienced both applications, they were asked to answer a relating to that phase. Unfortunately, for most of the initial tests, the tests had significant time constraints. This made it hard to conduct the survey on all users. For these tests, we supplemented the survey feedback with verbal feedback which was written down during the user tests.

4.2.2 The Surveys

The surveys we used changed throughout the phases. Initially, the focus was on gaining feedback for developing the applications rather than answering the research questions.

This was partly because the applications were not at a stage where we thought they were adequately immersive for the users to answer questions about our research questions, and partly because we were a lot more focused on the development at this point. The survey for phase 1 was written in English, but was changed to Norwegian for later phases as all test subjects were Norwegian, and some had trouble understanding certain questions in English.

The surveys were structured into three main parts. The first part was aimed towards gathering data about the user, such as age, gender, occupation, and previous experience with AR/VR, to better understand their backgrounds. The second part of the surveys contained a multiple choice section for the users to rate several statements from important to not important. They were asked what they thought was important for creating such applications and how well our applications were related to this. As the development progressed, this part slowly changed into questions relating to the research questions and comparing the two applications. In the final user test this was the sole purpose of the survey. The last part of the survey contained more open-ended questions where the user could write in their own words what they thought about the applications, what was good, what could be better and if they saw any use cases for such applications. The users were asked questions like how they thought the prototypes could become more educational, or how historical manuscripts could be better visualized through the use of the technology. To write some of the general questions posed to the users, we used igroup's presence survey as a basis [13].

4.2.3 Expert tests

In order to gain insight into what was necessary in order for the applications to be educational and to answer the second research question, the prototypes were tested on librarians at the Gunnerus library to evaluate the quality and presentation of the content in the applications. In addition to the librarians, we also ran a test on a user interface expert and conducted an open interview with him afterwards. This will all be discussed at the end of chapter 7.

Chapter 5

Phase 1: The First Prototype

5.1 Exploration and Planning

This phase contained a lot of planning and experimentation, as the requirements for the applications had not wholly been decided yet. It was understood that an essential part of this project was to create an immersive experience for historical manuscripts, but how this was to be accomplished had not been detailed. Because of this, much time went into finding out how such technologies could be used to do just this.

After much discussion with the people from the Gunnerus library, a plan was made for the development of the two applications. The Gunnerus library wanted to use the applications to draw more people to the library in order to increase its number of visitors and educate them about what it as to offer. They wanted to do this by letting users explore content from the library in a more exciting way, which is what the creation of immersive manuscripts is trying to solve. The development directions were strongly based on making these manuscripts more exciting and engaging, at the same time as being educational.

The main focus for the applications became to "augment" manuscripts using holograms and 3D-models in order to achieve this effect, similar to how some of the projects mentioned in related work had done it. By opening up for interaction with these elements and giving users freedom to explore them, it will hopefully be easier to get immersed in the world of the manuscript, and also more interesting to learn about what these manuscripts have to offer. Because of this, one of the first goals for the prototypes was to be able to display interactable holograms on top of the manuscripts, and creating an atmosphere for the manuscripts.

Both applications have the same primary focus, but because of the difference in technology, some parts of each application were emphasized more than others, and some design differences had to be present. This chapter will focus on how these prototypes were implemented and tested on users and the decisions that were made during the development.

5.1.1 Requirements

These were the main requirements for the applications which were planned in collaboration with the Gunnerus library. Requirement **F1**, **F2** and **F6** focus on making the applications more exciting in order to draw more people to the library, while **F3**, **F4** and **F5** focuses on the educational aspects of the applications. Because of the uncertainty around the project, some of these requirements were changed throughout development. The changes will be outlined in each phase.

F1 The two applications must be immersive, with the goal of giving the user a feeling of presence.

F2 Users should be able to interact with the environment.

F3 The augmented content must be a copy of the content displayed in the manuscript page.

F4 The two applications must help the user get educated about the manuscript.

F5 The manuscript selected should tell a story to the user.

F6 The VR application must visualize a good representation of the Knudtzon Hall located in the Gunnerus Library.

F7 The two applications must be developed in VR and AR, respectively.

5.1.2 Development decisions

Choice of development platform

The two separate applications that were to be developed should share the same resources when possible, in order to decrease the development effort and create reusable material that could be used in future work. Because of this, we decided to develop both applications in similar environments, which is an essential reason as to why Unity was chosen as the platform. Because Unity is well documented and has a large user base with many code libraries and existing projects, it was a good choice for being able to create something quickly. Unity also makes it easy to develop content that supports multiple platforms, which means that all the assets, in addition to some of the functionality, could be used for both the HoloLens and VR application.

In order to develop applications for the HoloLens, the Universal Windows Platform (UWP) had to be used for development. This is a platform for developing applications for various windows devices like the HoloLens or windows immersive headsets. This meant that the platform also had to be used for the VR application in order to make both applications as similar and reusable as possible.

On top of this, the Mixed Reality Toolkit (MRT) was used for both the applications. This toolkit was used for most of the functionality for AR or VR, such as teleporting, interacting with things, and VR/AR cameras.

VR

Virtual reality places the user in a complete computer generated virtual world, but this world has to be created by the developers. Because of this, it was necessary to create an environment for the user in VR before the creation of immersive manuscripts could begin. A decision was therefore made that the Knudtzon Hall located in the Gunnerus library should be chosen as the world that the user is placed in in the VR application. The reason that this was decided was that the room has much historical significance, and is a suitable context for exploring and experimenting with historical manuscripts as the Hall is filled with bookshelves containing old books and manuscripts. As this was a time-consuming task, the main goal for the first prototype was to recreate this room for VR and to let the user explore and interact with simple objects in the room. This meant that the focus on creating immersive manuscripts had to be postponed for the VR application, but we felt that this was necessary because of the importance of a proper environment in VR. Creating the Knudtzon Hall also allowed us to provide a context for the manuscripts, and shows the user where these manuscripts are located in reality. Once this had been done, functionality like interacting with manuscripts and other objects in the room could be implemented.

AR

For the AR application, there was no need for developing a world in which the user could be placed because one could simply use the real world. The environment and context for the application was therefore decided by the user, not by the developer. The goal for the AR application for this phase remained to create an immersive manuscript in AR.

5.2 VR Implementation

The strategy for implementing the 1st VR prototype consisted of first creating the environment which the user could operate in, and then add functionality for interacting with manuscripts in said environment. The environment was created in two stages, the first being the creation of the 3D-model for the environment, and the second being implementing it in Unity.

5.2.1 Recreating the Knudtzon Hall

For the VR part of the project, the Knudtzon Hall was to be used as a "hub" for the rest of the application. From here, one should be able to interact with different books in various ways and also walk around the library to get a feeling that you are actually there. To enable this, we needed a 3D model of the Knudtzon Hall that could be visualized in VR. An image of the real Knudtzon Hall can be seen in figure 5.1.

Figure 5.1: The original Knudtzon Hall

Mapping

We used a technique called "Range Based Modelling" [47] with the use of the HoloLens built in scanning capabilities to create a 3D scan of the Knudtzon Hall. The models produced by such a scan are not detailed enough to be used for visual applications on their own but can be great reference points for further modeling. Getting correct sizes and dimensions for the room itself and objects in it can be a hard and tedious process, and performing such a scan simplifies this. The scanned model was imported to be used as an overlay or blueprint in the modeling software. The 3D scan can be seen in Figure 5.2

Figure 5.2: The room capture of the hall

Choice of modelling software

There is a wide range of different 3D software available to use for this task. Due to some previous experience in Maxon's Cinema4D[17], this was chosen as the primary modeling software for this project. Both group members had limited modeling experience, so for the more complex models such as the busts, we looked online on sites like sketchfab for models similar to what we needed for our project.

Modeling

The scanned 3D-model of the Knudtzon hall was used as a base for a model that was created from scratch, where the proportions and details of the model were used to create a realistic representation. Even though creating the model from scratch required a lot of work, this resulted in a very accurate representation of the room as both the proportions of the room and the placement of furniture and other objects were correct. The model that was finished at the end of the first iteration can be seen in Figure 5.3

Figure 5.3: First iteration of the Knudtzon Hall

Texturing

Most of the textures used in the first prototype were created either directly in unity, or first in Photoshop and then imported to unity. For some of the more complex textures like those used on the walls, a photograph of the real wall was taken and edited into a game-optimized tile-able texture in Photoshop. We also had a photographer take a panorama image of the entire room so that we had access to a reference point for everything in the library.

As the main focus of the applications is on manuscripts, the most critical textures were the textures for the books. These textures had to be somewhat similar to the books in the real room as they are essential to the application, and could not be replaced by something found on the internet. The images from the photographer were therefore used for texturing the books. This was not optimal, however, as the textures were taken from a 2D image

and mapped onto a 3D object, resulting in the books in the bookshelf looking flat and unnatural. This was a problem because the interactable books that were to be added to the bookshelf did not visually fit into the bookshelf. The bookshelves were improved in the second iteration of the project.

Figure 5.4: First iteration of the bookshelf

5.2.2 Implementing VR in Unity

For the VR implementation, we imported our 3D model of the Knudtzon Hall described in section 5.2.1. We then added lighting and functionality to the scene as described in the next sections. To ease the implementation of VR functionality such as movement and interaction using the motion controllers we used Microsoft's own Windows Mixed Reality Toolkit, which is a collection of pre-made components and scripts for basic features for Mixed Reality headsets.

Lighting

To provide light to our scene, we used Unity's built-in lighting tools. We experimented with several different techniques commonly used in games and real-time graphics applications to achieve a realistic result that was optimized enough to be used in VR. Using Unity's mixed lighting mode, we were able to combine baked and real-time lighting to provide high-quality lighting at a low-performance cost, and still have real-time shadows for moving objects. Unity's mixed lights works by baking light into the textures of all static objects that are affected by the light, and only casts real-time light onto objects that will move during runtime. This allows for much fewer calculations while the application is running, but requires a new light baking calculation every time something affected by the light is modified.

Movement

The most common form of movement in VR applications is teleportation. Partly to prevent motion sickness[14] and partly to preserve the amount of space required to use the

application. The Windows Mixed Reality Toolkit provides a basic teleportation script for unity, but it was not an ideal solution out of the box for our application due to how the user perceived the teleportation. The screen would be blacked out for the user during the entire teleportation causing a sense of disorientation, which was especially noticeable in our application as it is in a confined space and the user can see the entire room at all times. To remove this feeling of disorientation, we opted to rewrite the teleportation script such that it gradually moves the player to the teleport position over a set time. When doing this, we needed to be careful as to not cause any discomfort and motion sickness for the player, which is commonly linked to moving the user outside of their control[14]. The moving/teleporting is therefore performed very quickly so that it does not feel like natural movement to the user, but still slow enough that they can identify and keep track of where they teleported from and where they ended up. Microsoft uses a similar type of teleportation movement in their Mixed Reality Demo Scene "Cliff house".

Interactable Books

As there was not enough time to implement a fully working manuscript with functionality for opening and browsing through in VR for the first prototype, a closed manuscript was added to give the user the possibility to pick up and place manuscripts with the handheld controllers. In order to save time, this manuscript was a simple book prefab imported from the asset store. Scripts from the mixed reality toolkit were then implemented for the book in order to make it possible for the user to interact with it such as being able to pick it up with the controller, move it around, and for realism's sake, throw it. The intention of implementing this was to gather feedback on how it was to interact with the books, and what the user's thoughts were on the matter. An example of this book can be seen in figure 5.5.
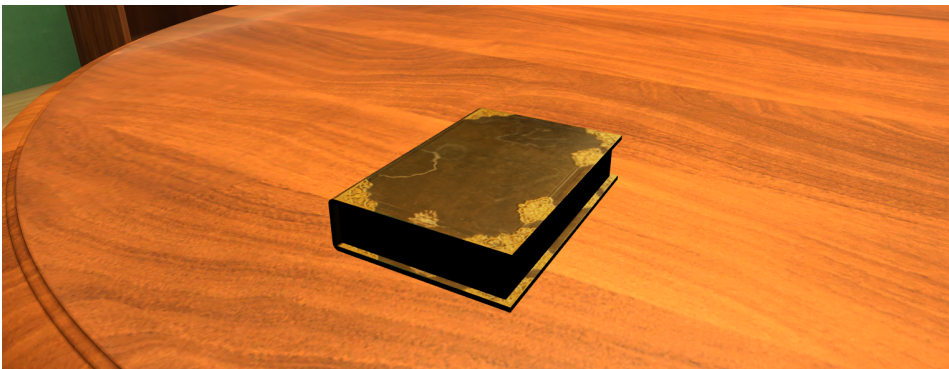
Figure 5.5: The first interactable book

5.3 AR Implementation

A significant part of the first phase went into getting a simple program to run on the HoloLens. Compared to most VR headsets, the HoloLens has less support and a smaller

community, which makes it harder to get the documentation needed when developing. This is mostly because the HoloLens is aimed at large businesses and is still at a prototype stage.

5.3.1 Application Skeleton

The first goal for the AR prototype was to get a basic program with Vuforia at its core up and running. As mentioned, Vuforia is software for tracking real-world images with the HoloLens and can be used to make virtual holograms follow these images. By adding images such as manuscript pages to the application, Vuforia can track these in the real world and apply 3D-models to them, which follow the image as they are moved around in the real world. This makes it look like the 3D-model is a part of the image.

After a lot of research and experimentation, we managed to get a simple image recognition program to run on the HoloLens. Once this was in place, manuscript pages had to be found so that the application had images to track, and objects to be displayed on top of these manuscript pages had to be added. When this had been implemented, a physical representation of a manuscript was made. An example of the first version of the application used on a physical version of the manuscript can be seen in figure 5.6. It is worth noting that it was not possible to take screenshots of the AR application due to the built in camera being used by Vuforia, so all images had to be taken through a smartphone camera placed inside the headset.
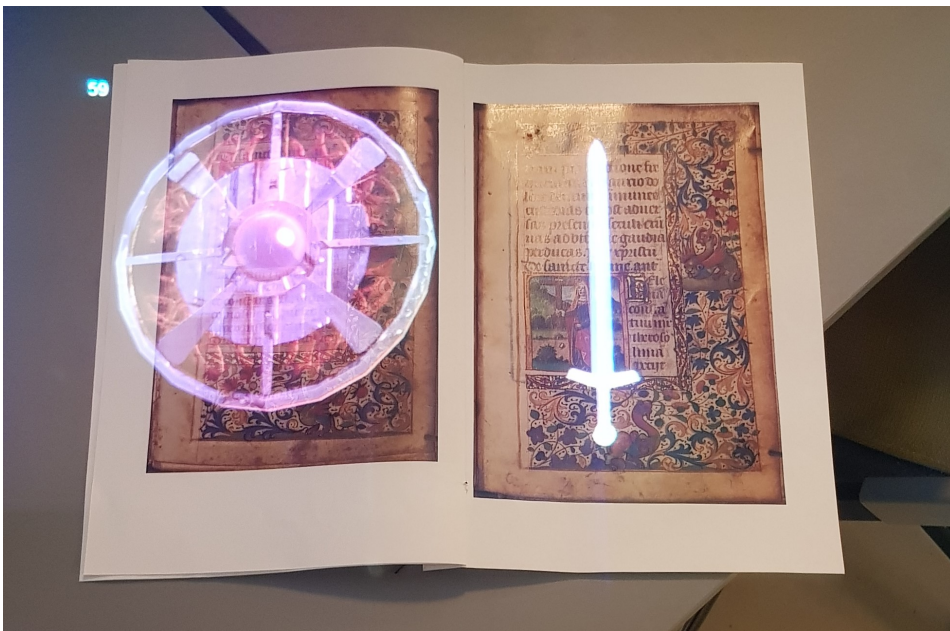
Figure 5.6: The first version, displaying holograms on top of each manuscript page

5.3.2 The Manuscripts

For the prototype, four "dummy" manuscript pages were selected as the tracking images in order to make development faster and to test the concept with low effort. The manuscript pages that are presented in Figure 5.7 were found online and used for the prototype as placeholders until a suitable manuscript could be found for the application.

5.3.3 The Models

Similar to the manuscript pages, the models for the prototype were found online in order to be able to develop and test the application quickly. This was partly done to save time, but also because neither the Gunnerus library or we had access to suitable models for the manuscripts. The selected models were not related to the manuscript for the prototype but were meant for gathering user feedback for the prototype. The objects can be seen in use in the application in Figure 5.7.
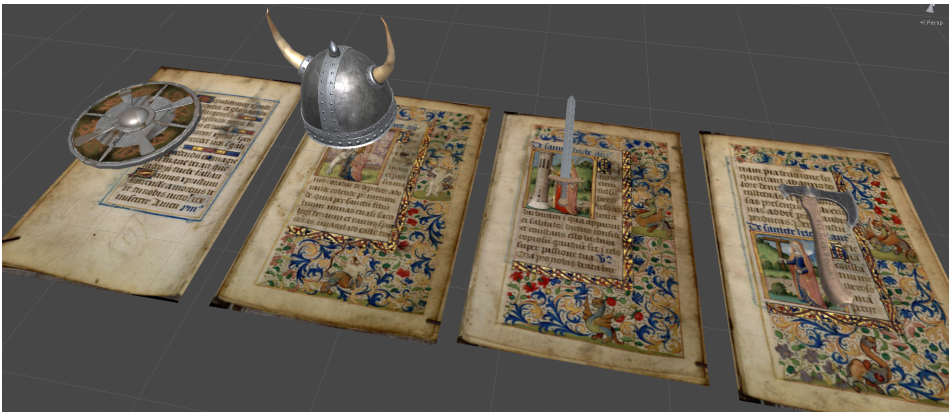
Figure 5.7: The four manuscript pages and the 3D-models as seen in the Unity editor

5.3.4 Tweaking Images

Most of the Vuforia settings for creating optimal tracking was set by default, but some settings had to be tweaked. In order to get the tracking to work well, both the sizes of the manuscript images in the application and the sizes of the manuscript images in real life had to be precisely the same. The limited field of view (FOV) of the HoloLens also meant that not all image sizes were suitable for the real-life images. The initial images were in A4 size, but this did not work well as the FOV did not cover the entire book unless the user stood very far away from it. After much experimenting, A5 was selected as a suitable trade-off between being able to see the holograms and being able to see the details of the manuscript pages.

5.3.5   Issues

Hologram placement

The first idea was to place the holograms on the side of the manuscript pages in order to let the user see both the manuscript page and the hologram at the same time. This was, however, hard to do because of the hardware limitations of the HoloLens. The camera has a limited width, so users had to look directly towards the manuscript to enable the tracking. Because the tracking stopped when users looked away from the manuscript, and because the limited FOV only enabled users to see things right in front of them, the holograms had to be placed directly on top of the manuscript pages.

Hologram visibility

Because of the nature of holographic displays, the holograms which are rendered are also harder to see compared to when viewed on a smartphone. This is partly because the holograms are rendered by projecting light onto a transparent glass pane, but also because the technology behind the HoloLens is relatively new. The HoloLens works by adding light on top of the real world, where black appears as transparent while white is very visible. The darker the color of an object, the more transparent it becomes. Because of this, some aftereffects had to be added to some of the models to make them appear less transparent when viewed on the HoloLens. An effect called "emission" was added in order to make the objects appear more bright. Emission in Unity means that the object emits light, which makes them appear brighter. The emission value was tweaked for each model in order to make them more visible without compromising the visual quality of the model. The downside of this was that the higher the emission, the more bland and colorless the models appeared, which meant that a trade-off had to be made between quality and visibility.

Other issues

Because few people and companies own HoloLens, there are not as many existing projects and libraries that can be used for development. This means that the process of developing a complete product is a lot more time consuming and dependent on trial and error compared to VR. Another challenge is that it is harder to get accurate and stable models when using the HoloLens compared to modern smartphones. The camera installed on the HoloLens has some hardware limitations, which makes the tracking somewhat slow and less reliable compared to the smartphone counterparts. The holograms that are rendered seem to lag a bit behind and do not manage to follow the images as well as they do on phones. There is unfortunately little that can be done to improve this, but it is worth noting that it is a hardware issue and will most likely be solved in the future with the introduction of more sophisticated technology.

There were also some challenges regarding the use of the Mixed Reality Toolkit as this toolkit is under heavy development by Microsoft, so the code is somewhat unstable and is not as well documented as would be desired.

5.4 First Evaluation

The first evaluation was held at the Gunnerus Library, where a total of 14 users responded to the survey. Most of them were students or employees working with the library.

The surveys featured ten questions consisting of multiple choice questions and short text answers. The feedback was used to improve the implemented features, scrap unnecessary features, plan upcoming features, and answer the research questions. The full results from the survey can be seen in Figure A.1.

5.4.1 User test data

Most users were positively surprised by the prototypes. They enjoyed experimenting with them, and many were surprised with the HoloLens itself. Most of them meant that both the VR and HoloLens prototype were immersive, and several users stated that they felt like they "were in the library" while they were using the VR application. Many users were although a little confused about what they could do and what they were supposed to do in the prototypes. Some users were able to experiment a lot, while others needed help most of the way.

13 of 14 users meant to a "large" or "very large" extent that being able to interact with things was an important element in creating an immersive experience of manuscripts, and 12 of 14 users had the same attitude towards having enough things to interact with. A significant part of the users also meant that realistic graphics were important to achieve immersiveness, where 11 of 14 meant this to a "large" or "very large" extent. Users did not mean that the story that was told through these manuscripts was as important, where 7 of 14 to a "large" or "very large" extent meant that it was important that the story reflected the manuscript and 7 of 14 responded the same for how important a continuous story was. The rest of the results from this test can be seen in Figure 5.8.

As when it comes to the learning elements of the prototype, several people commented that it was important the prototypes focused on showing historical artifacts to the user. This both to improve the learning outcome, but also to improve immersiveness. It was also mentioned that applications such as these could make students more excited about the themes that are presented, and encourage them to read up on them afterward. Many users were also surprised by what this technology could potentially achieve, and how this technology could be used to make existing content more exciting.

The respondents to the survey also provided some verbal feedback during the test, and some of the librarians mentioned that it might be a good idea to be able to see a transcription of the text written in the manuscripts as it would make it possible for the users to read the manuscripts without knowing the language. It was also mentioned several times that the application should show content directly from the original manuscripts, instead of random placeholder objects. Regarding the AR application, people liked that the application was simple to use and that the limited amount of objects displayed on the pages made it clear and understandable.

Of the respondents who had an opinion of which application they preferred, 4 of them preferred both, 3 preferred the AR application, and 1 preferred the VR application. The people who preferred both said that each application had its own advantages and fields where they might have great potential, as they were quite different technologies.
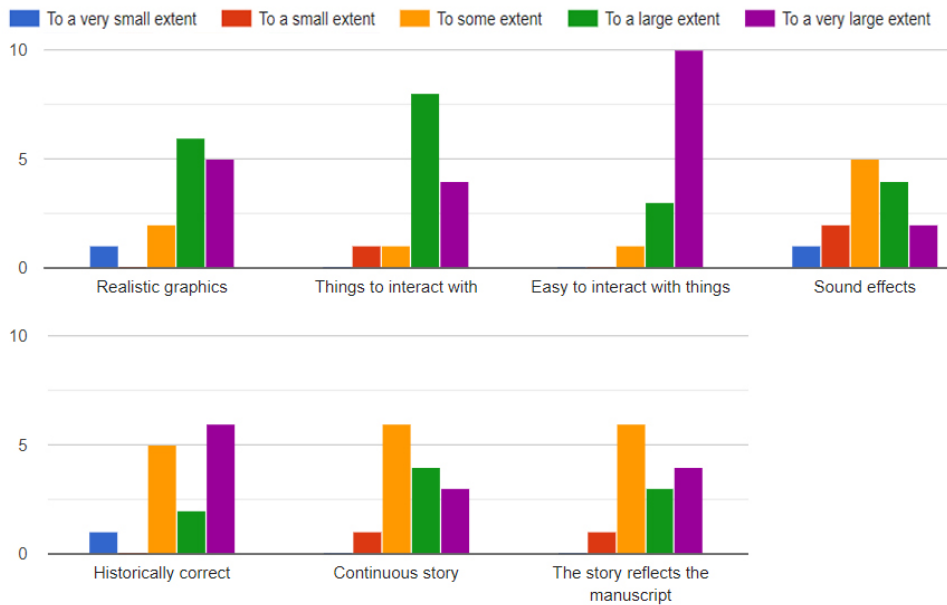
Figure 5.8: What people meant was important for immersiveness

5.4.2 Analysis

The results indicate that the prototypes can make manuscripts more immersive. Although at an early stage, the prototypes helped users get more engaged in old manuscripts to some extent, which means that the core fundamentals that the prototypes were based on like displaying objects above pages and changing the environment based on which book the user is reading are ideas that are worth to continue working on.

Interaction and realism

Users meant that things like the ability to interact with things and the visual quality was important. The focus on interactiveness might be a good idea as this is one of the areas where MR separates itself from traditional desktop applications. MR allows the user to interact with their surroundings with the use of their head and hands, and to some extent, their whole body. This leads to a more realistic experience compared to a typical computer application, which should be taken advantage of. A possibility may be to let the user interact with the objects displayed above the manuscripts. It might also be beneficial to create an application that resembles the real world, as the user may be more immersed if it is harder to discern the virtual world from the real world.

Visibility and simplicity

Several of the librarians mentioned that the holograms made it hard to see the manuscript that was beneath it. This is a good point as it is important that the use of technology does not come a the cost of the learning outcome, but rather helps improve it. It is therefore important to make sure that the user still has the possibility to properly see the manuscripts when using the HoloLens application as the holograms are meant to augment the manuscripts, not replace them.

Several librarians, however, liked the simplicity of the application, and mentioned that it was an advantage that it was simple and easy to understand. There were few objects in the scene at the same time, and it was easy to know what was important to focus on. It may be a good idea to try to keep things simple at later stages in development as more functionality is added.

Real content

At the time of the demo, the historical content for the prototypes was not related to the manuscripts, which several users reacted to. For the next phase, the content should be related to the manuscripts that are used, and the manuscripts should be real and coherent. It might, therefore, be a good idea to use 3D models of real historical objects as much as possible to ensure that the applications are historically correct and also educational. Real objects and artifacts might also make the applications more interesting as the user can know that what he/she is looking at is real instead of made up.

Transcriptions

Implementing a way for the user to be able to read transcriptions of the manuscripts as they scroll through the pages might have significant benefits for the applications. As a majority of the manuscripts found at the Gunnerus library are in different languages than Norwegian or English, being able to translate these to a language the user can read could make them both more educational and more interesting as it would be easier to understand the content of the manuscript.

Considerations for the next survey

When analyzing the results, it became clear that some of the questions did not provide the answer that was needed. Some of the questions did not focus on the themes that are central to this thesis and some users were confused with certain questions. Although the survey covered most of the requirements, some were not adequately answered. The requirements for letting users get educated about the manuscript content, creating a good representation of the Knudtzon Hall and comparing VR and AR technology were not fully answered in this survey, which means that it might be beneficial to focus more on these aspects of the thesis for the next survey.

Most of the respondents for the survey were adults above the age of 25, so a large amount of the feedback came from adults. In the future, a larger part of the audience should be younger people, as one of the goals for the project is to attract young people to

the library through the use of modern technology. These problems should be taken into consideration when creating the survey for phase 2.

Updated Requirements

The results from the first evaluation had an impact on how important it was to achieve some of the requirements, as the focus on being able to interact with the environment became more significant than expected. Because of this feedback, it was decided that the requirements had to be modified for the second phase. This will be covered in depth at the start of phase 2.

Chapter 6

Phase 2: Main development

The second phase consisted of planning the way forward once the simple prototypes from the previous phase had been implemented, and implement the most essential features that were needed in order for the applications to reach their goals. The goal for this phase was to implement functionality focusing on letting the user interact with the environment, and finish the most important parts which had already been somewhat developed.

6.1 Planning and Changes

The planning phase went on for a large part of the second phase, as the details for some of the requirements were quite easy to decide while others took many meetings and much discussion to get right.

The test conducted at the Gunnerus library at the end of phase 1 provided a great deal of insight for the prototypes. Potential improvements were discovered, feedback was given on what worked well and what did not, and some ideas regarding new features and possibilities were discovered. Enough preliminary work had been done to start deciding the parts that should be focused on, and the parts that should be discarded.

The AR application was now far ahead of the VR application in terms of functionality, so for the start of phase 2, the focus shifted onto the VR application in order to get it to the same point as the AR application was. The AR application could already show holograms on top of individual manuscript pages, although these holograms were not interactable, while users could only explore the Knudtzon Hall in the VR application with no possibility of viewing manuscripts.

As mentioned in the Research Methodology chapter, the approach done in this phase was a bit different. Instead of one extensive user test at the end of the phase, several smaller user tests were conducted throughout the second phase. This was done due to the current uncertainty of the project and the fact that this phase was going to be longer than the first and last phase.

6.1.1 Manuscript content

The AR application had enough content to be testable on users, but this content only consisted of relatively random materials found online. Before development could continue, it was therefore important to find out exactly what content the applications should revolve around to avoid developing unnecessary functionality and content. This had already been discussed several times with the library, but the uncertainty around finding the right 3D-models for the manuscript pages made it hard to decide what kind of manuscripts to use. Because a decision had to be made before development could continue, it was decided that a manuscript describing a Norwegian noble traveling through Europe, named Lilien-Skjold, should be chosen as the main manuscript for the applications. This was decided for several reason, most importantly because it had enough images to work with Vuforia's image tracking, and because these images described objects which were possible to represent using 3D-models. A downside with this was that a compromise had to be made for the 3D-models for the manuscripts, in that these models would most likely not be an exact representation of the images found in the manuscript pages. Because of limited resources and limited compatible manuscripts, it was instead decided that the 3D-models should represent the manuscript image as good as possible. Because of this, the requirement *"The augmented content must be a copy of the content displayed in the manuscript page."* from phase 1 was changed to requirement **F5** *"The augmented content must be a close representation of the content in the manuscript"* in phase 2.

6.1.2 Telling a story

The requirement *"the manuscript selected should tell a story to the user"* from phase 1 was removed, mostly because of the reasons described in the previous paragraph, meaning it was too hard to achieve with the resources we had been given. Instead of telling a coherent story, the focus was instead moved to educating about important parts of the manuscript through methods like augmentations and being able to explore and interact with its content.

6.1.3 Diving into manuscripts

To improve the level of immersiveness for the applications, requirement **F3** *"Users should be able to "dive into" a manuscript and explore its world"* was added to the list of requirements. This meant that users should be able to dive into a world described in the manuscript such as a city or a particular historical landmark such as the area surrounding the tower of Pisa in order to be more immersed and experience important sites close-hand. Adding this to our applications would provide more content that compliments the context that was added through the Knudtzon Hall in phase 1. This part of the application can also be related to virtual heritage, depending on how the historical landmarks are implemented. Because other features had to be implemented before this one, it was moved to the last phase.

6.1.4 More interactions

From the surveys gathered from the end of the first phase, it was clear that most users thought that being able to interact with the environment was necessary for an immersive experience. Being able to interact with the environment in a natural, intuitive manner is a crucial factor in the process of creating an immersive experience, and giving the user a feeling of presence. Requirement **F3:** *"Users should be able to interact with the environment"* from phase 1 was therefore moved to be requirement **F1** in phase two, as it now was the most important requirement for this phase.

6.1.5 Translations

Even though the chosen manuscript is written in Norwegian, it is written in cursive and such an old language that it is hard for most people to be able to read the full text properly. Based on this and user feedback, it was decided to display translations of the text for each manuscript page when displaying the holograms. The actual translations could not be obtained during the second phase, so dummy text was used until the third phase. An example of these translations can be seen in figure 6.8.

6.1.6 Updated Requirements

As mentioned above, some requirements were replaced or moved. The requirements marked in bold are the new or modified requirements for this phase.

F1 Users should be able to interact with the environment.

F2 The two applications must be immersive, with the goal of giving the user a strong feeling of presence.

F3 **Users should be able to "dive into" a manuscript and explore its world.**

F4 The two applications must help the user get educated about the manuscript.

F5 **The augmented content must be a close representation of the content in the manuscript.**

F6 The VR application must visualize a good representation of the Knudtzon Hall located in the Gunnerus Library.

F7 The two applications must be developed in VR and AR, respectively.

6.1.7 Development Decisions

VR

While the AR application lets the user use real books, these books had to be created digitally for the VR application as this application was entirely virtual. An interactable virtual book was, therefore, made to ensure that both the VR and AR application had the same functionality. The advantage of this was that once the book had been created, it could be

used as a template book to easily create new manuscripts by adding different content to the template book. The most important features for this template book were therefore features for interaction, and allowing developers to add content to the manuscript in a simple manner. Less important features were adding animations where appropriate, and create a realistic 3D-model of the manuscript to make it seem more real. As this was the core functionality of the application, this was one of the main goals for the second phase and a considerable amount of time went into developing a functional interactable manuscript.

The current version of the Knudtzon Hall had been the same since the end of phase 1 because other features such as interaction were more critical to the experience. One of the essential points from the user tests was the importance of realistic graphics for immersion. A goal for the second phase became to create a more realistic representation of the Knudtzon Hall in VR, as this environment was both critical for creating immersion, had historical value for teaching about the library, and was important as a context for the manuscripts.

After finishing the features in phase 1, and supplementing with much more interaction throughout phase 2, we realized that the application required to be a lot more performant to be able to maintain an acceptable framerate. The framerate is a vital property of creating an immersive application as described in the immersiveness section 2.2. Therefore we decided to allocate some development time to optimize the application to increase it. As we have no prior experience with optimizing a unity application or a VR application in general, this required a lot of trial and error as well as looking at general optimization guidelines [42].

AR

As the VR application was prioritized over the AR application during this phase, the goals for the AR application was less ambitious for phase 2. The main goals were to implement possibilities to interact with the holograms displayed over the manuscripts, including some other features which were needed based on the feedback from phase 1.

The first feature was the ability to see holographic translations of the text in the manuscripts, with the goal of increasing the possible learning outcome as described in the translations section. The second feature was the ability to toggle the holograms. This feature was needed because the HoloLens hardware limitations required the holograms to be placed on top of the manuscript pages, occluding the manuscript itself. By being able to toggle off the holograms, users could then also be able to see the manuscript pages and not only the holograms, which is important to ensure that the use of technology does not overshadow the historical content of the manuscripts. The third feature was the ability to manipulate objects, namely the 3D-models shown over the manuscript pages. This was done to increase immersion and give the user more freedom to explore the content of the manuscripts properly. The last feature was functionality for manipulating the objects with a minimal need for interaction. This feature was added later in phase 2 as users had problems with manipulating objects due to the hard to learn hand gestures. By pressing the button instead, users could somewhat manipulate objects with more straightforward gestures than the ones needed for manipulating the objects by themselves.

6.2   VR implementation

6.2.1   Interactable Manuscript

The first and most important feature for the interactable manuscript was the ability to flip through the manuscript pages like in a real book. This was accomplished by using the handheld controllers, by putting the controller inside the page of the open book and then lifting it similarly to a real book. Like most of the other interactions in the VR application, code from the Mixed Reality Toolkit was used as a base to achieve this. Based on early testing and user feedback, it was hard for the user to move the book and turn the page with the same button, so the interactions for flipping pages and moving the book was later moved to separate buttons on the controller.

The next feature was the ability to pick up a book, and then open it to reveal the interactable book with flippable pages, as mentioned above. In order to make this action seem realistic, the book had to be opened by grabbing the closed book with both hands. The intention was to let the user gradually open the book by moving the hands apart, but due to time restrictions, the closed book was just replaced by an open book when grabbed with both hands. To make development easier and because of restrictions in the Mixed Reality Toolkit, the opened version had to float in the air while the closed book was affected by physics. This also made it easier to use the application as users could leave the book floating in the air while interacting with other things.

To make the manuscript similar to the AR application, the associated 3D-models for each page also had to be shown when browsing through the manuscript. The VR application had fewer limitations than the AR application regarding visibility, so it was decided that the 3D-models should appear on top of the table at the center of the Knudtzon Hall. This way, the models would not be in the way of the manuscript pages, and could also be a lot larger than if they were placed by the manuscript. This was implemented by creating two placeholders on the table, one for each currently visible manuscript page in the opened book, and then update which models should be shown in these placeholders based on which page the user was at in the manuscript.

The last feature was a feature meant for developers, which was the ability to add 3D-models, text, and the manuscript images themselves to the template manuscript without much effort. The intention of this was to make it easy to add many different manuscripts to the VR application if it was needed either later in development, or in case someone wanted to continue working on the project after the thesis was completed. A system was made where each manuscript page was linked to a specific text input field, image field, and a specific game object for the chosen 3D-models was created to solve this. By doing this, future developers could create prefabs of the 3D-models in unity and link them to each manuscript page to add the 3D-models, add the image file for the manuscript page to the image field, and paste in the text they want to display in the text field to add content.
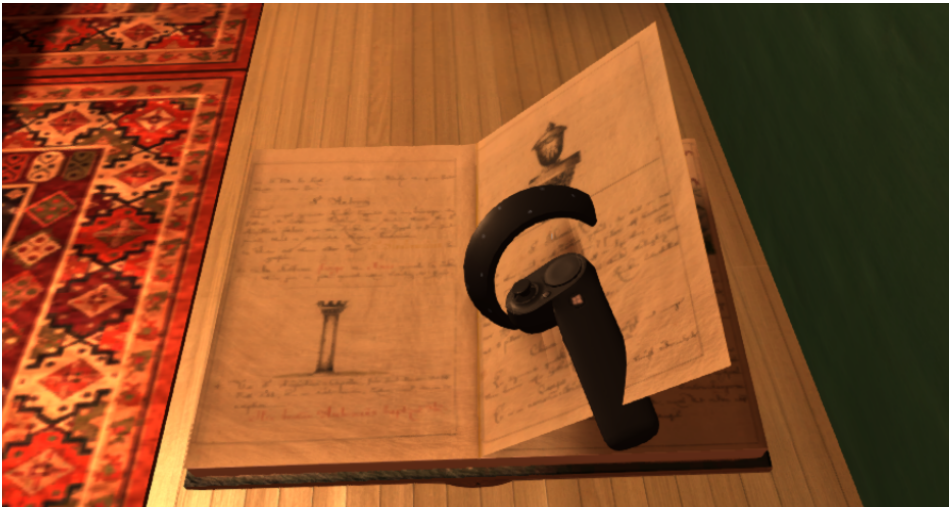
Figure 6.1: The interactable manuscript

Manuscript Content

3D-models found online comes in a range of different file formats, so most models could not be imported directly into unity. To get around this problem, Blender[5] was used as an intermediate step both for importing models with the right file format, although this still did not allow us to use all types of file formats. These models were then modified to fit the project, such as reducing the number of triangles in the models as the HoloLens hardware only supports up to 200,000 triangles at the same time, and cutting off parts of the 3D-models that were not needed for the applications. Some recoloring and minor improvements were also done, mostly to make the models more visible on the HoloLens or look better in VR.

The biggest challenge was the fact that the images contained in the manuscripts were often vague and hard to tie to something concrete. Like mentioned above, finding 3D-models for images such as hills and furniture was hard, so in many cases, we had to go with models that looked a lot like the image but was not a direct copy of it.

6.2.2 Improving the Knudtzon Hall Graphics

This was a process that had many small steps and required much experimentation to get right. The process of creating a realistic representation of the Knudtzon Hall included things such as normal mapping materials, baking lights, experimenting with multiple light sources and importing existing 3D-models. As there are many things which can be done to improve realism, only the most relevant techniques will be described in detail. An image of the improved version of the room can be seen in figure 6.2.

Figure 6.2: The improved Knudtzon Hall

Light Sources

The first version had a single light source at the top center of the room, while the real version of the Knudtzon Hall had a large number of directional spotlights in the roof and a window for letting light into the room. In order to try to replicate this, several directional light sources were added to the Knudtzon Hall. This made the room look more realistic, but it also had a considerable impact on the performance as several realtime light sources shining on the same objects are demanding to calculate. When the improved version of the bookshelves was added, it became clear that it would not be possible to have more than one realtime light source in the scene at the same time. An important reason for this was because of the use of a unity feature called GPU instancing, which will be described in further detail in subsection 6.2.3.

Evolution of the Bookshelf Rows

The books contained in the bookshelves underwent three iterations throughout phase 1 and phase 2. In phase 1, each row in the bookshelf consisted of a square-like shape with an image of the bookshelf row from the Knudtzon Hall pasted onto it, as seen in the top image of Figure 6.3. This did not look very good up close, so a technique called displacement mapping was used in an attempt to add depth to the bookshelf rows [28]. Displacement mapping is a technique where an image of an object, such as a book, is modified to create a displacement map of that object. The image can then be applied to the object to create depth to it by adding 3D-geometry generated from the displacement map. The results of using this technique was a more realistic representation of the bookshelf rows, but it had some trade-offs such as a higher performance cost and the fact that each bookshelf row still was one large static block, instead of an individual object for each book. This version of the bookshelf rows can be seen in the center image of Figure 6.3. The books placed in the bookshelves still did not look as realistic as we wanted, so at the end of phase 2, a third attempt was made on creating more realistic bookshelf rows. This time a collection of free

models of old books was imported from various 3D-model sites and the unity asset store. These models were shuffled around and used to fill all the bookshelves with books. This was the most realistic approach as each book was an independent object, and the models were fairly detailed. This method did have some performance issues and came with some other trade-offs, but there were also several significant advantages, such as a high level of realism and an easy way to interact with each individual book. This version of the bookshelf rows can be seen in the bottom image of Figure 6.3.

Figure 6.3: The three iterations of the bookshelf rows. From oldest to newest, top to bottom.

Normal Mapping Materials

To create more realistic surfaces in the room and on objects found in the room, a technique called normal mapping was used [28]. This technique has a similar effect as displacement mapping, but instead of creating additional geometry on the object it is applied to, it instead creates "fake" details on the object. The surface of the object is still flat, but it appears as if it has crevices and details not possible on a flat surface. The normal maps were either found online, or they were generated using a program called Materialize, which can be used to generate detailed normal maps by tweaking images. [6]. The advantage of using this technique compared to displacement mapping is that the result does not have a very negative performance impact, which makes it a good cheap alternative to displacement mapping or complicated 3D-models. An example of the difference of using normal mapping can be seen in Figure 6.4, where the left image is a surface without normal mapping, and the right image is with.

Figure 6.4: An example of the use of normal mapping

6.2.3 Optimization

We started by looking at optimization problems that are common in most visual applications, such as lighting. We then lowered the number of realtime lights that were enabled in our scene and changed less fundamental lights to be baked instead of real time. Baked lights are precomputed before runtime and saved into lightmaps that are a lot more performant to apply when the application is running, as very few calculations have to be done realtime. This increased the framerate significantly, and only a single realtime light was used to get shadows for our dynamic objects.

As we in this phase also filled the bookshelves with individual books to increase the realism of the application, we had to lower the polygon count of the books slightly because of the large number of books. We also divided the books into the three categories static, dynamic, and openable. Static books were the books located at the highest shelves that the user was never supposed to be able to reach. Dynamic books are the books that the user could reach and grab during regular use of the application. The openable books are a small subsection of the dynamic books that the user could interact with even further than just picking up and also open and interact with further. This also had a significant impact on the application's performance, as physics calculations now only had to be done on a smaller subset of all the books in the library instead of all of them. The user should also not be able to notice this, as the static books are out of their reach. In addition to separating the different types of books, we also allowed unity to use the appropriate batching method on them. Batching allows unity to draw similar objects (similar shape, material, etc.) in one go instead of separately [39]. Unity handles batching differently for static and dynamic objects. Static objects are combined into bigger meshes and rendered together in a faster way. For dynamic objects, there are two different types of batching. Dynamic batching is for smaller meshes in the scene, and their vertices are transformed on the CPU, grouped together and then drawn in one go by the GPU. With GPU instancing the first part is skipped, and the meshes are just sent straight to the GPU, thus giving a performance boost as long as the instanced mashes do not change between frames [40].

The last significant optimization change we applied for this phase was changing from multi-pass to single-pass rendering in VR. Multi-pass tells unity to go through most of the rendering process twice, one for each eye in the head mounted display. Only culling (cal-

culating which objects are to be shown) and shadow calculations are shared between them. The different eyes will have different render targets which can introduce CPU overhead compared to only using one render target [35]. Single-pass combines more of the rendering process as can be seen in Figure 6.5. Since single-pass uses a double-wide texture for the rendering process, for regular use, the user will still have a slightly different view in each of the eye displays. As our application will not leverage the use of two separate rendering targets for eyes in any specific way, single-pass was chosen as the better option for this application.
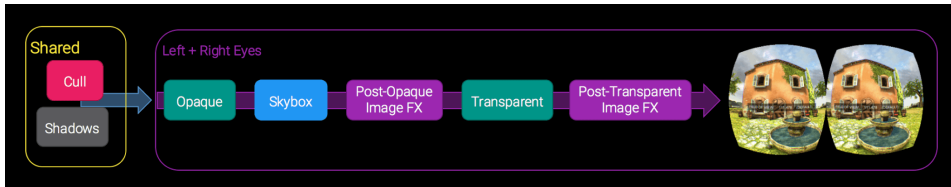

Figure 6.5: Shows the single-pass rendering process

6.2.4 Tutorial/Get started help

Since most users spent some time getting used to the VR application, some measures were done to make it easier to understand. A system for displaying labels for each controller button was added, which displayed a small description for each of the buttons on the VR handheld controller. These could be toggled on and off.

The HoloLens did not require a tutorial at this point, as it was still a quite simple application.

6.3 AR implementation

The AR application changed quite a bit after the feedback had been received at the end of phase 1. Throughout this phase, the application underwent several iterations as features were implemented, tested on users, and improved or changed based on feedback. Implementing the requirements for the HoloLens proved to be a challenge due to the technical limitations of the headset, such as the field of view (FOV) and the hand gestures, so frequent user feedback was important.

6.3.1 Translations

Translations were implemented by displaying a text field as a hologram on top of the associated manuscript page. It was placed directly beneath the 3D-model to make it more clear that both the 3D-model and the text was associated with the manuscript page. TextMesh-Pro, a unity-package was used to ensure that the text was as readable as possible and made it easier to format the text. The limited FOV, unfortunately, meant that users had to be a minimum distance away from the text to be able to see all the text, which means that the text also had to be scaled up to be able to read from this distance. This limits the amount

of text that could fit into each page, which means that the entire translation for each page could not be included for each page, and had to be replaced by a summary of it.

The actual translations could not be obtained during the second phase, so dummy text was used for testing purposes until the start of the third phase. An example of these translations can be seen in Figure 6.8 at the end of this section.

6.3.2 Manipulating objects

The Mixed Reality Toolkit was used as the base for interacting with objects in the AR application. This toolkit contains various scripts for interacting with things in various ways and can be somewhat customized to fit one's needs. Various scripts from this toolkit have been used and modified to give the user the ability to move these 3D-models with the use of the HoloLens' built-in hand gestures. "One-hand-movement" scripts were added to the 3D-models so that the user could move them around using one hand, and "two-hand-manipulatable" scripts were also added so that more advanced users also could scale and rotate the same models using both hands. This gives the user the ability to view the objects from different angles and in different levels of detail based on the size of the object, similar to how one can interact with an object in the real world. Figure 6.6 shows how it is possible to interact with an object using hand gestures.

Figure 6.6: A user interacting with a hologram

6.3.3 Toggle holograms

Similar scripts from the Mixed Reality Toolkit were used to enable various functionality for pressing buttons. This feature was implemented by creating a button that could be

interacted with using hand gestures to toggle the holograms on and off. As seen in Figure 6.7 and Figure 6.8, all manuscript pages are initially visible, and the user has to press a holographic button to display the intractable 3D-models and the translations. The user can hide the holograms again by pressing the translation text, which is indicated by the yellow description at the bottom of the translation. The downside of this feature is that it adds extra steps for the users for using the application properly, and more importantly, demands that the user is able to use the cumbersome hand gestures required by the HoloLens in order to view the holograms. This is, however, a necessary trade-off if the educational part of the application is going to be retained.
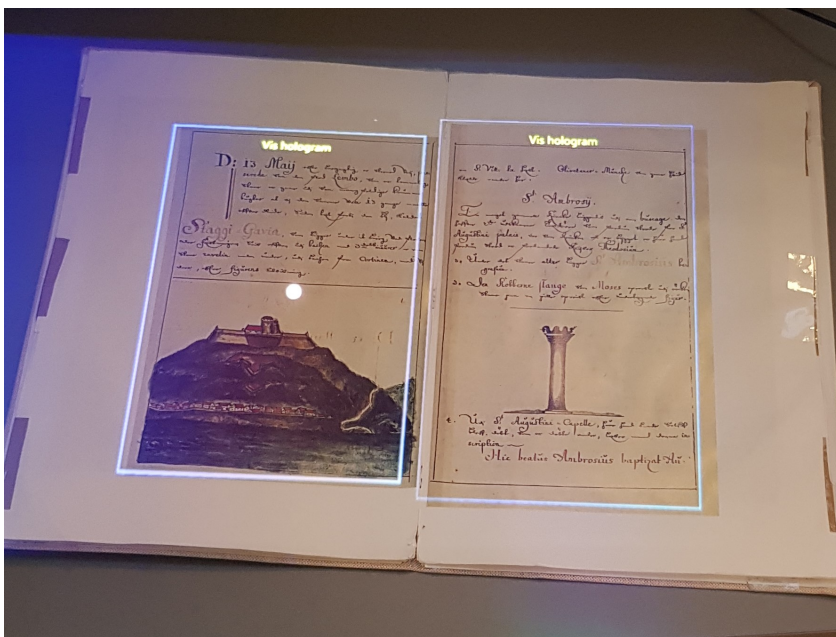

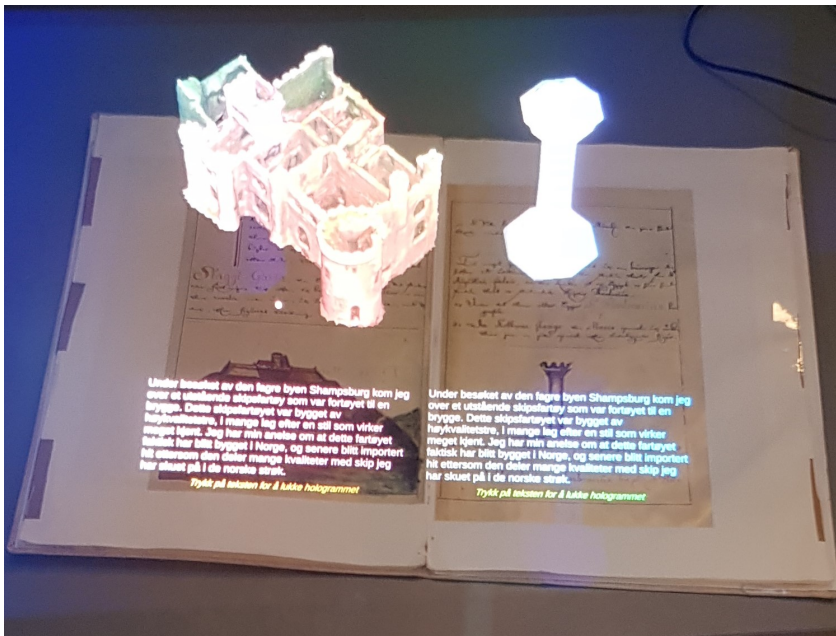**Figure 6.7:** Holographic buttons for displaying holograms

Figure 6.8: How holograms appear after a holographic button has been pressed

6.3.4 Reset and resize buttons

In order to make it easier to manipulate these 3D-models without using two hands, a resize button was added for making objects larger or smaller without the need for the complicated two-hand gesture. The method for adding this button was similar to how the button for toggling holograms was added. A reset button was also added to make it easier to get the object back to the default position in case the user moved, scaled or rotated it in a way that is hard to revert. These buttons were first implemented as a part of the models and followed the object around when as it moved, but based on feedback it was later changed to always sticking to the manuscript page it belongs to in order to make the application more intuitive and easier to use. The buttons only appear after the user has interacted with the object for the first time. This was done because the space above the manuscript pages is quite limited, so unnecessary content was removed for clarity. This was tested at the end of the second iteration in order to ensure the effectiveness of the feature.

6.3.5 Optimization

The HoloLens is only capable of rendering about 200,000 vertices at the same time, due to the limited hardware present in the headset. As the models became more complex, it was necessary to reduce the quality of these models. This was done to keep the frames per second (FPS) at a stable 60FPS, which is very important for immersion as described in section 2.2. Blender [5] was used for doing this.

6.3.6 Challenges

It was already clear that the limited FOV made it harder to create an immersive experience for the HoloLens. The fact that holograms had to appear directly in front of the user's gaze made it challenging to develop an application that immerses the user in the world of the manuscript.

Another challenge is that the HoloLens is a new type of technology which most people are not yet used to. Communicating how to use the application properly to the user was another development challenge. It was also hard to place everything that was needed within the small without making the experience confusing for the user.

On top of this, the Mixed Reality Toolkit, which was used for large parts of the development had many flaws and inconsistencies, which made development a lot slower and cumbersome than expected. Microsoft also abandoned this version of the toolkit when they suddenly started creating the next version of the toolkit from scratch, making it hard to upgrade to a future version if that would ever be needed. [19]

Many of the features in this phase were implemented as an effort to solve some of these challenges.

6.4 Second Evaluation

Three user tests were conducted at three points during the second phase in order to gather continuous feedback on the implemented features and ensure a fast, adaptable development process. A few questions were changed from the first survey to accommodate the second phase. There were a total of 11 respondents on the survey and a total of 8 additional test subjects which only provided verbal feedback due to time restrictions. A total of 19 users provided feedback for phase 2, and all the results can be seen in Figure A.2.

6.4.1 User test data

Similar to the user tests done in the first phase, most people were positive to the applications in general and meant that there was much potential in how this technology could make learning both more fun and more engaging. Most people agreed that this was a fun way to learn about the Gunnerus library and that the use of such technology could be a good alternative to current learning methods.

Similar to the last user test, people were very positive towards the importance of realistic graphics and the possibility to be able to interact with things without much effort. All 11 test subjects responded that realistic graphics were important for creating an immersive experience of these manuscripts to a "large" or "very large" extent, while 9 of 11 responded the same for "having things to interact with", and all 11 users responded with the same for "easy to interact with things". For the question "Was there something you wish you could do in the application", 4 respondents mentioned that they wanted to be able to interact with things to a greater extent. 9 of 11 respondents also meant that animations were important for being immersed in these historical manuscripts to a "large" or "very large" extent.

This time, people were evenly split between preferring VR vs. AR. 4 of 11 people said they preferred VR, while 5 of 11 people preferred AR, and 2 did not have a preference. Most of the people who preferred VR explained that this was because they felt more immersed, or that they felt that they were in a different place. The people who preferred AR either meant this because there were more things to do, or that the experience was something entirely new for them.

The overall layout of the AR application also received some criticism. 2 survey respondents mentioned that the FOV made it harder to use, and 7 users mentioned the same thing verbally. Many users also struggled with using the touch gestures for the HoloLens for interacting with objects in the application. 3 respondents mentioned in the survey that it was hard to use the hand gestures when using the AR application, and the external supervisor had to explain how the gesture system worked to nearly all users. Some users still did not understand how to use it correctly, even with the help of an external supervisor. When users first understood the gestures, however, it was quite easy for them to use the application properly. People had similar issues when using the VR application, as the external supervisor had to guide most users through how to interact with things once these had been implemented.
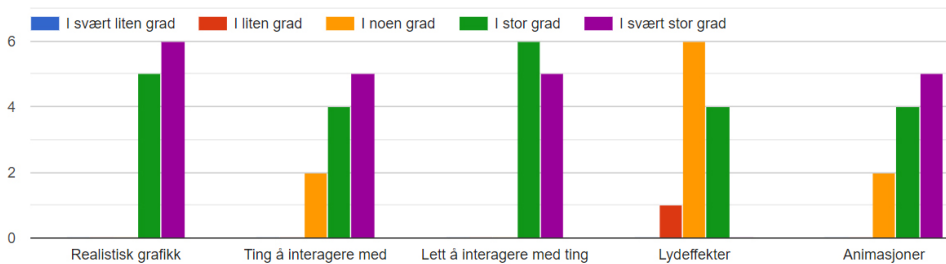
Figure 6.9: What people meant was important for immersiveness

6.4.2 Analysis

Parts of the results from the user tests were as mentioned used throughout phase 2 as they were gathered to implement the features and ensure that these features made the overall applications better. Most of the planned features for this phase were therefore implemented in time, and the feedback for the features which did not get implemented was used for implementing phase 3. This section describes how the results were analyzed to make decisions for developing features during this phase, and what should be done for the next phase.

Interacting in VR

Users did not have the same options to interact with the environment in the VR application as they had in the AR application when the first user test was conducted. Even though people could pick up books and place them on the table, there was no way of interacting with

the content of the book, such as the 3D-models or the text like in the AR application. This was a more requested feature than previously expected, and because the ability to interact with things both makes the application more fun to use and improves the immersiveness, this feature was set as one of the most important features for the rest of development. Because interactions had already been implemented for the AR application early in the second phase, more focus was shifted onto implementing this for the VR application similar to how it had been done in the AR application. The parts of this requirement that did not get fully completed were pushed to the start of phase 3.

Improving realism

All users agreed that realistic graphics were important for an immersive experience, and since immersion is one of the cornerstones of the thesis, more time than what had been planned went into creating a good representation of the Knudtzon Hall. Because of the ability VR can have to make users feel like they are in a different place, it might be a good idea to make the user feel like they are actually in the library, reading and exploring old historical manuscripts. Because users meant that realistic graphics were this important for an immersive experience, this will be an important focal point when developing the requirement "Users should be able to dive into a manuscript and explore its world" in the third phase, along with the focus on interactions.

AR challenges

Because some users thought that the AR application was somewhat confusing, measures were taken to improve the overall presentation of the content. Apart from this, most of the problems users reported having with the AR application was somewhat related to the technical limitations of the headset. This is expected as it is a prototype headset and one of the first of its kind, and the headset itself is not targeted towards the general consumer due to its high price [45].

Users had the most problems with the limited FOV and using the built-in hand gestures. The small FOV most likely made it hard for users to orient themselves in the augmented world in order to find the holograms and contributed to breaking the immersion as holograms popped in and out of existence as the user moved their head. Because holograms are a relatively new phenomenon, users may also use some time to get used to them. This means that the presentation is even more critical than with other technologies, as users should not be overwhelmed with content in a format they are not familiar with. Because of this, it may be a good idea to limit the number of holograms present at the same time in the application, and be smart about placing holograms at places where users will most likely look. An example of the FOV can be seen in Figure 6.10.

Figure 6.10: The hololens' field of view

Most users struggled with using the hand gestures for the headset, and this is challenging to solve as it is an integrated feature of the headset. A possibility may be to use gestures to a lesser degree, but this limits how the user can interact with the environment, which is an essential part of creating an immersive experience. Voice commands are also a possible replacement for gestures as an optional means of interaction but should not be mandatory as not all people might not be comfortable with using these.

Like in the user test for phase 1, users complained about the holograms not always following the manuscript pages. The best solution to this would be to ensure that the content is placed as close to the center of the manuscripts pages as possible.

Tutorials

Interacting with things needed a lot of explaining in VR, and was confusing and hard to learn in AR. A tutorial might therefore be suitable for each application in order to make it easier for them to learn how to use them without help from an external supervisor. The VR application already has labels explaining what the different buttons do, but a tutorial for teleporting and the details of interacting might be a good idea. For the AR application, as the hand gestures are the biggest unsolved problem, this might be a good focus for an AR tutorial.

Animations

As users meant that animations had a significant impact on the immersive experience, some animations were added to the application. While we neither had the skill or time to create complex animations such as movement for characters, some simpler animations were added such as rotations and transitional animations. This was done to create a more

immersive experience and to make the applications feel more alive. Smooth movement feels more realistic than sudden moves and hitches, and rotating objects makes it easier for users to see it as a whole without having to interact with it. This was also carried over as something that had to be taken into consideration during development in phase 3.

Dummy content

As the content that was used for some parts of the applications was still "dummy content" it was at some points hard to gather useful feedback from users, especially regarding features that was directly linked to the said content such as the learning quality of the applications. All dummy content should therefore be replaced by real content as early as possible in phase 3 in order to be able to gather as realistic feedback as possible.

Chapter 7

Phase 3: Last Requirements and Finishing Up

The main goal for phase 3 was to complete the rest of the requirements, polish the applications, and conduct the final evaluations.

7.1 Planning and Changes

The most essential features had now been implemented for the VR application, and the AR application was close to completion. Some features still had to be implemented for the AR application, and both applications needed a proper tutorial. For the VR application, one major feature still had not been implemented, namely "diving into Pisa".

7.1.1 Diving into Pisa

In the previous phase, it was mentioned that one of the intended features would be to "dive into a manuscript and explore its world". This feature intended to allow the user to explore a place found in the manuscript in AR and VR to experience it in a more thorough way than reading about them. After a lot of research on both real cultural sites and available assets that could potentially be used for creating a city, Pisa was chosen as the city that the user could dive into and explore as it was relevant to the manuscript and known to most people.

During planning how the representation of Pisa should look like, an idea about recreating the famous "Piazza del Duomo", the place where the leaning tower of Pisa is located was added. This place is also on UNESCO's world heritage list, so adding it to the application could have advantages on its educational values. The thought of this was to give the user the chance to explore Pisa's historical landmarks while visiting Pisa. As most people are familiar with the leaning tower of Pisa, some research went into whether it was possible to recreate a representation of the area where this tower is located. This eventually led

to the decision of creating a representation of this plasa, and connect it to the Pisa city so that the user could explore Pisa and its historical landmarks at the same time. This plaza contains three important historical monuments: the famous leaning tower of Pisa, the Pisa Cathedral, and the Pisa Baptistery.

7.1.2 Historical Content for the Applications

After several iterations of user testing and content scavenging, the final historical content for the applications was decided. Both the manuscripts and the content connected to these manuscripts had to be the same for both the applications for the sake of being able to compare the effectiveness of the applications to each other, and to save development time. As it had been decided that the manuscript describing Knudtzon's trip to Pisa was to be used for the applications, some suitable pages from this manuscript had to be chosen. Because of the limitations for Vuforia and because pages with images were needed, eight suitable manuscript pages containing text and images were chosen as the content for both the applications.

7.1.3 Tutorials

The user tests had shown that most users needed help from an external person when using the applications. This was partly because both VR and AR are technologies that are new to the general public, and because of the need for complex interactions in the applications. Because of this, it was decided that both applications had to have some kind of tutorial to introduce the users to the relevant concepts.

7.1.4 Final Requirements

Most decisions had been made by the time phase 2 was completed, and the requirements did not need to change. Most of these requirements had now been partly or wholly fulfilled, and the only requirement that had not previously been worked on was the second one.

F1 Users should be able to interact with the environment.

F2 The two applications must be immersive, with the goal of giving the user a strong feeling of presence.

F3 Users should be able to "dive into" a manuscript and explore its world.

F4 The two applications must help the user get educated about the manuscript.

F5 The augmented content must be a close representation of the content in the manuscript.

F6 The VR application must visualize a good representation of the Knudtzon Hall located in the Gunnerus Library.

F7 The two applications must be developed in VR and AR, respectively.

7.1.5 Development Decisions

VR

In VR, the intention was to let the user explore Pisa by walking/teleporting through the city. It would then both be educational for the sake of learning about Pisa, and it would be a possibility to create a strong immersive experience by giving the user full control of exploring a "real" historical location. This lets the user experience how the author of the manuscript would have experienced it, without having to read a book. The user can instead use an increased number of senses to experience how it would be like to visit the area first-hand. The goal of this is to give the user a more complete and realistic image of how this compared to when reading a book.

AR

Because of the nature of augmented reality and the technological limitations of the HoloLens, it was not possible to create the same experience of visiting Pisa as in VR. The user is still present in the real world in AR, so the focus was instead shifted onto how the user could experience this city from the real world. The solution was to instead let the user explore Pisa from a bird-view, viewing the entire city from above. By doing this, the user could then place the city in the room, and then experience it from different angles and different levels of detail. This still lets the user explore the city and get a feeling of how it looks like, but from a larger and less detailed perspective. The advantages of this approach are that the user can move around freely by walking around the model, and can look at the city from whatever perspective they wish. Users can step away to see the entire city as a whole or step closer to see each building up close.

Based on the feedback from phase 2, there were also some areas that could be improved, such as manuscript visibility and making the application more understandable.

7.2 VR Implementation

7.2.1 Diving into Pisa

Because modeling a city would take months or even years for someone without any modeling experience, a pack with most of the assets required to create this city was bought through the Unity asset store [38]. Although the pack had a Roman theme, the assets included were general enough to make it possible to create a good representation of how Pisa could have looked like during the 16th century. The pack included structures such as buildings, streets, realistic materials, various props like vases, furniture, rocks, and so on. The pack also included a demo scene of a small city that was possible to explore. Because of the limited development time that was left for the theses, the demo scene was used as a base for the city. This scene was then modified and built upon to create a more fitting representation of Pisa, and VR functionality was added so that a user could move around and explore the city using VR headsets and controllers. Adding this feature to the VR application distinguishes it from the applications mentioned in related works even further, as there are now three main parts to the application: the augmented book (manuscript),

context to the manuscripts (the Knudtzon Hall) and virtual heritage through the content found in the manuscript (dive into Pisa).

Figure 7.1: The Pisa city representation

The process of creating a representation of the "Piazza del Duomo" started after the Pisa city had been made. Because the three historical structures were too complex to model ourselves, they were also bought from a 3D-modelling site. The area was created using assets from the Rome city pack [38], various free assets, and unity's build in tools for creating geometry. The Piazza del Duomo area was then connected to the Pisa city so that the user could explore both Pisa and Piazza del Duomo as the same area. 3D-models and images such as the ones found on google maps were used when creating Piazza del Duomoto ensure that the scale and proportions of the area were as close to reality as possible and that most of the similarities were preserved. When this had been done, the three historical buildings were added to the plaza. Because the area was supposed to be a representation of how it could have looked like during the 16th century, some alterations were made to the area to make it look like it belongs to that time period. Screenshots from the final version of the city can be seen in Figure 7.1 and Figure 7.2.
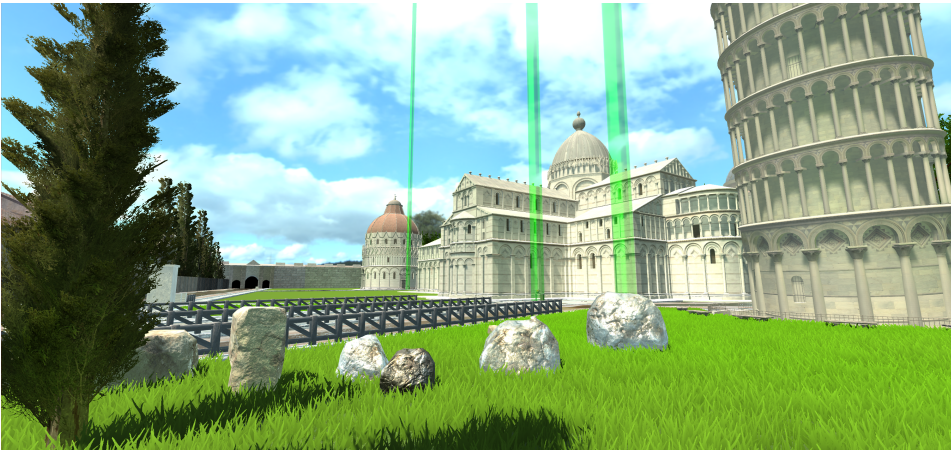
Figure 7.2: The Pisa Plaza representation

Changing scenes

Because the VR application now had both the Knudtzon Hall and the Pisa city as two separate areas, functionality for how a user could move between these areas had to be implemented. This feature was challenging to implement, as some modifications had to be done to the application architecture in order to make it work. When setting up the project initially, it was not expected that we would have to change scenes during gameplay. Because of this, the architecture concerning how scenes were organized had to be changed, which gave us less time to work on other features. A new empty main scene was created where constant components like the camera and mixed reality toolkit were placed, which made it possible to load other scenes such as the Knudtzon Hall or the Pisa city on top of this scene. This made it easier to swap between scenes whenever it was needed, and also made it easier to add more scenes at a later stage such as in the case of a more thorough tutorial.

It had already been decided that a user would open a specific manuscript in the Knudtzon Hall, and then interact with it to be transported to the Pisa city. Because of time constraints, however, this feature ended up with the user being transported to the city instantly when opening the book, instead of being able to browse through it first.

7.2.2 Tutorial

The tooltips added in phase 2 were not enough to explain how to use the application correctly, as most users still needed much guidance in order to use the application to its full extent. A more thorough tutorial was implemented to teach the user enough about the application to be able to use it without external help.

A new game scene was added as the tutorial, which consisted of a white room where the user had to complete several tasks which taught them how to use the application before they could enter the Knudtzon Hall. These tasks included teleporting, interacting with the manuscripts, and understanding general concepts of the application such as closing

and opening books. In order to be able to use the main application, the user now has to complete these steps in the tutorial successfully. Figure 7.3 shows the tutorial scene.

Figure 7.3: The VR tutorial

7.2.3   Smaller features

While transcriptions were added to the AR application already during the start of phase 2, this feature had not yet been added to the VR application due to other features being more important. Because it was essential to have this feature in both applications, it was implemented during the third phase. In the AR application, the transcriptions had to appear on top of the manuscript pages because of FOV restrictions, but in VR, this was not a problem. Because of this, the transcriptions were placed directly above the manuscript pages themselves, such that both would be visible when browsing the manuscript.

To make it more obvious which books were possible to open, a shader was added to these books. This shader was placed on a sphere which was then placed on the intended books, which gave the impression of glowing books. A blue shader was used on the Lilienskiold manuscript, while a yellow shader was used on the manuscript for diving into Pisa.

Figure 7.4: Final version of the interactable manuscript, now with transcriptions

7.3 AR Implementation

In this phase, the main focus for the HoloLens was to implement a working tutorial, to create a substitution for the VR feature for "diving into a city", and polishing and finishing the rest of the application. At this point, the AR application was ahead of the VR application and closer to being finished, so more time was spent on the VR application for the third iteration.

7.3.1 Diving Into Pisa

This was implemented somewhat similar to how the other holograms were implemented. The "Piazza del Duomo" can be seen above the manuscripts similar to in the other manuscript pages in the application, along with a text field describing what the city is and how to interact with the city below it. The model shown on top of the manuscript is a miniature version, which the user can then pick up and place wherever she may want it in the room. The city then expands, and the user can walk around the room and observe the city from above. This was implemented by using a script from the Mixed Reality Toolkit called "Tap to Place", which works by tapping an object once to pick it up, then look at where you want to place it, and tap again to place it at the specified location. This feature intends to immerse the user in the city, at the same time as letting the user learn about it by exploring it in a safe and controlled environment. Because of hardware limitations in the HoloLens, some less critical parts of the city had to be removed in order to reduce the polygon count and keep the FPS stable.

Figure 7.5: The AR version of diving into Pisa

7.3.2 Tutorial

The poster created in phase 2 was useful for explaining how to use the gestures for the HoloLens, but it did not give the user a chance to experiment with the gestures. In order to make it easier for the user to understand how to use these gestures, a short tutorial was created which the user had to go through before using the main part of the application. This tutorial consisted of two parts, one part for learning how to use the tap gesture, and one part for moving/dragging objects. Each step was implemented as a panel containing information about how to complete the task, and an interactable example so that the user could experiment with executing the task. The panel used a script called "tagalong" which made it follow the user's head direction so that the tutorial never disappeared out of sight. The tutorial can be seen in Figure 7.6.
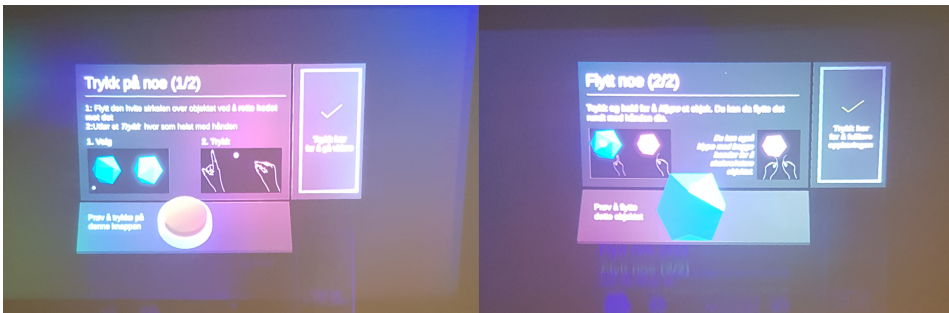
Figure 7.6: Both steps in the AR tutorial

7.3.3 Usability Improvements

The combination of the real world and holograms can quickly become cluttered, as a lot of various elements are present at the same time. It might therefore be beneficial to keep the application simple by limiting the number of holograms present at the same time. To ensure this, elements were hidden from the application when not relevant to the user, such as buttons and situational information. These elements were then enabled again when they were needed, which might also help draw attention towards them when they are relevant.

As previously mentioned, many users reported that the small FOV had a negative impact on their immersion, especially when the limited FOV clipped objects. Because of this, the holograms were made smaller and moved closer to each other in an attempt to get more things within the HoloLens' FOV. This also helps moves the focus onto the manuscripts and makes it easier for the user to get a better overview of the entire application and its content. This can be seen in Figure 7.7.
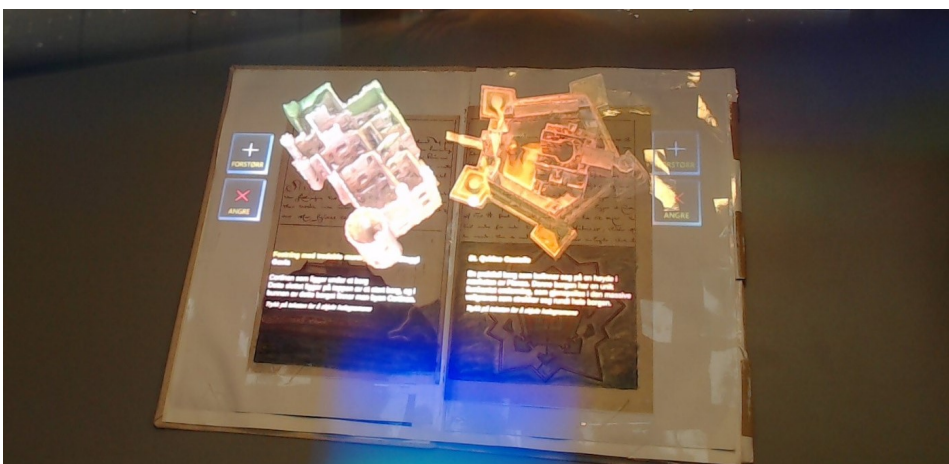

Figure 7.7: Final hologram placements

7.3.4 Unimplemented Features

Due to time restrictions and unforeseen challenges, some smaller features were not developed and implemented for the AR application.

Voice Commands

Voice commands were intended to be added as a feature for the application to make interacting easier. This feature intended to allow the user to use voice commands to interact with objects in the application instead of using hand gestures. This might have made it easier to use the application for some users, as some people struggled a lot with the hand gestures.

Sound Effects

The user tests showed that people did not think of sound effects as a significant part of an immersive experience. Although this might have been affected by the fact that the applications did not have any sound effects when tested on users, other features were more important, so sound was put as a possible future implementation.

7.4 Third Evaluation

The third evaluation was conducted after development had finished, and was the last user test meant for evaluating the applications. Some testing remained for gathering data to answer the research questions accurately. The third evaluation was conducted at Teknobyen Studentboliger, a student residence with over 100 students from a range of different studies and technical levels. 10 people responded to the survey, and feedback was gathered verbally from 6 subjects which did not answer the survey. The applications were also later tested on a user interface expert, where feedback was gathered through an open interview afterwards. The interview can be seen in Figure A.5. A total of 17 people tried the applications and provided feedback for phase 3, and all results from the survey can be seen in Figure A.3.

7.4.1 User test data

8 of 10 meant to a "large" or "very large" extent that being able to move around easily was important for an immersive experience. Similar to the previous user tests, most people still agreed that interactions and graphics were important. 7 of 10 meant to a "very large extent" that having things to interact with was important, and the same amount of people meant that it was that it was easy to interact with these things for the immersiveness of the applications to a "very large" extent.

The results from these user tests on the tutorial were that although the tutorial resulted in users spending more time before they could use the actual applications, most users spent less time being confused when using the applications and were also able to interact with objects properly. 5 of the 10 test subjects wrote that the applications were hard to use initially, but that it was intuitive once they learned how to do it. Most users seemed okay

with the overall tutorials, but a couple of users mentioned that the text could have been easier to understand at points.

All 10 respondents meant that this was a good way to learn about history. 3 subjects wrote that being able to visualize the content from the manuscripts made it easier and more interesting to learn. 2 subjects meant that being able to achieve this could be challenging and that it was important to ensure that it still remains historically correct. Nearly all test subjects liked the idea of being able to explore Pisa, and 2 subjects mentioned that being able to explore other places or historical events could be a great use of VR or AR.

Users were asked about if there was something they wanted to do in the applications, where 8 responded to this. 3 of them mentioned things related to more interactions, especially regarding exploring Pisa. 4 of the 8 responded with things regarding Pisa, either it being possible improvements or potential new features to implement.

Some of the feedback was directly related to limitations to the hardware and software used in the applications. 3 users mentioned in the survey that the text was sometimes hard to read on the HoloLens, 4 users said that the movement in VR could be better in some way, and similar to the previous phase several subjects struggled with using the gestures for the AR application.

7 of 10 users preferred the VR application. Users meant this because it was easier to interact with things in VR, that VR was somewhat more immersive, that VR was more polished, and that the technical limitations of the HoloLens had a negative impact on the overall experience compared to the VR application.

The user interface expert meant that the holograms for the AR application should not be placed on top of the pages, as the holograms are then in the way of the manuscripts and take the focus away from it. For the VR application, he meant that it should be easier to see what each manuscript was about. He suggested adding additional information to the cover of the manuscripts, such as popup-information and titles. He also mentioned that the different perspectives of the "dive into Pisa" feature between the two applications, was a good thing, as it is crucial to take advantage of the strengths of each technology.
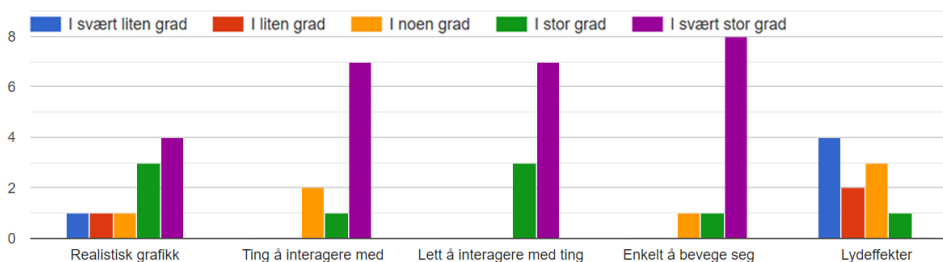

Figure 7.8: What people meant was important for immersiveness

7.4.2 Analysis

Movement

Being able to move around easily might be very important for creating a good immersive experience for the applications, as both literature and the respondents meant that this was important for the experience. This includes things like teleporting, being able to walk around yourself, and for instance, having six degrees of freedom for VR [46], and developing the AR application so that moving around feels natural. Slater [32] states that one of the essential parts of an immersive experience is to feel that one is physically present in the virtual environment (VE). This also applies to the AR application, although it does not have to be taken into account as much as VR because the VE is the real world and the user will move around as usual. It might, therefore, be a good idea to look at how moving around can be done better.

Learning outcome

As most users liked the idea of exploring historical sites, this may be something that can be continued on. M. Slater's discusses this in his paper "Implicit learning through embodiment in immersive virtual reality" [32], where the presence in a virtual environment can be used as a form of implicit learning. By focusing on enveloping the user in the world of the manuscripts, it may thus be possible to increase the learning outcome from the applications. One challenge of creating such experiences is that it often requires a lot of resources, as creating realistic representations is challenging.

Tutorials

The tutorials made it easier for the users to use the applications properly without help from an external supervisor. In time, most users were able to use the applications as intended on their own. One possible improvement for the VR tutorial could be to add images showing how to complete each of the steps. This was done for the AR application and worked quite well. Even though the tutorial could use some more work to make it easier for users to understand the central concepts, it already has a positive effect on teaching new users the basics.

VR vs. AR

At this point, most of the test subjects preferred the VR application. This makes sense as the total amount of time spent developing the VR application is significantly higher than the AR application. It might be hard to get people to prefer the AR application at this point, as the current AR technology may not be good enough to outclass VR for such applications. It is worth mentioning that users still liked the AR application, and they just felt that the VR application was a more complete product.

Expert evaluation

As mentioned by the user interface expert, placing the holograms on the sides of the manuscript pages has several advantages such as being able to see manuscripts and holograms simultaneously thus making it easier to connect the holograms to the manuscripts for the user. This was attempted already in phase 1, where it was discovered that it was hard to achieve with the current AR technology as the limited FOV and camera tracking is not good enough. So until an AR headset is released which solves these issues, the holograms should stay on top of the manuscript pages. The idea about adding titles and labels for the book covers in VR is an idea that may be worth implementing as it gives more context to the manuscripts.

Chapter 8

Final Evaluation

The previous user tests were mostly focused on testing the application functionality, so not enough feedback had been gathered for answering the research questions. Because of this, the goal of this test was to gather enough data for accurately answering the research questions.

A new survey was done for this purpose, with questions centered towards the level of immersiveness of the system, its potential for education and comparisons between VR and AR. This test was conducted in two separate locations, first at Lukas VGS where it was tested on ten high school students, and then at the Gunnerus Library where it was tested at five historians. It was tested on high school students as it was the most optimal target group for the thesis, and the historians because they could provide expert feedback on the historical aspects of the application. A total of 15 people tested the applications and responded to this survey, and these results can be seen in Figure A.4 in the appendix.

8.1 User test data

None of the 15 users had visited Pisa before, but all 15 replied they got a better understanding of how it was to be in Pisa after using the applications. Many answers were positive towards the benefits of experiencing it this way, such as being able to see the city how it could have been like at the time and the feeling of being there. In total, 10 users said they preferred the VR application, 3 said they preferred the AR application and 2 had no particular preference. Several users meant they had a stronger presence in the VR application, as 5 users wrote that they felt present in the library or Pisa to some extent and that the VR application "seemed more real".

8.1.1 High school students

The applications were first tested at 10 students from Lukas VGS. Their interest in history was modest, as expected from high school students. 3 of these 10 students said they were interested in history to "a very large extent", while the 7 others were either somewhat or

not interested in this. This was also the case for their interest in reading books, where only 2 of 10 said they were interested to "a large extent".

When asked about the applications, 8 of 10 users meant to a "large" or a "very large" extent that this was an exciting way to learning history, both in VR and in AR. 6 of 10 students said that these applications to a "large" or "very large" extent would make it more interesting to visit libraries, and the results were similar for the AR application where 5 of 10 meant this. When asked about if they wanted to know more about the Gunnerus library after trying both applications, 4 of 10 said they to a "large" or "very large" extent wanted to know more. People were even more positive towards this for the AR application, where 5 of 10 meant this. 9 of 10 said they to a "large" or "very large" extent felt present in the VR world, while users were not as positive towards the AR application as 5 of 10 meant the same for this case.

8.1.2 Historians

When tested at the five historians at the Gunnerus library, the interests towards literature and history were a bit more positive. 3 of 5 historians were interested in reading books to "a very large extent", and 4 of 5 historians were interested in history to either "a large extent" or "a very large extent.

All 5 historians meant that the VR application to a "very large" extent was an exciting way to learn about history. This was similar for the AR application, although 2 of these positive answers were to a "large" extent and the 3 others to a "very large" extent. Their attitudes were also positive towards the applications use concerning libraries, as 4 of 5 historians said that they to a "large" or "very large" extent had a greater desire to visit libraries if they had these applications. The attitudes were a bit less positive for the AR application however, as 2 of 5 meant this. For both the VR and AR applications, 3 of 5 said they to a "large" extent wanted to know more about the Gunnerus library after trying the VR application. When asked about if they felt present in the world of each application, 4 of 5 said they to a "large" or "very large" extent felt present in the VR world, while only 2 of 5 felt the same for the AR application.
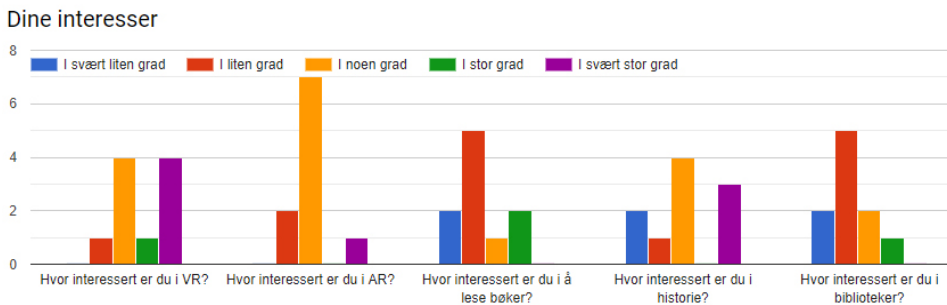
Figure 8.1: Students' interests, from the Lukas VGS user test.
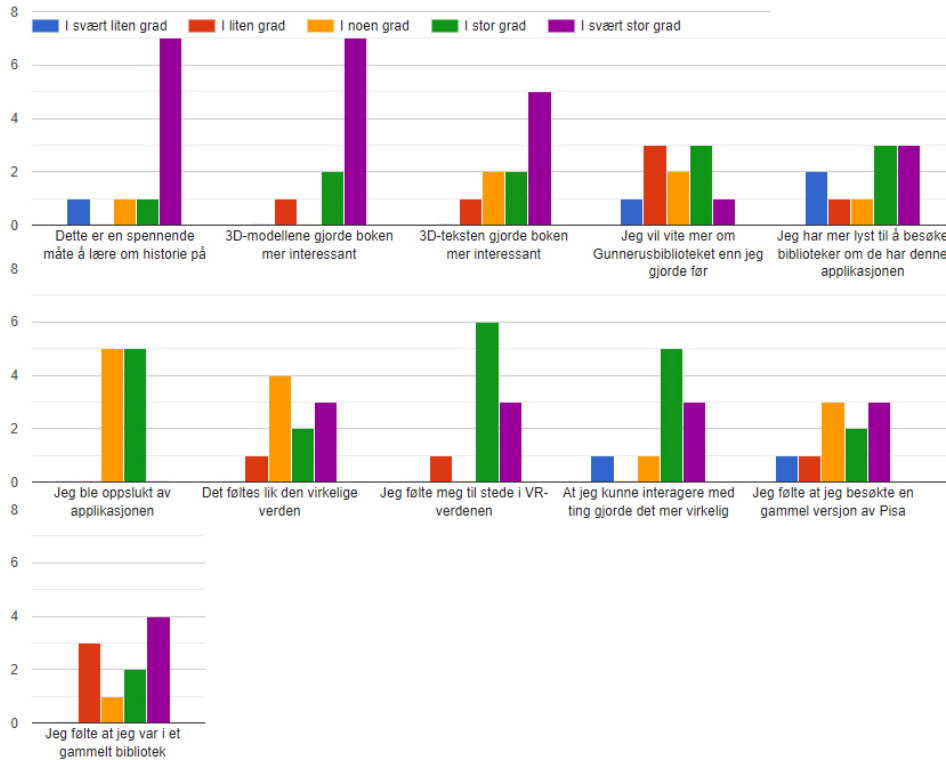
Figure 8.2: Feedback on the VR application, from the Lukas VGS user test.

Figure 8.3: Feedback on the AR application, from the Lukas VGS user test.

Dine interesser

Figure 8.4: Historians' interests, from the user test on historians

VR-applikasjonen

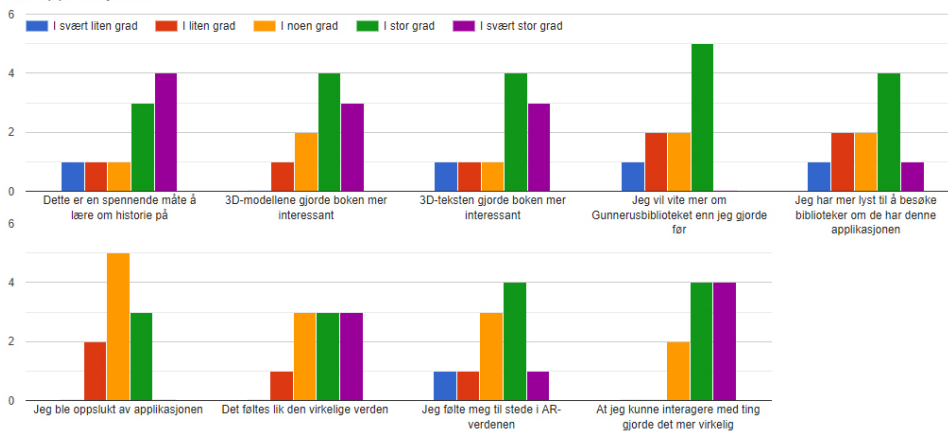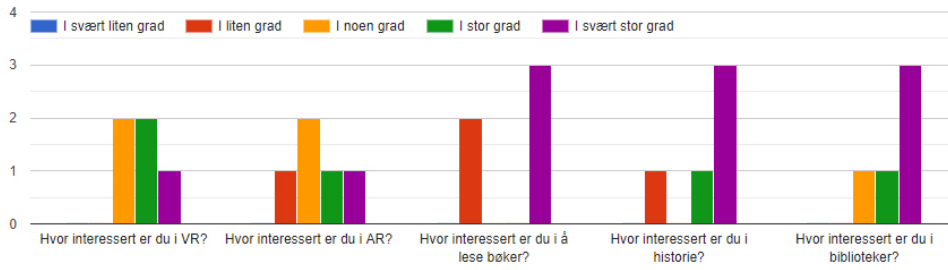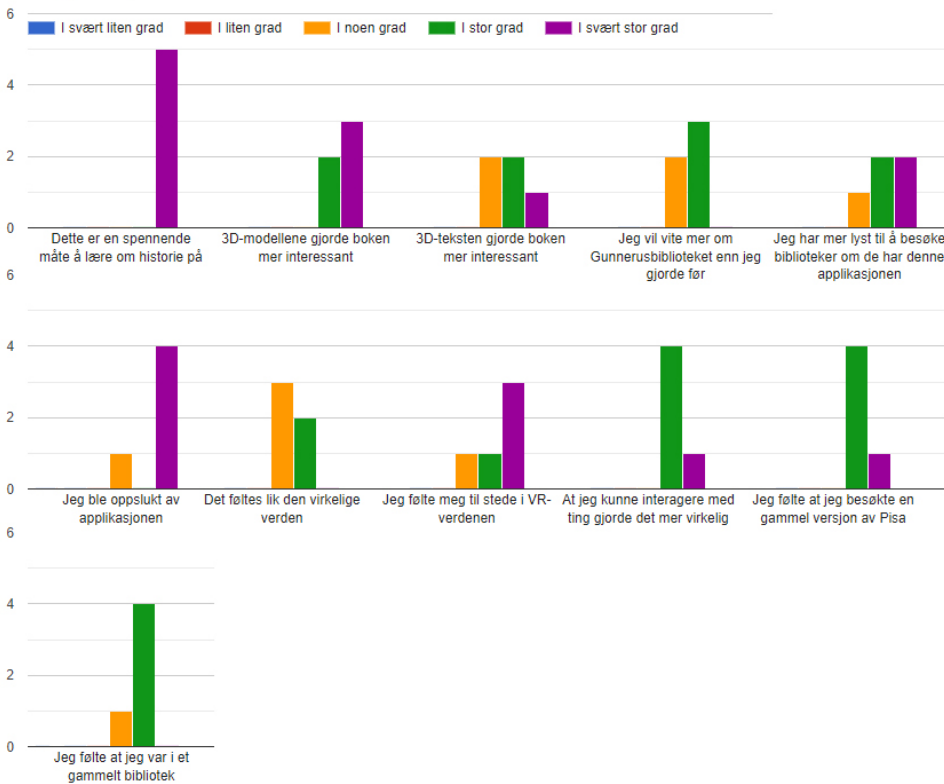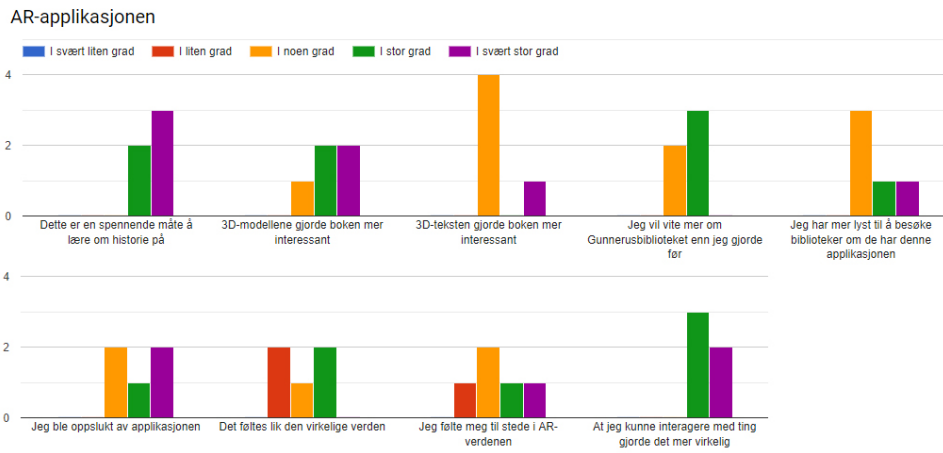**Figure 8.5:** Feedback on the VR application, from the user test on historians

Figure 8.6: Feedback on the AR application, from the user test on historians.

Chapter 9

Discussion and Conclusion

9.1 Discussion

For this thesis, we have attempted to create an immersive manuscript with the goal of giving the user a feeling of presence in its content. This was done by ensuring a high level of immersion in the system as described by Slater [33] as well as adding multiple possibilities for interactions with the manuscripts. The content of the manuscripts was presented in various ways, through 3D models, text, and a recreation of Pisa to make the manuscript more exciting and educational. In addition to this, we have provided a context for the manuscripts for making the experience more authentic and give the user an idea of how these manuscripts relate to the Knudtzon Hall in the real world. Although the context is most relevant for the VR application in terms of the Knudtzon Hall, this is still possible to achieve in the AR application as it is possible to use the application everywhere. This means that the context for the manuscript is entirely up to the user. As we did not consider the environment the users tested the applications in, this is reflected in the data as well, and we can see that there is a difference between how immersed the users felt in the VR and AR applications. The users in general felt more immersed in the VR experience, where most of the students said they felt like they were present in the VR world, while only half of the students said the same for AR. The results from the evaluations from phase 1-3 also show similar traits.

Virtual heritage is central to the thesis, but the focus is mostly on the presentation. By using virtual heritage in combination with immersive techniques, it may be possible to create an engaging way of learning about history, which could have many benefits. Results strengthen this theory, as users were positive towards learning in an interactive manner. By learning history this way, users can explore at their own pace, and focus on the parts that they find interesting. This may be used to spark interest in history and can be used to complement traditional learning instead of replacing it. The results presented in section 8.1 also strengthens this hypothesis and show that the users are indeed interested in using such applications in the context of education. This will be discussed further in subsection 9.1.1.

No existing research had been done on using mixed reality for immersive manuscripts, but as shown in the research behind both the M.A.R.T.S [24] and Mubil [1] applications, there are many different approaches to how one could make historical content more interesting regardless of whether it is a manuscript or not. Both these applications include many features which are relevant for an immersive manuscript such as augmented text, 3d-models, and a context for the historical content used in the applications.

The Mubil project has been especially relevant for this thesis, as its features are quite similar to our applications. It has been used as an example of how a virtual manuscript could be made, and this idea has been improved upon gradually to create an immersive manuscript. The most significant improvement from the Mubil project to our applications is the level of immersion, as it gives the user the possibility to freely move around and explore both the environment, the manuscript, and its content.

9.1.1   Research Questions

In this section, we will go more in depth to how each research question has been answered based on the applications and the data gathered from testing them on the general public.

RQ1: *How can mixed reality be used to create an immersive experience of historical manuscripts?*

A range of techniques have been implemented, and many considerations have been done in order to provide an experience that is as immersive as possible, given the resources available. Hardware plays a quite important role in creating an immersive experience, as stated by Slater [33], but the hardware chosen for the applications was not anything we could impact to a large extent. The software was therefore the primary focus for creating the immersive experience.

One of the most important things that was done to create this experience was to allow users to move around an environment freely, by creating software for taking advantage of the headsets' six degrees of freedom and let the user interact with this environment to a large extent through the use of hand controllers (VR) or hand gestures (AR). Features such as these are seen as very important for creating an immersive experience according to Slater [33]. The purpose of this was to give the user a stronger feeling of being present in this environment. If this environment also feels like a realistic representation of reality, it is easier to achieve this presence, which is why so much time went into creating a realistic representation of the Knudtzon Hall and Pisa. The results from phase 1-3 support these statements, as most users meant that being able to interact with the environment and realistic graphics was crucial for an immersive experience.

It is of course hard to measure how effective each of these individual parts is for the immersive experience, but they all add up to the complete experience the user has. In the final evaluation, users were positive towards the immersive experience the applications provided, and a large part of the users said that this experience felt like the real world to some extent.

RQ2: *How can this experience be used to educate about history?*

The VR application allows the user to explore the Knudtzon Hall in their own pace, looking at, reading about, and interacting with manuscripts and their content in various ways. Multiple of the reasons to use VR for education as described by Slater [32] are relevant throughout the different parts of our application, as they are providing both environments and manuscripts that are not accessible by the general public. As Slater suggests the applications allows the users to do rather than to observe, and also visit places that are impossible or infeasible to visit in real life. There could have been implemented more features aimed at improving the educational aspect of the application, but as stated in the requirements the focus was to present the contents of the manuscripts rather than replace a classroom setting for the students. We did this mostly due to time constraints, as developing the applications with educational and pedagogical content is an enormous task in itself and we instead displayed the historical content "as is" to see how the students would react to it when presented using this technology. Instead, the focus was to spark an interest in the manuscripts and the library for the user and rather complement traditional education. The data gathered from the user test at Lucas VGS suggests this was the case to some degree in most of the respondents, as the majority of them said that this was an interesting way to learn about history. To answer precisely how much the students learned from the applications, further tests are needed. The students were somewhat less interested in the AR application, but the majority still thought it was an interesting way to learn. Since the content for the two applications is similar, reasons for this may be technical limitations for the HoloLens and the nature of AR. The data gathered about the content in the applications such as the 3D-models and text also suggests this, as users generally meant that the content in the VR application did a better job of improving the manuscripts than the content in the AR application.

RQ3: *What are the differences between VR and AR for these applications?*

As mentioned in section 2.2 and described by Milgram et al. [26] with the reality-virtuality continuum, VR provides an experience that is to a much higher degree virtual than AR. When working on projects such as this, where the original manuscripts and environments are not available to the user, this provides a greater opportunity to deliver context through the virtual environments which are hard to replicate in AR. This is both positive and negative, as it gives the developers more control of the application and ways to cater to the users, but it also requires more development and resources to utilize constructively. This is the main reason why more time was gradually devoted to the VR application towards the end of the development, as seen in Table 4.1. VR also provides more interaction opportunities through the use of handheld controllers, which allows users to manipulate the virtual world with a high degree of precision and control.

When it comes to AR, according to Usoh et al. [34] things such as the field of view (FOV) and frames per second (FPS) are important for immersion. The HoloLens' small FOV and limited hardware have been a challenge for creating a similarly immersive experience as the VR application. There are, however, some advantages to immersion in AR, such as being able to move around freely on your own in a physical space. The interaction in AR is mostly limited to hand gestures, which provide basic interaction possibilities and

requires some effort to learn for a new user. Since AR also takes advantage of the physical world, it is possible to interact with digital content using hand gestures and physical objects using image recognition, as the physical book in our application demonstrates. The user feedback suggests that the AR application was a good immersive experience despite its shortcomings, and it is important to note that a large part of what makes AR immersive depends on how sophisticated the hardware used for the application is, and the HoloLens is still at an early stage.

It is clear that there are several significant differences between using AR and VR technology. Some of these are seemingly quite obvious inherently from how the technology works and how it is used but may have a more severe impact on how the users perceive the applications than expected. It is much harder to create an immersive experience that creates a feeling of presence for the user in AR due to technical limitations in the technology such as computing power and display method. Another big difference is methods of interaction, where both AR and VR have their positives and negatives. AR usually required more effort from the user to learn how to interact using the gestures, compared to the controllers in VR. VR also provides more accurate ways of interacting with the digital elements of the application, but in AR, users can interact with both physical and digital objects. This makes choosing the best alternative hard as they are better suited for different tasks. VR might therefore be the best alternative if the goal is to create both context and content for the manuscripts and immerse users using this, while AR may be a good alternative if it is the content of the manuscript which is most important, and the context can change based on the location the application is used in. All in all, the gathered data suggests that the users found the VR application somewhat more immersive than the AR application, but it is also worth noting that measuring immersion is difficult and that more research should be done in this field as technology evolves.

9.2 Contributions

The most important contribution this thesis has to the field is the research that has been done on how one could potentially create an immersive manuscript by using mixed reality and the possible benefits of this. Related works such as the Mubil project [1] has done this in a similar fashion, but with a focus on creating a digital, less immersive manuscript. Our contribution is therefore focused on how modern technology, in this case mixed reality, can be used to make manuscripts more immersive by focusing on aspects such as interactions and realism.

Our applications take inspiration from the M.A.R.T.S. application for exploring museum exhibitions [24], in that the content of the Lilienskiold manuscript is built upon with MR in our applications just like the various museum exhibitions are built upon with AR in the M.A.R.T.S. application. Our research contributes to how immersive manuscripts can be used for education, by suggesting ways of sparking interest in the user by letting them explore the historical content in their own ways and at their own pace, and immersing them in the world of the manuscript. The main difference for our thesis is the focus on promoting learning by engaging users, by enabling them to interact with the environment to a large extent and immersing them in the manuscripts' world.

Lastly, we have compared VR with AR and described how each of these technolo-

gies could be used for creating immersive manuscripts, each with their own benefits and disadvantages.

9.3 Limitations

Due to the current state of the technology behind these applications, there are some challenges to creating immersive experiences of historical manuscripts. This is especially true for the AR application, as users reported already during the first phase that the limited FOV had a negative impact on immersion, and the hand gestures were hard to learn. It is worth noting that these challenges may not be as big a problem in the future, and Microsoft has already announced the HoloLens 2 which presumably will fix many of the problems and limitations of HoloLens 1 [23].

Although the applications are made with the intention that it should be easy to add more manuscripts and more content for said manuscripts, making the content itself is a time-consuming process. There are many steps necessary to prepare a manuscript for the applications such as transcriptions, finding or creating 3D-models, digitizing and so on, and because of this, there was only enough time to add one manuscript to the applications, which ended up being the Lilienskjold manuscript.

Most of the VR issues users reported about the movement in VR can be improved by merely replacing the mixed reality toolkit with a better toolkit such as Steam VR. Many users reported that it was cumbersome to move around, such as the teleporting being confusing, the button configurations being strange and so on. The fact that many aspects of the movement options in VR were less than optimal sometimes hurt users' level of immersiveness, which could have been avoided had this been known earlier in the process.

Despite these limitations, we feel that the applications were complete enough to provide the feedback necessary to contribute to this field of research.

9.4 Conclusion

For this thesis, we have described how mixed reality can be used to create an immersive experience of historical manuscripts. Two separate applications were made in VR and AR with the same core functionality, and were developed iteratively based on user feedback in an attempt to reach the goals of this thesis to the best extent possible. Both applications were made in Unity, where the VR application uses Mixed Reality headsets and the AR application uses the Microsoft HoloLens headset. Both applications let the user explore a version of the Lilienskiold manuscript found at the Gunnerus library, and the user can interact with digital representations of the content from this manuscript in various ways.

Based on the results from the surveys, the applications do a good job of immersing the user in the manuscript and sparking interest in history, despite their shortcomings. Our research shows that there is potential in using this for educational purposes, as results from the user tests suggested that users were quite interested in learning about history this way despite a somewhat low interest in book reading and history. If these applications are going to be used for anything more than drawing people to the Gunnerus library, however, more work must be done for adding historically accurate content and ensuring that the learning

outcome from using the applications is good enough. It is also essential to choose the right tool for the job, where VR and AR each have their advantages. Results suggest that both technologies are good choices depending on the situation, but that it is easier to create an immersive experience of historical manuscripts using VR with the technology available at the time of the thesis.

9.5 Future Work

This section will suggest what can be done in the future to build upon the research that has been done in this thesis, both in the context of improving the applications and further research on the topics discussed in the thesis.

Sound

For both VR and AR, sound can be implemented to be a part of the application. This was not implemented due to time constraints as other features were more important. Sound could be useful for providing a more immersive experience in the form of sound effects, but can also be used to provide educational content. This can, for instance, be done by adding a narrator who guides the user through the application and describes relevant historical aspects or events in the application. To achieve this, more research and testing would be required.

Historical Content

The models used to represent the manuscript content are not completely historically accurate and had to be approximations of reality as we are not 3D modelers. Adding historically accurate content could be beneficial in order to make the applications more educational. This is, however, a process that requires a significant amount of time and resources, as recreating historically accurate 3D-models is a research field on its own.

Although we have focused on educational content in both the applications and research, our background is in IT, and we are not qualified educators. As was decided early on in the development, we have not focused on making the content of the applications directly pedagogical. Researching, developing, and testing the educational value of historical content in MR, especially in relation to immersive manuscripts, is something that could be expanded on in the future.

Experiment with new hardware

As already mentioned, the HoloLens is still at an early stage. HoloLens 2 is set to release during 2019 [23] and could improve many features that are sub-par in the current version. Microsoft has already stated that the HoloLens 2 will improve gestures, FOV, and overall hardware power, so implementing the AR application for this headset may solve many of the problems mentioned in this thesis. This also applies for VR gear, as hardware is continuously evolving. Better resolution, FOV, more complex handheld controllers with features such as advanced sensors and better haptic feedback are examples of things that can improve immersion.

Small improvements

Some features, such as the interactable VR manuscript could be more polished. Smoother and more intuitive ways to interact with it, gravity for the open version of the book and more realistic animations are examples of improvements that can improve the level of realism. Replacing the mixed reality toolkit would probably also solve many of the problems users had with interactions.

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Appendix A

User Test Results
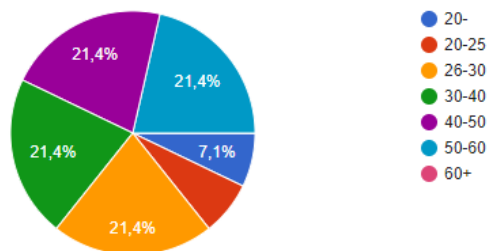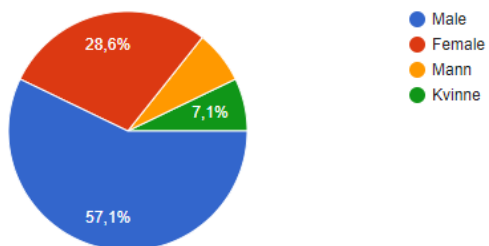
A.1 Phase 1 Full Survey

Age

14 svar

Figure A.1: Results from the first evaluation

Gender

14 svar

- ● Male
- ● Female
- ● Mann
- ● Kvinne

28,6%

7,1%

57,1%

Occupation

14 svar

					5 (35,7 %)				
1 (7,1 %)	1 (7,1 %)	1 (7,1 %)	1 (7,1 %)	1 (7,1 %)		1 (7,1 %)	1 (7,1 %)	1 (7,1 %)	1 (7,1 %)
Architect		Førstekonsulent		Senior Researcher		art, media, kulture		journalist	
	Cpmmunications p…		Innovasjonsleder,…		Student		head of library		programe…
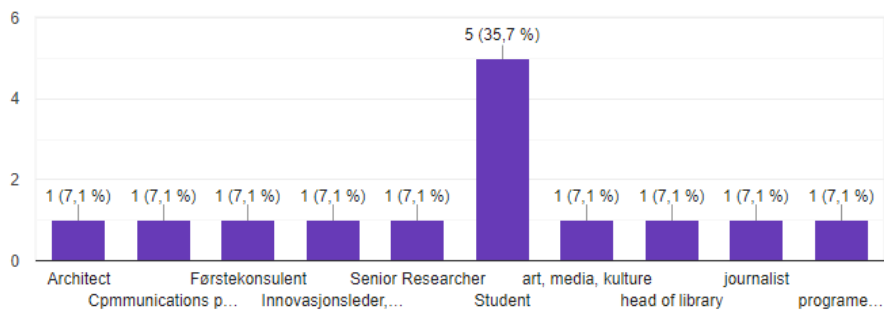
What elements are important for an "immersive experience" of manuscripts

■ To a very small extent   ■ To a small extent   ■ To some extent   ■ To a large extent   ■ To a very large extent
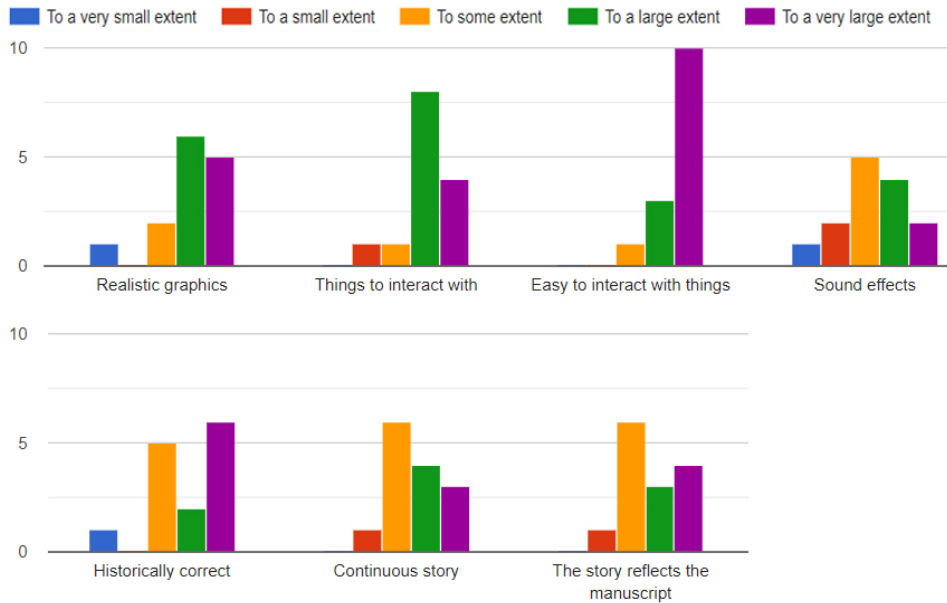
How can a story be told in these applications?

9 svar

Treasure hunt - look for clues?
more sound
in many ways
By having your choices alter the storyline
Use the pictures in the manuscripts
through communication of the mood, essence of the story
Literally any way you want, i guess. One could be immersed in the life of historical figures, witness important events take place around them, have a presentation with somewhat interactive experiences. It's honestly limitless. The gamer in me might prefer something very immersive and cool, but an interactive presentation might be better for learning purposes, i think.
Combination of movie and reading
Visially and with audio

What type of manuscripts might be appropriate for such applications?

10 svar

Rare manuscripts that can't be touched?

etnography, fauna, flora

almost anyone

sagas

any

illuminated medieval manusrcripts and scientific illustrated books from the 17th and 18th century

Maybe factual texts for learning about specific things and events and myths/legends to get a feel for the time and the people.

Stories will be appropriate. Theory (maths) may be visualized.

Lærebøker

Authentic

How can this be used for educating about history?

8 svar

Bring artifacts into the classroom

presenting how artefacts wre used in the past, objects that we don't use anymore

make history even more exciting

by having children play through and see different outcomes based on choices

show the tools and technology of the time

Immerse people in the history, i'd say. People remember what they experienced better than what they heard.

You will be able to show the students and engage them, not just tell them to read. My making sure they finish the sequence you know that they have seen everything.

Connected to an educational activity

How can this get young people interested in history?

9 svar

Show them this first, let them read more about the background afterwards

I think history can be brought to people and become more real

insight into history

If the story is well presented, yung people can get interested in anything

Interact with the technology and understand the amount of manual labor that was required

By extracting or capturing the esscence of the story and transforming it

Just by being VR... Thought cool interactive models for storytelling might be a better answer.

VR/AR is cool, they will think it is exciting

If you inspire them.to engage

What seems most promising between the AR and VR application? (Hololens or VR-headset)

10 svar

AR

begge, men for ulike anvendelser

both

Avctually, the MR from Micrsoft (nr 2 is the Knutzon)

Hololens seems better for education

Equal, with different applications that needs to be refined, hololens is probably more demanding regarding choiche of the approbiate content or illustrations that has the best potential for this technology

Different fields iif you ask me. VR for experiences and immersion and AR for more everyday applications, like replacing or supplementing monitors and virtual desks, etc.

VR

Did you feel any discomfort while using any of the headsets? If yes, what?

11 svar

No
no
a bit too havy
ok
the VR made me a bit dizzy
sense of hight
Non
Struggled slightly with unclear vision. Got better with adjustment, but slipped out again. I need glasses usually, which might have made it worse. Otherwise great
Nei
NO

A.2 Phase 2 Full Survey

Kjønn

11 svar

- Mann
- Kvinne
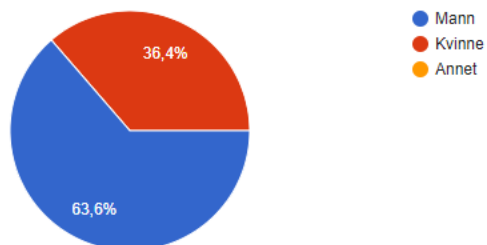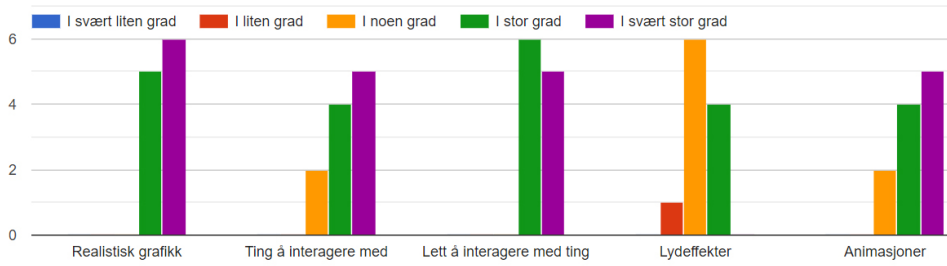- Annet

36,4%

63,6%

Figure A.2: Results from the second evaluation

Hvor viktige er disse elementene for å bli "oppslukt" i de historiske manuskriptene?

Noe du ønsker du kunne gjøre i applikasjonene?

8 svar

Bedre zooming og interaksjoner med objektene

Å kunne interagere med objektene i VR

Kaste boka i VR. I AR

Interagere med objektene som kom opp av bøkene

Skrift/informasjon sammen med figurer fra bok

Lese latin

Gå under vann

Se alt som vises på en gang uten klipping

Noe som var uoversiktlig/vanskelig å forstå i applikasjonene?

9 svar

Nei
Ja, noen av sidene var litt feilplassert.
AR var litt uoversiktlig
Ja, og kanskje større hologrammer.
AR, større field of view
Kontrollene
Litt tricky å venne seg til AR kontrollene med klyping

Hvilken applikasjon foretrakk du? Hvorfor? (VR/AR)

10 svar

AR, siden det var nytt for meg.
AR. Bedre interaksjonsmuligheter.
AR fordi det var mer å gjøre
VR, siden det var mer "immersive"
AR, ny erfaring for meg, og potensiale for bruk av AR
AR, mest fordi det var kulest og ikke like vanlig som VR
VR, følelse av et annet sted, farger
VR
Begge, de virket kule på hver sin måte
VR, det virket mer polert

Følte du deg ukomfortabel når du brukte en av applikasjonene? Hvis ja, hvordan?

8 svar

Nei
Nei.
AR måtte jeg holde oppe for å se klart, da jeg zoomet inn på et hologram ble det uskarpt "dobbelt".

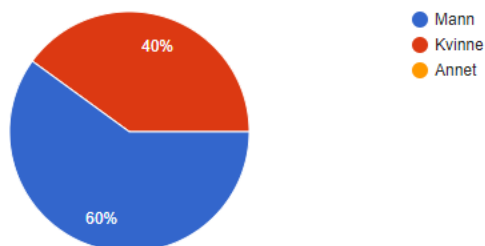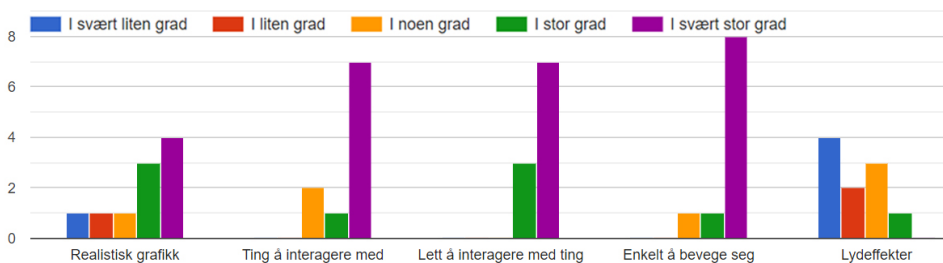## A.3 Phase 3 Full Survey

Kjønn

10 svar

Figure A.3: Results from the third evaluation

Hvilke elementer er viktige for å bli mer "oppslukt" i disse historiske manuskriptene?

Er dette en interessant måte å lære på? Hvorfor? Hvorfor ikke?

10 svar

Som å være der

Ja, gir en mulighet til å visualisere objekter som forekommer i tekster, som ikke alltid er like intuitivt

Hvis det er realistiske miljøer og ting bygget opp fra historisk fakta og kunnskap. Det samme for tekster og bilder som brukes. Det er viktig at referanser til kilder er tilgjengelig

Det er en litt mer "immersive" måte å gå rundt på et museum på. I enjoy

Opplegget gir personen muligheten til å benytte seg av flere sanser. Om det ikke hindrer eller irriterer synet, rygg og helsen, så kan opplegget hjelpe flere til å lære om historie.

Ja, man opplever "tingen". Kan være kjedelig med 2d bilder, 3d gjør ting mer spennende. Men hvis bildekvaliteten er dårlig, kan vanlige 2d bilder være bedre mtp læring.q

Ja. Jeg tror dette er en veldig god måte å lære på, siden man får visualisert det man leser om, og det virker relativt ekte. Jeg tror også det er en veldig god måte å lære på for de som sliter med å lese bøker (typ dysleksi og lignende).

Interessant fordi man får interagere med gjenstander og se seg rundt der bøkene er skrevet om.

Absolutt. Det å føle at man faktisk er der gir en bedre tilnærming til historien. Terskelen ligger dog høyere for å lære historie på denne måten og krever mye utvikling.

Ja. Hele grunnen til at jeg elsker VR og dataspill generelt er at man selv kan velge hva man vil se nærmere på, og ofte hvordan man ser på det. Gode 3D-modeller man kan studere på hvilken måte man vil er flott. Hadde vært helt perfekt til å lære anatomi! ♥ Skulle ønske jeg kunne det.

Noe du ønsker å kunne gjøre i noen av applikasjonene?

10 svar

Høre lyder i byen kanskje

Å kunne zoome inn i teksten for å kunne lese den. Kan hende dette har noe med oppløsningen å gjøre, eller at jeg normalt bruker briller.

Å gå inn i en borg/festning hadde coolt.

Kaste det skjeve tårnet i Pisa. Neida. Joda. Bortsett fra det så skulle jeg gjerne sett mer dynamikk i både verden og bevegelse Kan så klart se for meg at det kan bli en del tyngre. At det er smooth er enda viktigere enn at det er realistisk

Mulig få veiledning av en AI gjennom startfasen i programmet.

ikke noe spesielt som ikke er med

Gå rundt selv.

Ikke som jeg kommer på nå

Hadde vært stilig å se viktige historiske hendelser som f.eks. kriger, kjente møter som nattverden eller annet.

Plukke opp ting uten å bøye meg 😊

Noe som var uoversiktlig/vanskelig å forstå i noen av applikasjonene?

10 svar

Nei ikke egentlig

Det var vanskelig, i 2-3 minutter, å forholde seg til hvilke knapper som utførte hvilken handling. Dette kan også være rett og slett fordi akkurat dette VR-settet var uvant.

Sammen med instruksjonene jeg fikk gikk det ganske bra. Et par ganger brukte M. samme begrep til ulike ting, da var det litt forvirrende.

Ikke så mye som uoversiktlig som at det er vanskelig å lese skriften hvis man er nærsynt/langsynt

Kjente jeg strammet nakkemusklene/ryggen mer enn normalt gjennom øvelsen. Mulig sette testboken høyere oppe så man unngår å bøye seg ned med rygg/nakken.

ikke helt intuitivt hvordan man interagerer med verdenen. Kanskje noe bedre intrukser

Litt uvant i starten, men det tok ikke lang tid å lære.

Ble ganske intuitivt etterhvert som man fikk prøvd litt rundt.

Litt vanskelig å forståseg på interaksjonen med bøkene først.

Teksten var vanskelig å lese, ofte var den for stor og uskarp. Hardwarebegrensninger spiller nok også en stor rolle i dette.

Noe som kunne gjort deg mer oppslukt i en av applikasjonene?

9 svar

3d kart og interageringen

Selv om den ikke var 100% historisk korrekt, var fremstillingen av Pisa veldig interessant. Å se bygningene og omgivelsene i skala sammenlignet med meg som personen gjorde at det føltes meget 'immersive'

Å ta frem en bok/papyrusmanuskript på latin/gresk og med en god oversettelse tilgjengelig hadde vært tøfft.

Mer realistisk bevegelse - Mindre teleportering, mer dynamisk

usikker

mer detaljert, og flere ting å interagere med

Ikke som jeg kommer på nå

Dersom teksten var spilt inn som lydspor, ville det kanskje dradd mer fokus på læringen samtidig som man kan interagere med gjenstanden.

-Physics på props var gode, men ikke bug-frie. Hovedsakelig å kaste ting i VR og registrering av boksidene så de ikke forsvant i bordet i AR.
-Det var en "lang" ventepause mellom hvert hopp som ble irriterende over de lange avstandende i torget i Piza.
-Å snu seg med spakene var inkonsekvent; det fungerte noen ganger ikke, registrerte dobbelt+ andre ganger, og spasset helt ut hvis man holdt spaken halvveis.

Hvilken applikasjon foretrakk du? Hvorfor? (VR/AR)

9 svar

VR, men jeg forsøkte bare denne.

Likte begge

VR pga frihet og underholdningsverdi. Men så er jeg litt barnslig, da

AR hvor man hadde friere hender.

Begge har sin sjarm, per nå så var det relativt liten skjerm i AR. Dette gjør at jeg foretrekker VR, men med større skjerm ville jeg foretrukket AR tror jeg

VR fordi man kunne utforske mer.

Akkurat no, VR, den var enklere å interagere med ting. Men kan se at AR blir å foretrekke hvis skjermen har vært større og den har registrert trykk bedre.

VR. Følte meg nærmere historien som ble fortalt. Veldig lite synsfelt i AR, men syntes det var veldig stilig hvordan det var koblet opp mot den ekte verden.

Største problemet med AR var hardware, så det er vanskelig å bedømme applikasjonene mot hverandre. VR-headsettet er mer stabilt og lengre utviklet enn HoloLens er, og det påvirket brukeropplevelsen.

Følte du deg ukomfortabel når du brukte en av applikasjonene? Hvis ja, hvordan?

10 svar

Nei men jeg trenger egentlig briller for å lese og se skarpt samt skjelver litt på en hånd :)

Ting så litt uklart ut, men dette er sikkert fordi jeg normalt bruker briller. Ellers opplevde jeg ingen vertigo, eller annet ubehag

Nei.

Nope

Øynene mine er ikke helt vandt til VR, så blir kun i korte perioder.

Nei

Litt ukomfortabelt å teleportere, men ellers ikke noe problem.

Ble litt svimmel av VR, men er første gang jeg bruker VR, så kan ha noe med saken.

Bare litt motion sickness i VR, men mest fordi jeg allerede er syk. I AR var det litt ubehagelig å være nærme ting.

Kvalm ved fps-drops 🤢 Ble desorientert og virkelighetsfjern etter å ha tatt av VR-headsettet. Er redd for å gå inn i bord som ikke er der og prøver å bevege hendene gjennom overflater.

A.4   Final Evaluation Full Survey

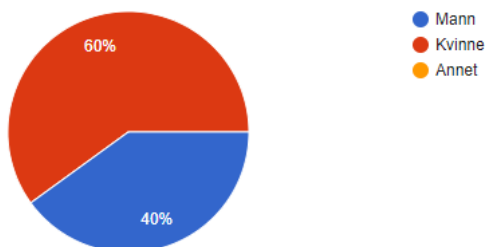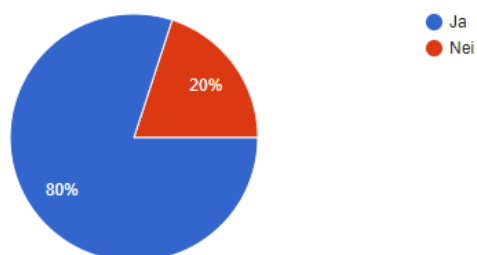## A.4.1   Lukas VGS User Test

Kjønn

10 svar

Figure A.4: Results from the final evaluation

Har du prøvd VR før?

10 svar

- Ja
- Nei

80%
20%

Har du prøvd AR før?

10 svar

- Ja
- Nei

80%
20%

Dine interesser

Legend: I svært liten grad | I liten grad | I noen grad | I stor grad | I svært stor grad

Categories: Hvor interessert er du i VR? | Hvor interessert er du i AR? | Hvor interessert er du i å lese bøker? | Hvor interessert er du i historie? | Hvor interessert er du i biblioteker?
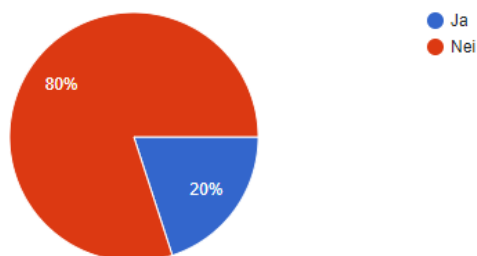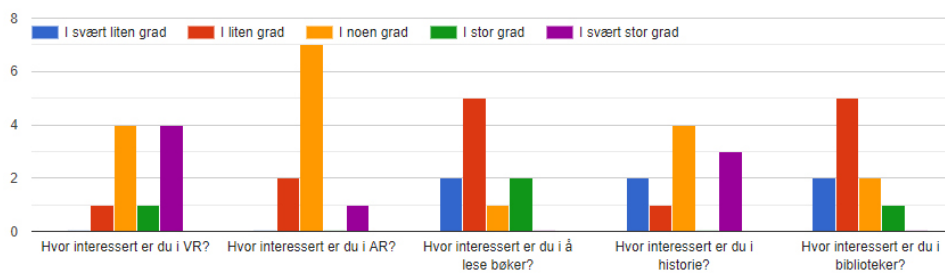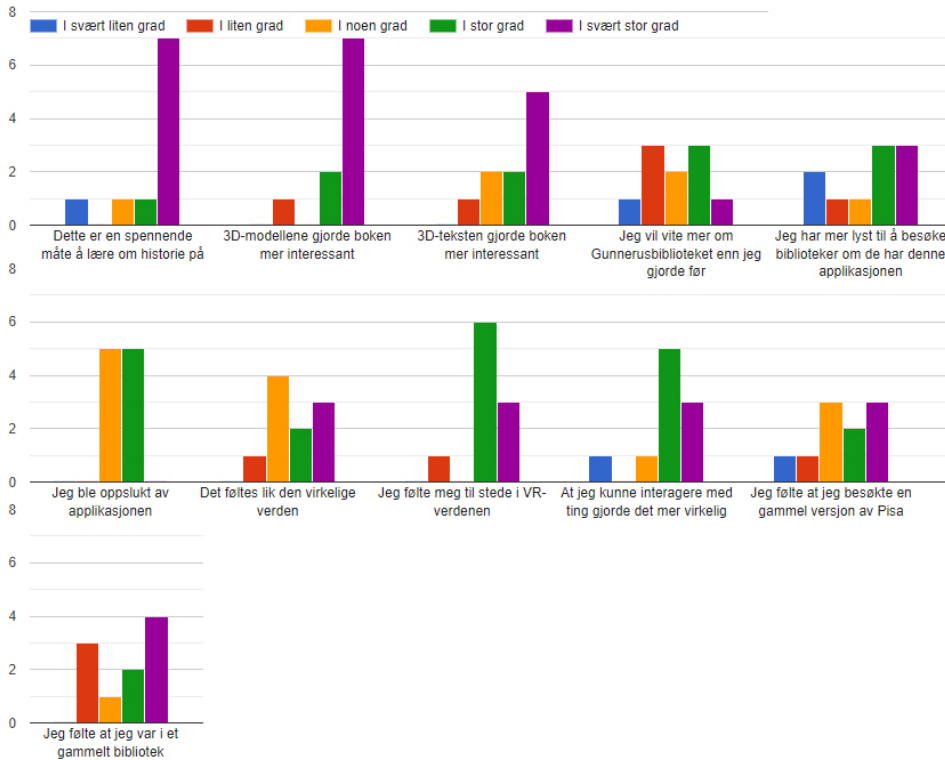
VR-applikasjonen

AR-applikasjonen
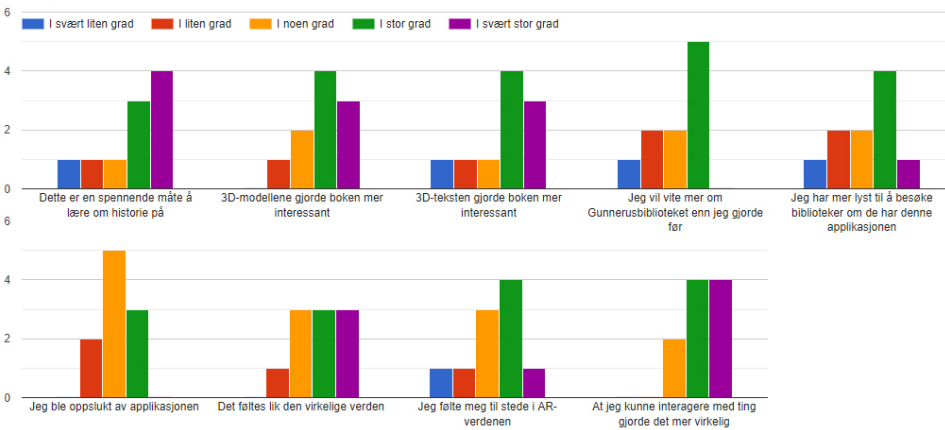
Har du besøkt Pisa før?

10 svar

- Ja
- Nei

100%

Fikk du en bedre forståelse av hvordan det er å være i Pisa? Hvorfor/hvorfor ikke?

10 svar

ja, virket som du gikk i byen
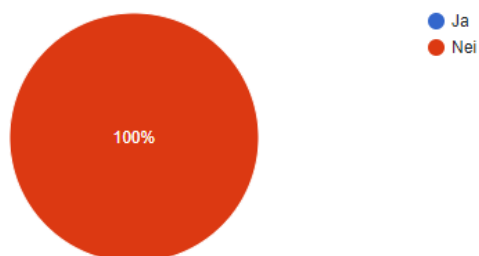
Ja, får satt seg mer inn i hvordan oppbygging av byen er

ja,man får finn ut sjøl når man reiser dit

ja, du ser hvordan pisa så ut før i tiden på en mer virkelig måte en og bare se på bilder.

Til en viss grad fikk jeg en bedre forståelse av hvordan Pisa var fordi man bli slukt inn i verdenen. Gatene og modellene ga inntrykk av at man var der, men det hadde ikke skadet med flere personer som "bakgrunnstøy" for å få en mer naturtro opplevelse.

ja, fordi man fikk et bedere blikkfang

ja, fordi det var likt virkeligheten

Man får oppleve og se hvordan det er, og føle at man er til stede. Bedre å faktisk føle seg til stede i Pisa, enn å bare sitte å høre på hvordan det ser ut der.

Ja, men aldri vært der

ja jeg følte at jeg var der

Likte du VR eller AR best? Hvorfor?

10 svar

VR var mye bedre lettere, og mer virkelig

Grei på hver sine måter, AR litt som tillegg til boken, VR mer som at du kommer inn i verdenen til historien

ja, spiller det ofte

likte VR bedre en AR men AR er mer nytt og "kulere" en VR.
VR er bedre med at du får en større opplevelse at du er til stede en med AR.

Jeg liker AR best, men kun fordi jeg har brukt VR en del fra før av.

VR det virket mer ekte

vr, fordi det føltes mer virkelig ut

VR, fordi man følte seg mer trukket inn i verdenen

AR, de gjorde omverden mere virksom, og gjorde det spennende.

VR best, dette fordi man følte man var i en annen verden. Og alt virket veldig virkelig, følte jeg faktisk var å besøkte Pisa

A.4.2 Historians User Test

Kjønn

5 svar

- Mann
- Kvinne
- Annet
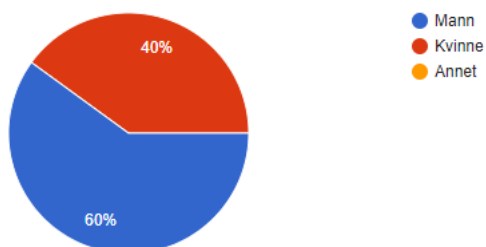
Har du prøvd VR før?

5 svar

- Ja
- Nei

40%

60%

Har du prøvd AR før?

5 svar

- Ja
- Nei

40%

60%

Dine interesser

Legend: I svært liten grad | I liten grad | I noen grad | I stor grad | I svært stor grad

X-axis: Hvor interessert er du i VR? | Hvor interessert er du i AR? | Hvor interessert er du i å lese bøker? | Hvor interessert er du i historie? | Hvor interessert er du i biblioteker?

VR-applikasjonen

Legend: I svært liten grad · I liten grad · I noen grad · I stor grad · I svært stor grad

Chart 1 categories: Dette er en spennende måte å lære om historie på · 3D-modellene gjorde boken mer interessant · 3D-teksten gjorde boken mer interessant · Jeg vil vite mer om Gunnerusbiblioteket enn jeg gjorde før · Jeg har mer lyst til å besøke biblioteker om de har denne applikasjonen

Chart 2 categories: Jeg ble oppslukt av applikasjonen · Det føltes lik den virkelige verden · Jeg følte meg til stede i VR-verdenen · At jeg kunne interagere med ting gjorde det mer virkelig · Jeg følte at jeg besøkte en gammel versjon av Pisa

Chart 3 category: Jeg følte at jeg var i et gammelt bibliotek

AR-applikasjonen

Legend: I svært liten grad · I liten grad · I noen grad · I stor grad · I svært stor grad

Chart 1 categories: Dette er en spennende måte å lære om historie på · 3D-modellene gjorde boken mer interessant · 3D-teksten gjorde boken mer interessant · Jeg vil vite mer om Gunnerusbiblioteket enn jeg gjorde før · Jeg har mer lyst til å besøke biblioteker om de har denne applikasjonen

Chart 2 categories: Jeg ble oppslukt av applikasjonen · Det føltes lik den virkelige verden · Jeg følte meg til stede i AR-verdenen · At jeg kunne interagere med ting gjorde det mer virkelig
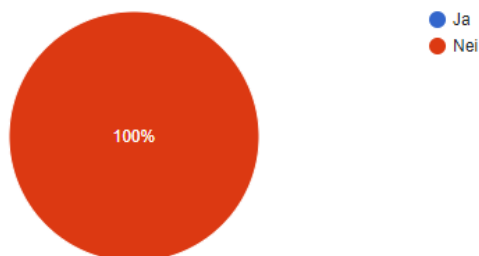
Har du besøkt Pisa før?

5 svar

- Ja
- Nei

100%

Fikk du en bedre forståelse av hvordan det er å være i Pisa? Hvorfor/hvorfor ikke?

5 svar

Fikk en veldig bra romfølelse, og størrelsen på tårnet kom virkelig frem i VR

ja fordi man kan gå rundt og se på bygninger, vandre rundt i gater og se pisa fra forskjellige sider

Ja, bedre forståelse av bybildet

Ja, fordi verden ble modelert som det kanskje så ut i gamle dager.

Har aldri vært der, så dette er det nærmeste jeg har kommet så langt. Kunne orientere meg i et miljø.

Likte du VR eller AR best? Hvorfor?

5 svar

VR applikasjonen føltes mer "virkelig", veldig bra romfølelse. Meget detaljrikt. AR var noe følsom for bevegelser og noe av teksten forsvinner når man flytter hodet. Fine modeller i begge appene. Men foretrekker VR appen.

VR siden det var noe helt annerledes

VR - mest spennende

AR, frodi brillen er ikke så tung og fungerer sammen med en "vanlig" brille. Det var mer muligheter å bevege seg interaktiv i rommet enn med VR.

VR fordi det gir en mer "immersive" opplevelse. Men de to er egentlig to ulike opplevelser som kanskje ikke bør sammenlignes?

A.5 User Interface Expert Interview

User interface expert interview

Q1: Is there anything you wish you could do / feel that is missing from the AR application?
- It would be a good idea to be able to see the manuscript as well as the holograms, to better relate the 3D-content to the manuscript itself. This way it would be easier to get an overview of everything, and the manuscript itself would not be hidden beneath the holograms. It would also make it easier to connect each manuscript page to the holograms connected to them.

Q2: Is there anything you wish you could do / feel that is missing from the VR application?
- Maybe some sort of networking could be implemented so that the AR user could see the VR user as she walked around the city.
- Research / user test ways to interact with books in order to find the best way of interacting with the VR books. This was rather confusing at first.

Q3: Is there anything you wish you could do / feel that is missing from both the applications?
- Use the different perspectives of VR and AR: In VR you walk around in the city, while in AR you observe the same city from above. This could be an interesting way of interacting with other people, where this interaction may even lead to better learning.

Q4: Could the user interface be improved in any way?
- AR: As already mentioned, it was hard to see both the manuscript pages and the holograms at the same time as they were on top of the pages. It is good that you added a feature for hiding the holograms in order to be able to see the manuscript pages, but i still think the holograms should be placed beside the pages.
- VR: The books should have more context. Right now all the books look the same, so adding a title or some kind of popup information on top of the books you can open could improve this. This could also pop up whenever you grab an object so that the user can know more about the item.

Figure A.5: Interview with the user interface expert

Martin Storødegård and P. A. Mathias Jørnsen

Creating an Immersive Experience of Historical Manuscripts using Mixed Reality

NTNU
Norwegian University of
Science and Technology