Lund University

Visualizing Archaeology

with Virtual Reality tools

Lund University
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1. Abstract

This thesis is concerning how archaeologists can use virtual reality for the 3D visualization of archaeological data. By studying different case studies concerning virtual reality and archaeology, I will try to define how the use of this technology is employed today to transfer knowledge in the sector of Cultural Heritage.

During this work I will develop a virtual reality system about Bishops cellar (Biskopskällaren), an archaeological site located in Scania, Sweden. This work will allow me to design and analyze a workflow data construction for the creation of visualization system, the results of this work will be analyzed and discussed.

Key words: Virtual Reality, Digital Archaeology, Virtual Archaeology, Virtual museums, Virtual models

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2. Introduction

In this research work I will analyze and present different kinds of archaeological case studies developed using virtual reality techniques, in order to provide an overview on how this technique is affecting the study and communication of archaeological sites. This research work will increase the understanding of what have been achieved so far using virtual reality technology in archaeology and it will provide guide lines to develop a virtual application that will be presented in this thesis. This work will also explore the emerging phenomenon of virtual museums and how we as archaeologists can use virtual reality tools to enhance our understanding of the past through the creation of scientific historical/archaeological interpretations.

In this thesis I will present a virtual application developed to increase the understanding of the historical monument of Biskopskällaren, in Scania, Sweden.

This work has been developed in collaboration with Skånes Hembygdsförbund and after the thesis it will be used as a tool to get a better comprehension of the site for the tourists.

3. Problem formulation

This project will investigate the use of virtual reality as an interpretation tool for visualization of historical/archaeological hypothetical scenarios. Moreover it is important to take into account that 3D interpretations of an historical environment are the results of fragmented information and therefore it is impossible to display a complete view of the original buildings.

Through this research work I will try to present different definitions on how Virtual reality - as visualization tool - can be used in archaeology to display the interpretation process. During my work I will take into account all the archaeological and historical studies so far developed on the historical site of Biskopskällaren in order to define different interpretations of the site.

Biskopskällaren is a monument located on the island of Ivö, near Kristianstad, and is now managed by Skånes Hembygdsförbund. The goal of this application will be to present different stages of the building proposing a virtual hypothesis of the structure.

The questions of this work will be:

- How can we interpret the past using Virtual reality tools?

- Can we use Virtual reality to enhance the understanding of historical archaeology sites?

- How can we use archaeological data to create a simulated interpretation? -*Case study, Biskopskällaren*

4. State of the Art - Virtual archaeology

Virtual reality has existed in the discipline of archaeology since the 1990's when one of the first case studies was created for the Cultural Heritage sector. In this chapter, I will describe the development of virtual reality in archaeology through time and how this has affected the virtual museums and archaeology. One of the first case studies created for archaeological purposes was a reconstruction of a tomb in Egypt, *The Tomb of Queen Nefertari* (figure 1) (Infobyte). The virtual version of this tomb was realized by Infobyte (http://www.infobyte.it/vartcollection/contenuto_uk.htm) and it was presented to the public in 1994 at the occasion of an exhibition in Rome, organized by "Fondazione Memmo" (Fondazione Memmo) and the Getti conservation institute.

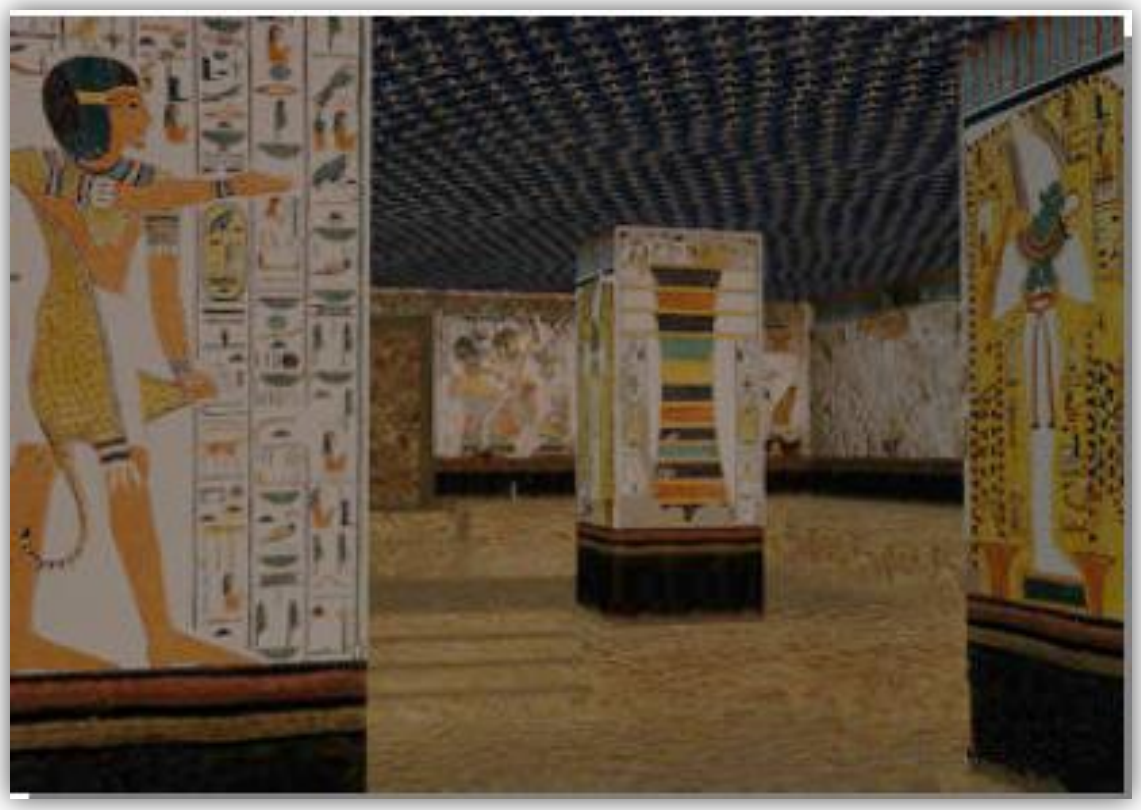


Figure 1. *The tomb of Queen Nefartari*. This is a part of the tomb that was shown to the public. The virtual reconstruction was created to substitute the real tour in the 1990's. (Dell'Unto 2013).

This application was realized at the end of the restoration work of the tomb, which started in the 1950's, "*Nefertari Light of Egypt*". The mausoleum was closed in 1950 and reopened in 1995. In the 1990's a virtual reconstruction was created with the hope that new technologies

would promote more virtual tours instead of real tours (http://www.fondazionememmo.it & Infobyte).

Another interesting example can be found in the Capella Degli Scrovegni project. This application has been developed by the National Research Council of Italy ITABC (Instituto per le Tecnologie Applicate ai Beni Culturali) in collaboration with the Municipality of Padua, also in Italy. This work has been developed in connection to the restoration of the chapel and in this occasion a virtual room next to the historical building has been built in order to host the application (Forte et al. 2002). Scrovegni's Chapel is completely decorated with frescos from Giotto, a famous Italian artist, from the period 1303-1305. Giotto is considered to be one of Europe's most important artist (Forte et al. 2002). Due to serious problems with preserving these paintings and limited accessibility for visitors: a virtual reconstruction was an important solution and supplement to this problem (Forte et al. 2002). The construction of a hypermedia room (a virtual application placed in this room) in the museum allows to contextualize the Giotto's world and his work in the Chapel (Forte et al. 2002). The creation of this hypermedia room (figure 2-3) was an immense project and not something the museum could manage itself, so the museum had to request help from different institutions and people with different skills, such as art historians, programmers, and multimedia experts to make this a reality (Forte et al. 2002).

Figure 2-3. The Scrovegni chapel's virtual reconstructions that the public could visit before entering the real chapel, showing the frescos of Giotto.This application was created in 2002 (Dell'Unto 2013).

This application has been designed in order to prepare the users to visit the monument by increasing their knowledge about the site before entering the monument. This was because the time visiting the Chapel was limited. After seeing the Virtual model and the visiting the Chapel, people could go back to the Virtual model if they wanted to see more (Forte et al. 2002). Differently from the reconstruction of the Nefartari Tomb, the aim of this application was not to substitute the real visit of Scrovegni Chapel, but to make the visitors aware of the context and prepare them with all kinds of different information and interactions that could be explored in the virtual application. (Forte *et al* 2002). The virtual model was created to make the visitors/users more interactive with the model of the Chapel. In the virtual application, the user could navigate the site using the mouse and keyboard or a joystick (Forte *et al* 2002). Sound was also important for the virtual model. By allowing the visitor to choose directly in the 3D space, the contents could also be explored through an audio or an animation. To make the virtual model more realistic, human silhouettes had been placed in the scene. This feature had been added to suggest to the users a correct sense of proportions inside the architecture (Forte et al. 2002).

Another case study that was created combining Virtual reality techniques with more advanced visualization tools was the Etruscan project developed from 2007 by a collaboration between

the National research council of Italy CNR ITABC, the University of Amsterdam, the Allard Pierson museum, the Visual Dimension in Ename, the Vatican museum, the National museum for Antiquities in Leiden, the Gallo-Roman museum in Tongeren and the National Etruscan museum in Villa Giulia, in Rome; the CNR ISCIMA (Pietroni *et al in press*).

The aim of this project was to try to re-create and restore the original context of the Etruscan graves Regolini Galassi that has been found by the priest Alessandro Regolini and general Vincenzo Galassi in 1836 (Pietroni *et al*). Another important goal of this project was to gain new perspectives on the ancient European culture of the Etruscans in Italy. It was a large and complex project; the Virtual model of the site has been created importing inside the 3D model of the tomb (acquired employing Laser Technology) all the objects found during the excavation (figure 4). All the findings have been acquired using photogrammetric techniques and have been virtually restored using software's of 3D modeling such as 3D studio Max and Blender (Pietroni *et al in press*).

Figure 4. Regolini Galassi tomb created as 3D model in 2007, where the visitors could navigate through the tombs and artifacts, to understand the context of the artifacts in the tomb (Pietroni *et al, in press*).

The 3D model of the reconstructed context has been placed inside Unity 3D (see chapter 10.1 for more information about Unity) and connected to a motion sensing input device developed

by Microsoft for the Xbox 360 video game console and Windows PC's. The use of such device allows exploring the application using natural body interaction (figure 5) (Pietroni *et al in press*), the user could now explore the 3D space by using the body. By navigating around in the Virtual environment with body movements, the user could directly interact with the inhabitants of the tomb, listening to narrative contents about the ancient site. The user could also get close to different artifacts just simply by moving the body.

Figure 5. The Allard Pierson Museum, in Amsterdam, 2007. People are trying out the applications with the Kinect technology (Pietroni *et al in press*).

The innovation of this work stands on his capacity of increasing the embodiment effect of the user inside the system (Pietroni *et al in press*).

5. Theoretical perspective and method

5 .1 Digital archaeology and Virtual Reality

Digital technologies have deeply impact archaeology. The introduction of new tools and instruments for the documentation, analysis and visualization of archaeological sites has affected the way of how archaeologists perceive and post process digital interpretations. Archaeologists, who are using digital tools to document, analyze and visualize archaeological material, are now self-identified as 'digital archaeologists' (Morgan & Eve 2012). Archaeologists are working with advanced techniques and are developing videos, 3D reconstructions, and photographs, video games to gain new knowledge and try out different hypothesis. The possibilities to employ such technique to interpret and communicate archaeological information allow providing and preserving a clearer picture of the relations that characterize the examples that I have mentioned above (Morgan & Eve 2012). With these new technologies and the increased portability of high-powered computers, archaeologists specialized in acquisition and post processing of digital data are available to work and participate in excavations and not only in a laboratory (Morgan & Eve 2012). The use of acquisition instruments and modeling software allow archaeologists simulating and testing different virtual scenarios in order to discuss and build new historical interpretations (Morgan & Eve 2012). It is crucial to recognize what these tools are and how archaeologists can approach them. Digital archaeology is often considered as a tool for archaeology. The term "tool" in this context, implies the use of computers and other instruments, such as GIS, laser scanner, alongside the traditional tools that archaeologists use (spades, trowels and wheelbarrows) and that our attitudes to information technologies have changed (Huggett 2012).

Digital archaeology is a way of approaching archaeology with digital techniques, which gives the archaeologist a better understanding of the strengths and limits of computers and information technology (Evans & Daly 2006:2). The techniques that are used in Digital archaeology are essentially methodological; they function as a tool for archaeologists to increase their capacity to understand the site. These tools could be used for solving problems and creating interpretations (Evans & Daly 2006). There have been a lot of discussions in the scientific field that digital archaeology is purely methodological and "none-theoretical". This argument is not entirely true since all methods have a theoretical standpoint (Zubrow 2006:9). Having digital archaeology as a theoretical standpoint, even if it is a method, is necessary for

my work. The developments for my case study, which can be read about in later chapters, have been developed using technology as a tool to discuss and test the interpretation of the house. By using this technology, the site can be studied in another environment. The main reason why I choose to study the use of Virtual reality as a discussion tool to interpret historical environments is to be able to have and show different hypotheses but it is also so that I can change the information of the site if it is necessary. The use of digital visualization tools to display and analyze archaeological and historical environments, allows the archaeologist to have different hypotheses and change the information if it is needed. This method I personally think is an immense method since it is not destroying archaeological data, since the data is stored and worked with in a computer to heighten a final result or hypothesis.

When creating a hypothesis in archaeology, we often ask questions like "why" or "how" to understand past situations of societies, which in fact are theoretical standpoints (Johnson 1999). When interpreting or creating simulated realities with the help of digital techniques, we need to have the knowledge of how to work with it, how to ask the right questions and how to answer them (Evans & Daly 2006, Forte 2000, Johnson 1999). It is also crucial to recognize the relationship that exists between digital technology and archaeological theory to reflect upon the advantages and limitations that the digital techniques bring to archaeological practice (Katanis 2012).

This new paradigm of visual interaction and interpretation methods has existed since the first case studies were made in virtual archaeology (Brogni *et al* 2000), as stated in the Chapter 4. Before archaeologists had the knowledge and skills of creating their own reconstructions/ 3D models, they needed collaboration with artists to create images from archaeological data (Barceló 2000, Foccillo *et al* 2003). If the artist, with the information provided by an archaeologist, created these images there might be consequences in terms of the image would be to personal and subjective to publish for the scientific sphere, since the artist often uses his/her imagination to complete the image (Barceló 2000). An option would be for the archaeologist to create and complete the model him/her self. For archaeologists to complete a model we need to reflect on the circumstances of the process of creation. In most cases we have fragmentary input data but we need this input data in order to generate "simulated" data (Barceló 2000). As Barceló state: *to see what archaeologically cannot be seen* (Barceló 2000). This means that virtual reality represents the process that all archaeologists perform in order to build information of fragmented groups of information.

Virtuality is not a new concept in archaeology which has been shown in the examples of in Chapter 4, but there are still some scientists that do not approve of this technology (Evans & Daly 2006). To understand what virtual reality can convey to archaeology, we need to have knowledge on what is "real" and what is "virtual" (Forte 2000). Archaeological material can be considered as real since it is something that has happened in the past and we have research data of it. Archaeology itself could be considered as virtual since we need to make multiple interpretations of a fragmentary nature, which is archaeological data (Forte 2000). The multiple interpretations an archaeologist makes could therefore be considered virtual, or as a virtual context to try and find answers to this fragmentary nature (Forte 2000). Archaeological data visualized by computers should be considered as a symbolic process, almost as a passage from virtual to virtual and not from reality to virtuality, as to photorealism to simulation (Forte 2000).

5.2 The London Charter

The London Charter is a document created by a group of researchers who worked together in order to improve the computer-based visualization projects, since 2006. Their main motive for establishing this group was to create guidelines which everyone working with computer-based visualization could follow. These guidelines were created to make sure that computer-based visualizations created for cultural heritage and for research purpose were made appropriately to their archaeological context (London Charter). There were several issues before these guidelines existed, when it came to computer-based visualizations that needed to be considered. These issues were visible in historical popular games and films, which made the visualization in the heritage sector, suffer why guidelines were needed to this sector. The question of intellectual transparency also became a problem for hyperrealism 3D interpretations. Computer-based visualizations created before the introduction of such guidelines were realized without taking into account the possibility to show the process of the work and without references to where the archaeological data came from (London Charter). Today networks are implementing the guidelines that the London Charter provides, such as Anna Bentkowska-Kafel (3DVISA) and Virtual Museums Transnational Network (V-MUST) (London Charter). By implementing these guidelines, more researchers can be certain that the

computer-based visualizations will be as accurate as they can be for research projects and for cultural heritage (London Charter).

The issue with transparency was something that needed to be looked at and required to be taken into consideration. The London Charter states in their document that:

> *In order to ensure the intellectual integrity of computer-based visualization methods and outcomes, relevant research sources should be indentified and evaluated in a structured and documented way (London Charter).*

The London Charter here states that we need to have documentation and sources of our computer-based visualizations. It is important to be able to show where the information of the visualization came from and also to provide this information to the Cultural Heritage sector and the public.

Moreover two important references for my research have been the points 4.4 and 4.6 where the document states:

4.4 *It should be made clear to users what a computer-based visualization seeks to represent, for example the existing state, an evidence-based restoration or a hypothetical reconstruction of cultural heritage object or site, and the extent and nature of any factual uncertainty (London Charter).*

4.6. *Documentation of the evaluative, analytical, deductive, interpretative and creative decisions made in the course of computer-based visualizations should be disseminated in such a way that the relationship between research sources, implicit knowledge, explicit reasoning, and visualization-based outcomes can be understood (London Charter).*

These two points have been particularly important because they show how a transparent model and a historical monument should be prepared and presented to the public keeping a

scientific integrity. It is essential to show the work-flow of the visualization and the documentation of it. By showing the work-flow, it would insure that the virtual model created follows the guidelines of the London Charter, but also to understand the interpretation stages of archaeological data.

The guidelines established by the London Charter can be used and understood by all individuals. For my own research project it was important to follow these guidelines, to make it as scientifically accurate as possible but also how I should represent the archaeological data of the historical monument.

An example of the best practice of 3D models can be recognized in the case study of *Daily Life in the Middle Ages*. This virtual application was developed by different experts where through the use of virtual simulations using 3D models were able to show historical scenarios of the daily life of people in Parma, Italy. This case study represents a case of best practice in the use of Virtual reality in archaeology. Different interpretations were made on the same location with the aim to present a diachronic interpretation of the space. This case study is a successful example of historical virtual simulation where the principles of the London Charter have been properly applied. The London Charter has these guidelines for helping the Cultural Heritage sector, so that the computer-based visualizations are presented properly but also so that they hold accurate archaeological data (London Charter). Following these guidelines can mean an essential starting point for understanding both the urgent needs and the implications of its principles for those in search of illustrating, in terms of creating or evaluating different visualization (London Charter).

5.3 Reconstructions and simulated models

Working with simulated models and virtual reconstructions it is important to gain a deeper understanding of the interpretation process itself. There are different ways to use software that allow building a model starting from a primitive object such as a sphere or a cube. Other methods are instead based on the use of instruments, such as Total Station, Laser scanners or Image based modeling techniques, to record at different level of details 3D models of archaeological contexts. By using acquisition instruments, the model become more accurate since these tools measure and record the geometry, while the 3D software is a way to recreate

information in your own way without using measuring instruments (Barceló 2001, Teichmann 2009). The way we archaeologists work with these different ways of building a 3D model, is based on what we want to portrait with the information and what tools we have access to. In my case study I choose to use 3D software to produce an interpretation of an historical environment. This work is focused on the virtual interpretation of an archaeological site employing 3D software. Even if 3D models are produced in different ways, by using different tools, they still have one thing in common; they are created for trying to understand the interpretation of the "real" data (Barceló 2001). A 3D model is a sample of theories that can show different hypotheses. This means that the interpretation never display a complete description of the past (Barceló 2001). The reasons why archaeologists use 3D models during the interpretation process can be found in the capability of such kind of data to display relations and connections between information of different nature. This typology of visualization increases exponentially the possibility to reconstruct historical and archaeological scenarios together with a large amount of data (Barceló 2001, Llobera 2010). 3D modeling is a process that cannot be easily compared with the - 2D sketching, which instead is irreversible and allow few interactions between different researchers. This is why a 3D model can be a good supplement for archaeologists, since it can be implemented if new information is found (Teichmann 2009), and allows engaging into a discussion between multiple stakeholders.

A virtual reconstruction is based on different features of a concrete or abstract entity (Barceló 2000). The reason for creating a virtual model is to recognize and understand this entity. Depending on what we want to portrait in the virtual model or reconstruction, this information can provide experimentation for researchers to try out different hypothesis of the input data and change the model if new data comes along (Barceló 2000). There might be consequences when showing abstract graphical representations, such as for who it is created for and the purpose of the representation, since it sometimes can be difficult to understand the scientific concepts or results (Barceló 2000), but this can be solved by using the London Charter guidelines. Having a description of the model will make it easier to understand the interpretation process performed by the researcher (London Charter).

To create these simulated models/reconstructions we need to have textual and archaeological evidence (Fattovich 2003). The textual evidence consists of everything that has been produced in a form of written material - such as literary texts, administrative records, and the archaeological evidence is the material culture of past cultures (artifacts; ecofacts; human

remains) (Fattovich 2003). These evidences are especially important when creating simulated models or reconstructions in order to show accurate information of our hypothesis or interpretations. The creation of a virtual environment foresees also the computation of the information which is increasingly affected by the way of how mechanism (computers and hardware) are employed (Forte 2000). When creating virtual environments it is necessary to study the perception of objects in real space and give additional information to the virtual environment but always through the senses. This is to try and give it a complete structure to this otherwise fragmented archaeological nature (Forte 2000). This could be called "computational-simulation" which we call a synthetic reconstruction of a conceptual phenomenon (Forte 2000).

It is always important to stress what we as archaeologists want to communicate with our virtual applications. An interesting example can be found in "*Daily Life in the Middle Ages*". This application is based on a virtual reconstruction, which consists of historical scenarios of the daily life of people in Parma, Italy, during the Middle Age (Guidazzoli & Delli Ponti 2007). The system has been build with a strong support by experts who analyzed the historical sources about the time period and the site. These analyses made different interpretations available (Guidazzoli & Delli Ponti 2007). To realize these interpretations into 3D visualization, three different reconstructions have been created and proposed in the system. The first virtual scenario was about the inner part of the Cathedral of Parma, the second simulation was based on a part of Garibaldi Square and the last one concerned a kiln found in Parma's urban area (Fig 6-8) (Guidazzoli & Delli Ponti 2007).

Figure 6. The virtual reconstruction of the Cathedral in Parma, 2007. Showing one of the interpretations made of the experts to have a better knowledge of the Chapel (Guidazzoli & Delli Ponti 2007).

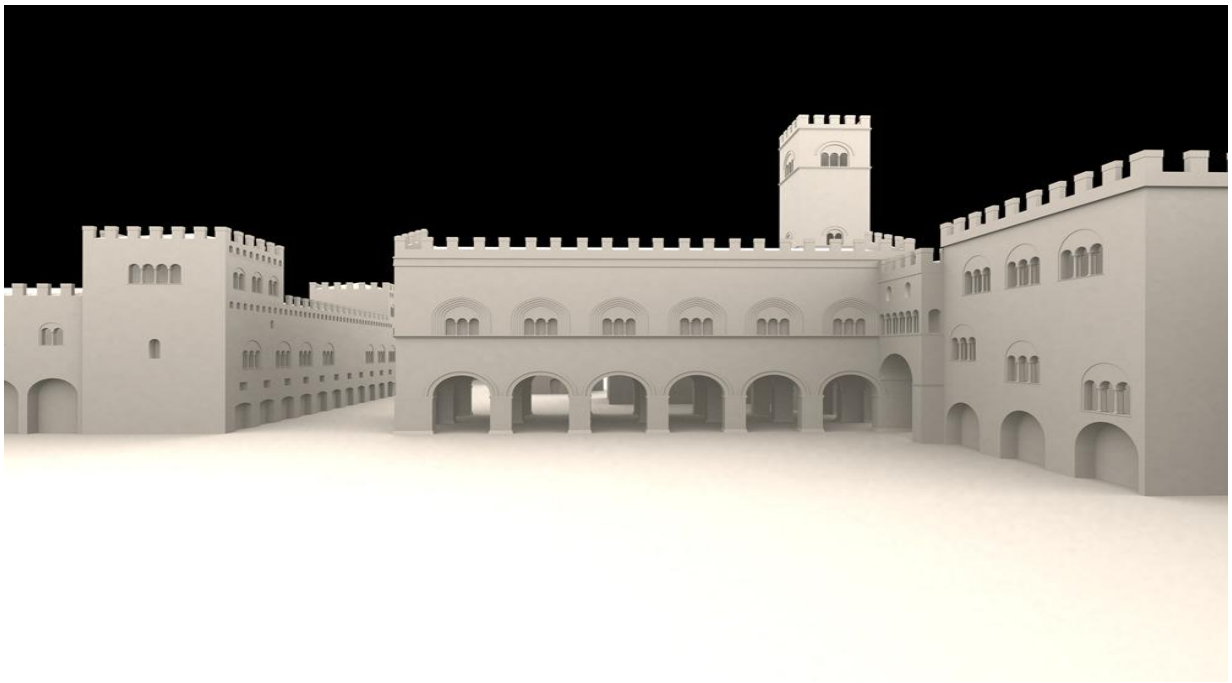


Figure 7. The virtual reconstruction of the Garibaldi Square, 2007, this was created to understand people's daily habits and trade (Guidazzoli & Delli Ponti 2007).

Figure 8. The virtual reconstruction of a kiln found in Parma. This was created to give an idea of what it could have looked like (Guidazzoli & Delli Ponti 2007).

In this case study it has clearly been stressed that the models were not created to replace any existing structure but instead they were realized to emphasize the differences between the past and the present. The virtual environments were created in order to help people to recognize different historical scenarios, allowing them to navigate through them and understanding the narrative scenarios of Parma, in Italy, during the Middle Age (Guidazzoli & Delli Ponti 2007).

By interaction in the virtual environments, people feel more involved in the process and it could be more comprehensible. In the Case study of the Daily Life in Parma, Italy, they also required the user to be more involved and at the same time, have the benefit of it.

6. Virtual Archaeology - as a pedagogical tool

In Chapter 4 I presented the case study *"The tomb of Queen Neferatari"*. Main goal of this application was to try to replace the real tours to the tomb with virtual tours (Infobyte). This way of approaching archaeology and virtual reconstructions were later developed in order to increase the interaction of the users and to increase the transfer of information.

Virtual reconstructions were no longer something that was supposed to replace a real tour. In this chapter I will write about some case studies that have been successful in showing and creating virtual environments in a more pedagogical way and not trying to replace real objects with virtual applications.

6.1 Etruscan project

The case study previously mentioned in Chapter 4 (Natural Interaction in VR Environments for Cultural Heritage and its Impact Inside Museums: *The Etruscan project*) was developed with the goal of making people experience a different interaction with the virtual application. Another important goal of this work was to present Etruscan tombs from different parts of Italy (Pietroni *et al in press*). The application has been presented in two museums, the Allard Pierson museum, in Amsterdam, and the Rijksmuseum Van Oudheden, in Leiden. Once realized the application has been used to run several tests in order to have a more clear perception on how the use of virtual reality connects with natural interaction tools (Kinect) affect the visitors. In both exhibitions where the test has been run, the users have been divided in two groups (according to gender) and an evaluation on how people would react and what their thoughts on the virtual applications has been performed (figure 9) (Pietroni *et al in press*). In both exhibitions they showed the virtual reconstruction of the Regolini Galassi tomb, some other Etruscan objects but also some original objects (which were a loan from the Gregorian Etruscan museum of the Vatican museums). The goal of this evaluation was to see people's response to virtual environments shown in a museum (Pietroni *et al in press*).

The evaluations process was divided in different stages of observation. The first stage was the evaluation of the installation of the virtual reconstruction. This stage was fundamental to have an understanding of how the visitors responded to the virtual reconstruction and if there was any technical issues with this interaction (Pietroni *et al in press*).

Figure 9. Virtual reconstruction in the Allard Pierson museum, in Amsterdam, 2007. The applications were shown at two different museums and two groups (divided according to gender) tried the application for evaluation purposes (Pietroni *et al in press*).

It also allowed an understanding between human and machine and if there were any technical issues while showing the virtual application. The result of this first stage was that there were some technical issues that needed to be fixed, for example some visitors showed visible signs of dizziness (Pietroni *et al in press*). This sometime occurred in immersive virtual reality systems where users show evident difficulties in recognizing themselves in the space (Pietroni *et al in press*). As explained in the article this was changed in the second stage of the evaluation process by adjusting the sudden turns. In this stage they also interviewed the visitors; this allowed a better understanding about the virtual reconstruction and the educational content. By making these kinds of evaluations, the museums found out that people of all ages found it easy to understand the interaction with the virtual reconstruction (Pietroni *et al in press*). The final results from both museums showed that the virtual reconstruction had a significant impact on the visitors. People were in general very positive about seeing the virtual interpretation and they felt that this was a good way of showing

archaeological data. At the end of the evaluations the visitors agreed that virtual objects should never replace real objects in an exhibition. Interesting information coming from the survey showed most of the visitors had never seen or experienced a virtual application in a museum before. Most of them felt that the virtual reconstruction made their visit to the museum more enjoyable (Pietroni *et al in press*). This evaluation shows that people are interested in virtual environments because they increase the perception of the archaeological material presented during the exhibition. To make people aware about our past, it is important, as I have stated before to stress that it is an interpretation and it should never replace any real objects or data (which people also thought in the Etruscan evaluation) but to be a supplement.

6.2 Skeingeborg project

During the spring of 2012, I attended a course *Virtual Reality in Archaeology (ARKN10)* at Lund University. In this course, students were able to choose among different archaeological sites to develop in 3D. I choose the archaeological site *Skeingeborg*, just outside Hässleholm, since it seemed as an interesting case study to develop in a 3D environment. Skeingeborg is today maintained by a museum Västra Göinges Hembygdsförening, a part of Skånes Hembygdsförbund, and therefore collaboration with these museums was necessary.

The main goal was to develop a 3D model of Skeingeborg and place it inside a game engine (Untiy3D), in order to show the visitors the archaeological site of Skeingeborg. I also wanted show people how we as archaeologists can work with other tools for presenting an interpretation of an archaeological site, such as virtual reality tools. Even though the goal of this work was not to display a detailed model of the site, this application should have served as a supplement for the visitors before approaching the real site. Today, there is not much left of the castle except small traces of the octagonal wall, and a 3D model could give the visitors an idea of what it might have looked like and have a better understanding of the castle and its surroundings.

The 3D model was a reconstruction of a castle, Skeingeborg, outside Hässleholm in Skåne. This castle is unique, because it was built with octagonal wall in the 1200's. There are

speculations that it was archbishop Absalon who built it. Today we do not know exactly what purpose the castle had or why it had octagonal wall. Perhaps the castle was for storing and shipping away goods (Ödman 2005). The castle walls were built in stone and had a timber construction upon it. Inside the courtyard, there was one large house with a cellar, two smaller houses, a blacksmith and a stable (figure 10). (Västra Göinges Hembygdsförening). When I visited the site in May 2012, I saw that there was a medieval road connected to the castle, which the Västra Göinges Hembygdsförbund showed me, which I felt was important to have in the 3D model (figure 11).

Figure 10. A snapshot from Unity 3D, from 2012. This snapshot is taken inside the courtyard showing one of the small houses and a part of the stable (Västra Göinge 2012).

By the use of what I observed during my visit, historical sources and information given to me by Västra Göinges Hembygdsförening, I could start to develop an interpretation of the castle. This model was mainly realized with the intent of providing a flexible view of the interpretation allowing the visitors of the museum to picture an idea of it. The model was

created in the 3D software Blender, which is software allowing the user to model, animate and make animated films and more (Blender). Once realized, the model was placed inside Unity 3D. Here I could start to create the environment surrounding the castle and also the environment inside the courtyard (figure 11). The only interaction that was possible in the application was to navigate freely around in the 3D space exploring the structures and environments.

My personal goals for this case study were to make people free to walk and explore a virtual interpretation. Since it was important for Västra Göinges Hembygdsförening that people also could see the nature outside the castle, I reconstructed hypothetically the vegetation (figure 11).

Figure 11. Snapshot from Unity 3D, from 2012, showing the environment outside the castle, the sandy beach and parts of the medieval road that lead to the castle (Västra Göinge 2012).

This 3D model has been represented during two different events, Uppåkradagen 2012 and Kulturnatten 2012.

Uppåkradagen is an event, where the latest research activities related to the archaeological site of Uppåka are presented (http://www.uppakra.se). Kulturnatten is an event where people are invited to join to several cultural events organized by the city of Lund in collaboration with the university. In this case an installation has been made available at Ingvar Kamprads Design Centrum, where - together with other research projects - has been shown to the public (http://web.lund.se/kultur2/kulturdefault____61918.aspx).

When showing this application to the public, I realized the different questions that came along and how important it is to share the archaeological data with the public, but also to make them aware that it is an interpretation. Children, automatically realized how to navigate in the game engine and they thought that it was a really good way of learning about past societies, but they wanted more. Avatars and tasks would have completed this application, according to the children. Older people, wanted to know how it is possible to create these kinds of applications with archaeological data.

7. Case Study

7.1 Introduction

This part of the thesis has been developed in the collaboration with Skånes Hembygdsförbund and it focused on a virtual interpretation of the archaeological site of Biskopskällaren. Skånes Hembygdsförbund is an umbrella organization for different museums in Skåne. Their member organizations are local history societies, museum associations and local historical associations. They are responsible for coordinating cultural activities of approximately 180 older buildings, including several museums. This umbrella organization is a part of the Sveriges Hembygdsförbund (Skånes Hembygdsförbund). They work primarily to preserve several sites and artifacts considered of particular interest in Sweden. Another important goal of Skånes Hembygdsförbund is the communication of Cultural Heritage and sites in Skåne; they in fact promote and support infrastructures for the accessibility and visibility of the heritage.

During my work of thesis I decided to develop a small application in virtual reality with the goal to increase the perception of Biskopskällaren, an archaeological site located on the island of Ivö near Kristianstad, Scania, and is a part of the development program developed by Skånes Hembygdsförbund.

The scientific interpretation of Biskopskällaren has been developed using the guidelines suggested in the London Charter. The application has been built using Blender, a 3D computer graphics software product used for creating animated films, visual effects, interactive 3D applications or video games (http://blender.org). At the end of this process the model has been visualized using Unity 3D, a powerful rendering engine developed by Unity Technologies (http://unity3d.com/company/).

8. History of the Bishop's cellar (Biskopskällaren)

8.1 The Bishop Andreas Sunesen

The name Bishops cellar (Biskopskällaren) comes from the archbishop Andreas Sunesen who lived there in 1224. The cellar is a ruin from a larger complex that was built in the 1200's at the Island Ivö, at Kristianstad. The house or the big complex that Andreas Sunesen came to build and live in was later on called Iföhus (Rignell 1964).

In historical sources there is information about the cellar but also about Iföhus that once was placed on top of the cellar (Olsson 1957). According to written sources the archbishop Andreas Sunesen, lived at this house through his last years in life. He chose to move to Ivö and abdicated as archbishop due to an illness, which for a long time was thought to be leprosy. But when archaeologists examined his body, which is buried in Lund Cathedral, they discovered that the illness he had was in fact rheumatoid (Rignell 1964).

Andreas Sunesen was born in Lolland, Denmark 1165. His family was the respected family "Hvidesläkten". Andreas Sunesen was a powerful man at this period. He had connections with King Valdemar, whom he worked for, and the archbishop Absalon was his father's cousin (Rignell 1964). At the age of 15, he went to Paris to study theology. After several years he went back home to Denmark where he was later on the dean in Roskilde. When archbishop Absalon died, Andreas Sunesen was given the roll as archbishop in Lund (Rignell 1964).

In later years Andreas Sunesen became so ill that he was forced to retreat to the Island of Ivö. He could no longer carry out his responsibility as an archbishop. After several letters to the Pope, he could finally rest at his house, Iföhus, at his last years before he died (Rignell 1964).

8.2 The Bishop Cellar and Iföhus

Andreas Sunesen and Iföhus have been mentioned in several historical sources, which also allows us to have the knowledge of this place and also when the house actually was demolished (Olsson 1957, Rignell 1964). In 1598 according to Hemannus Chytraeus in his publication "Monumenta praecipua qaue in Scania, Hallandia & Blekingia inveniuntur (...), the remnants of a house still visible and that the house was probably built of tiles (Winge 2012). In the 1700's a man named P. Muncks mentions in his publication, "Dissertatio

historico-topographica de Willandia", that the house was now gone and that there were no remnants left. The only thing that is left is a cellar (cvella arcutata) (Sofia Winge 2012).

In 1938 and 1949 Harald Olsson, who worked for Riksantikvarieämbetet, made excavations at this site. During the excavation he found the remnants of the house on top and also a marking on a stone at the cellar top with the year "MCCXXII" (figure 12). This year could indicate that this was the year the archbishop Andreas Sunesen moved to Ivö and made several renovations to the house and cellar. When Harald Olsson found this stone with the year marked on it, he actually was in doubt that the stone was original (Olsson 1957).

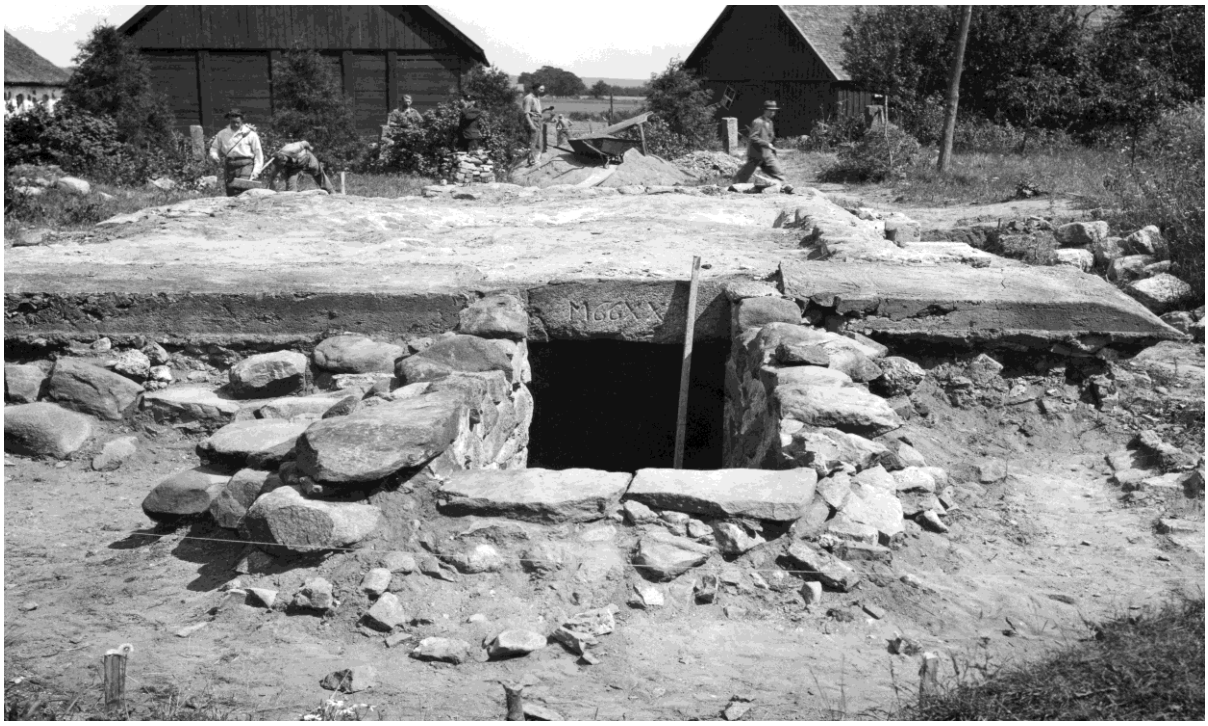


Figure 12. Picture from the excavation showing parts of the excavation carried out in 1938-1949. In this picture the stone is visible (Picture from Regionmuseets arkiv, Kristianstad 2013).

During the excavation Harald Olsson noticed that the walls were very solid at some places, around 123 cm, and came to the conclusion that Iföhus had to be a two story building (Olsson 1957). When Iföhus was standing during the medieval period, it was a really large complex. According to the excavation plans that were made in the early 1900's, the archaeologists found that the house was 30 meters long and 9 meters wide (Ödman 2002).

There is no doubt that Iföhus was a complex and important building during the middle age. The location of the house at the Island could be to show power to the surrounding area (Olsson 1957).

9. Reason for creating an application of Biskopskällaren and Iföhus

The goal of this practical work is trying to build and propose different construction hypothesis on Iföhus and designing a system able to present to the public the results using a visual language. As previously presented, the historical sources and the material investigation allow archaeologists to display several theories of how it could have looked like, in specific the house (Iföhus). This is based on the archaeological data found during the excavation from 1938-1949 by Harald Olsson (Olsson 1957).

The virtual interpretation model has been realized using Blender; a free and open-source 3D computer graphics software product used for creating animated films, visual effects, interactive 3D applications or video games (Blender). The structures have been developed importing maps and prospects of the cellar inside the platform.

Because of the few information left about the description of the materials I decided to not reconstruct any texture or color information, but just the geometry of the building, in order to allow the visitors of the site to visualize an idea of the volumes of the building, understanding the relations between the cellar and the interpreted structure on top of it.

This application, despite the small number of details will promote the idea of 3D models as a tool to enhance a fragmented knowledge, where several options are visualized. For pedagogical purposes, my goal was to show the process of creating a 3D model making visible the critical discussion around the process.

10. Blender

Blender is an open sources (free of cost) 3D program. It provides a broad spectrum of modeling, lightning, UV-mapping, texturing, animation and video post-processing functionality. Blender's aim is to have a complete package for the user and that this package is free. Projects that are created in Blender can be used in other 3D software, such as Unity 3D (http:// http://www.blender.org/).

Before starting developing the virtual models I performed an analysis of all archaeological data about Biskopskällaren. The possibility to have access to the documentation so far produced during the study of this monument was crucial to find a proper 3D interpretation strategy.

Due to the missing information concerning the structure above the cellar, I decided to avoid the visualization of the color information, focusing instead on the interpretation of volumes and geometry.

The first operation was importing in Blender, a historical map of the building realized by Harald Olsson in the 1900's (Olsson 1957). The map has been used as a reference to extrude volumes and shapes. The use of such document allowed a good control on the wall size.

Here the pillars and the vaults are visible in the plan, which makes the modeling process a bit easier (figure 13). After placing the plan of the cellar in Blender, I started extruding volumes from the drawing (figure 14).

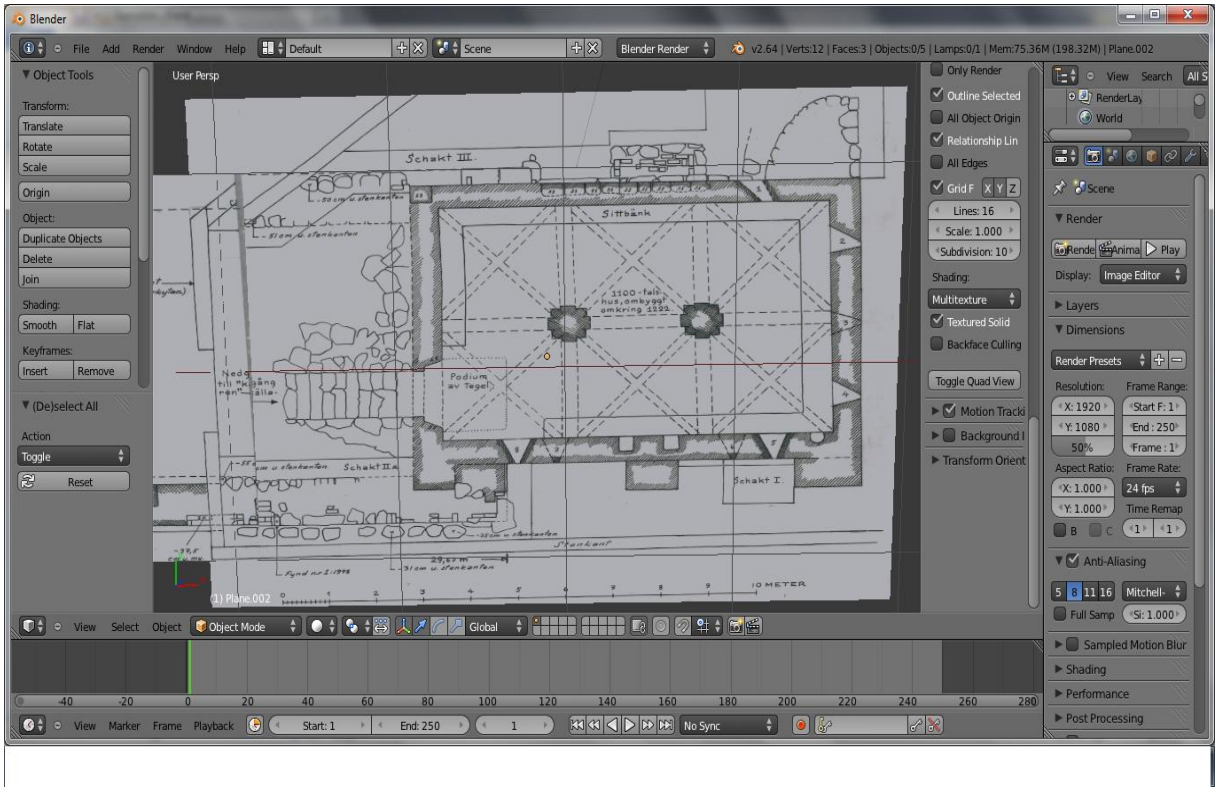


Figure 13. A snapshot from Blender, showing the map of the cellar before creating walls.

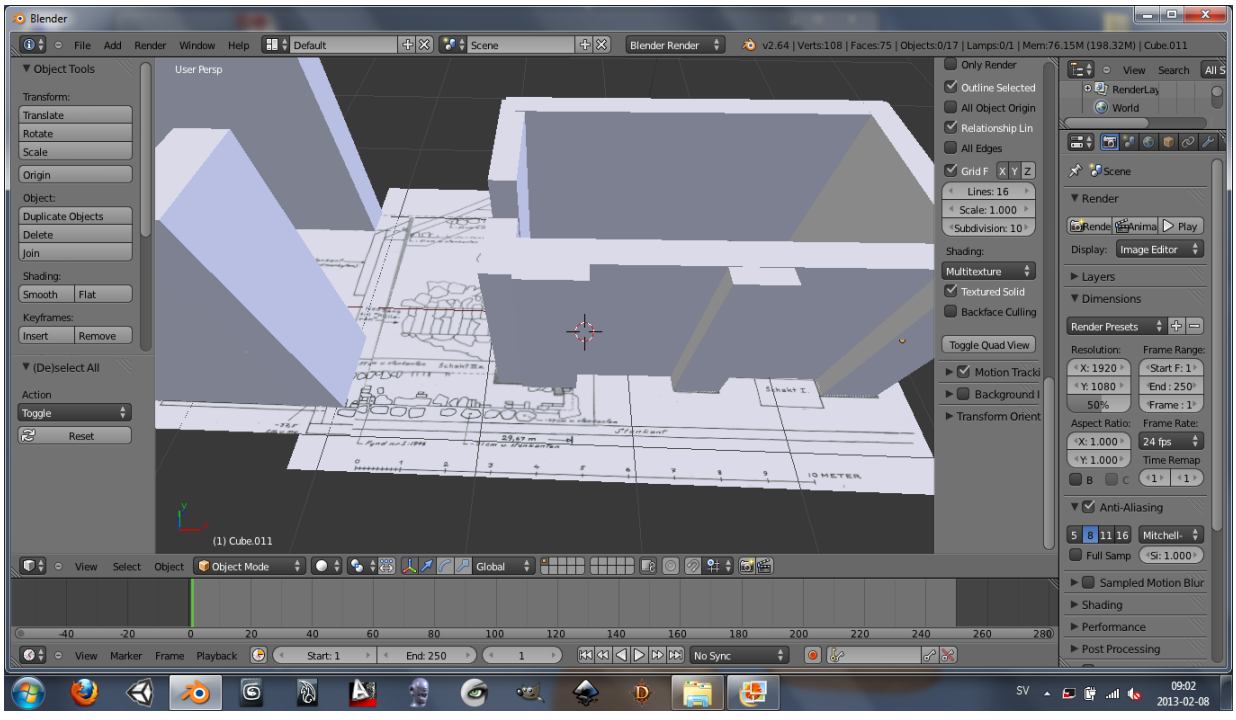
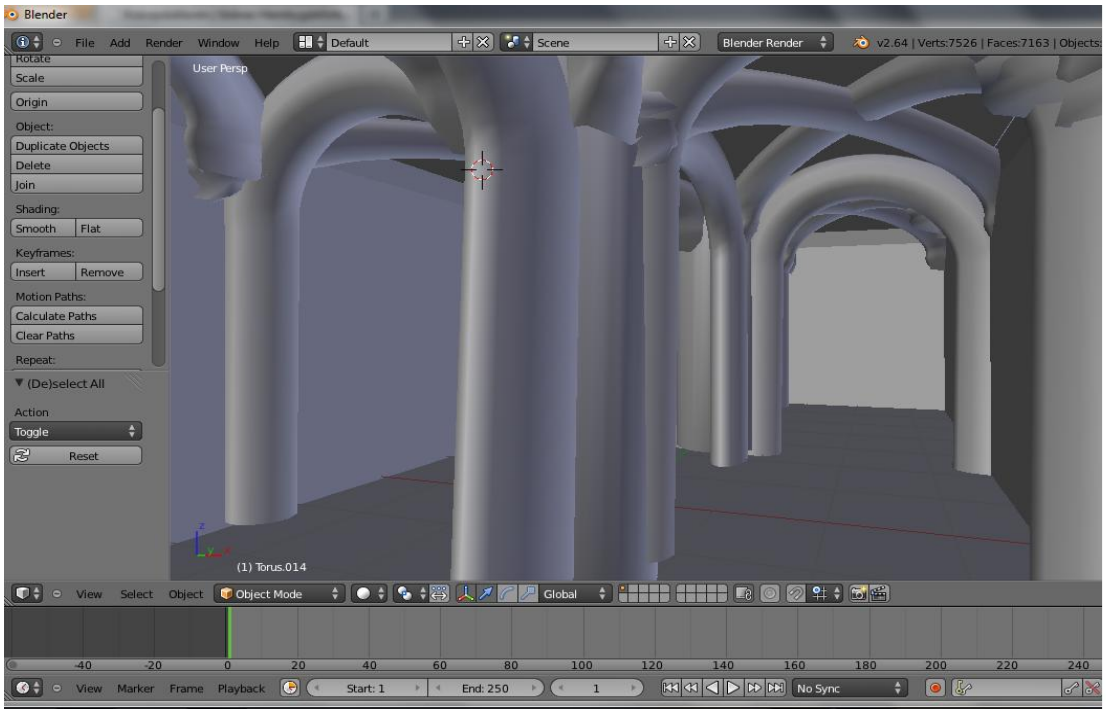


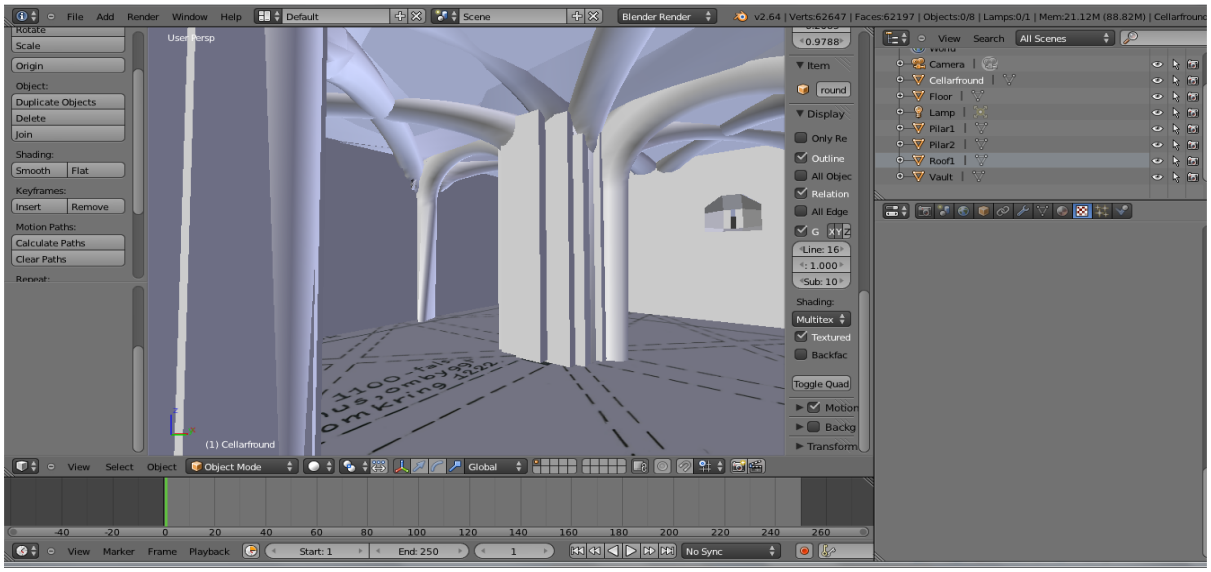
Figure 14. Snapshot from Blender, showing the process of building the geometry with the guide line of the map.



Figures 15.Snapshot from Blender, the vaults are almost done in this process.

After the walls were placed accordingly to the plan, I had to start and model the other architectural features, the vaults and the pillars that are inside the cellar (figure 15).

To recreate and model a historical monument is a difficult process because of its architecture, and to make it correctly takes time. To make it look good, without texture and color, requires good lightning. Recreating the roof was a long process since the roof is not straight (figure 16-17). Using the little information available I tried to reconstruct the structure following the indication of the map. In order to represent the environment I also used photographic material of the cellar available for this work.



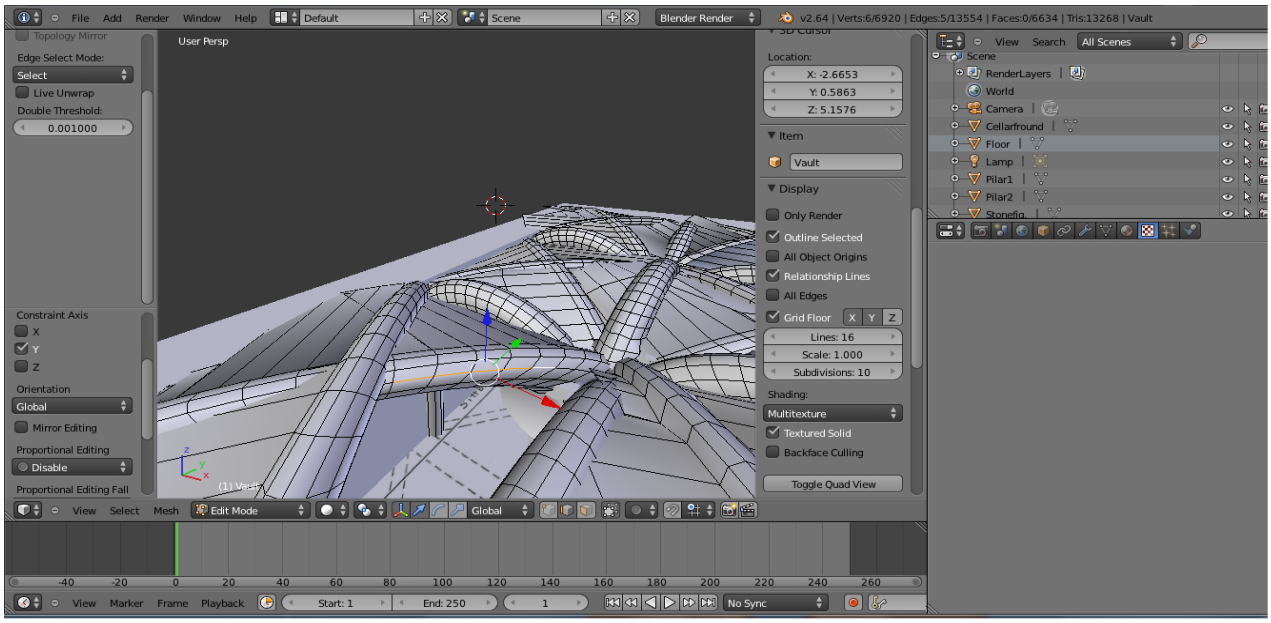


Figure 16 and 17. Snapshots from Blender. Figure on top (16) is a view from the inside of the cellar. Figure on bottom (17) is a view from the creation of the roof on top of the cellar.

Once reconstructed the cellar, I focused on building the house that once was on top of the cellar. This is a harder task since it does not exists anymore and the only thing that can help me in the building process is the plan of the house that was drawn during the excavations made in the 1900's.

After an evaluation of the sources I decided to use the study made by Sofia Winge, whom has recently investigated the site combining information from different sources (Winge 2012). Another important source for this work was associate Professor Anders Ödman, whom helped me during the entire building process to make this visual interpretation as accurate as possible.

Iföhus has been modeled using the same technique employed for the cellar. At the beginning I placed the map containing information from the excavation in Blender (figure 18). This was to make sure that I made the visual interpretation as accurate as possible.

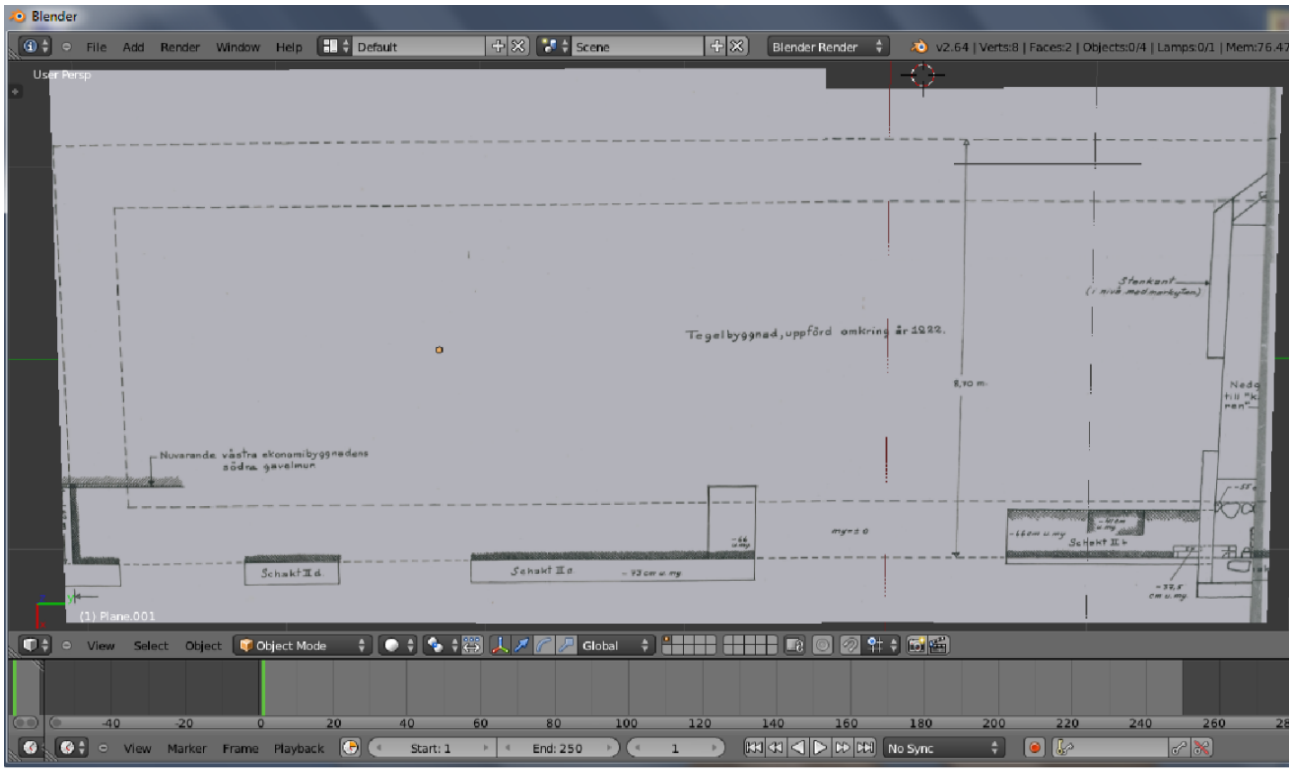


Figure 18. Snapshot from Blender, showing the map of the house before creating the walls.

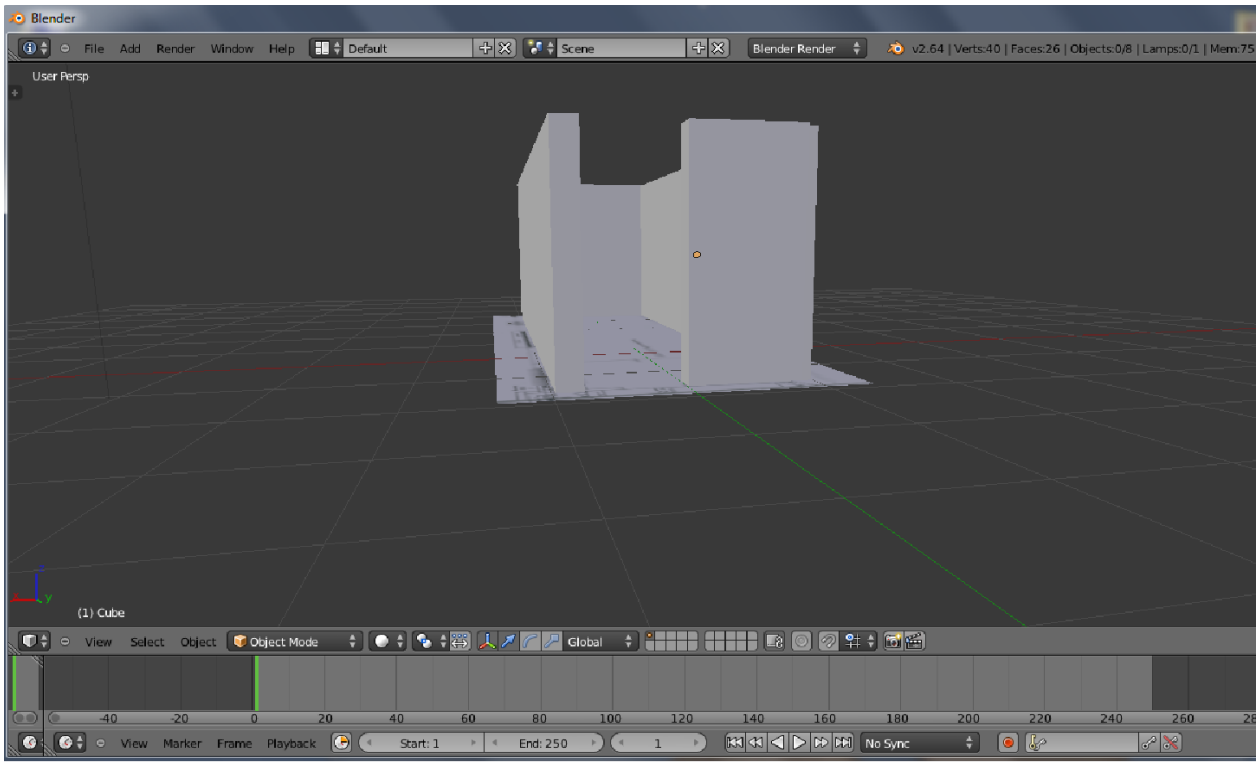


Figure 19. Snapshot from Blender, showing the process of building the walls according to the map.

Then I started modeling the walls according to the map (figure 19). Since there is no information about the roof, I applied a standard structure. The roof was probably built with tiles, according to Harald Olsson who did the excavation in 1938-1949.

The final stage in the modeling process of the house was just to complete the geometry. Since I do not have any information of doors and windows, I decided to not model them (figure 20-21). This means that if new information comes along, it will be possible in the future to re-model the house again, and placing new elements such as windows and door.

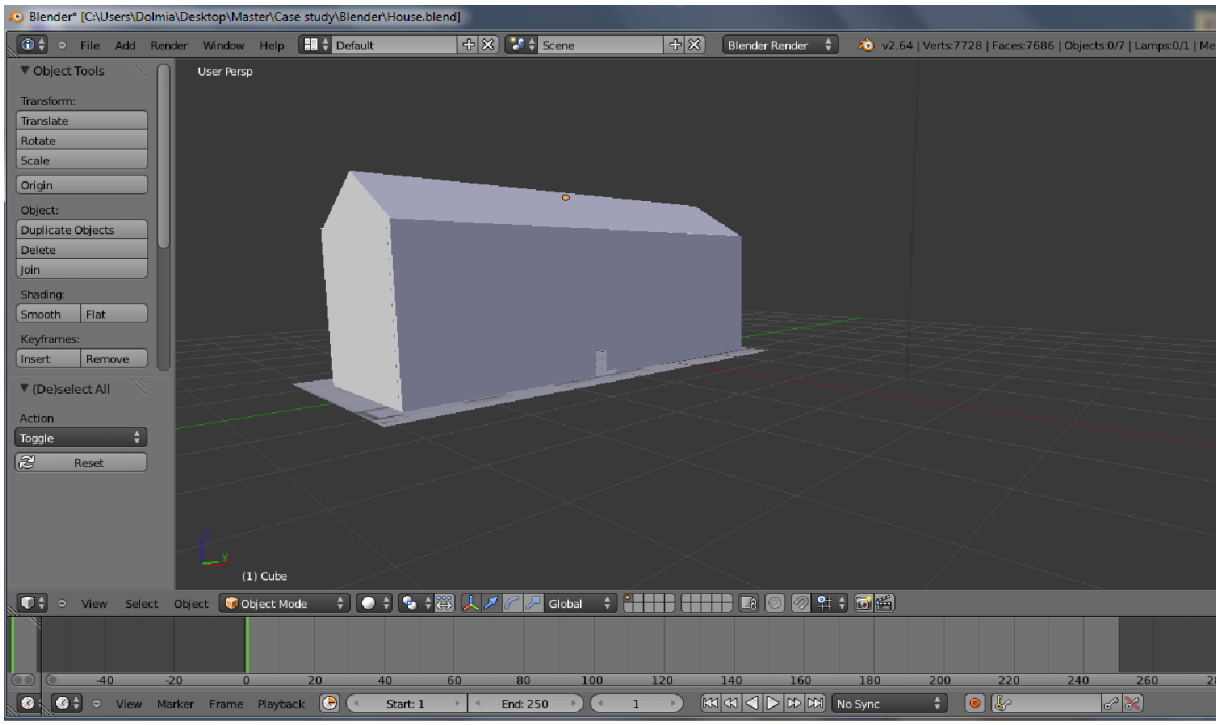


Figure 20.Final prototype of Iföhus in Blender

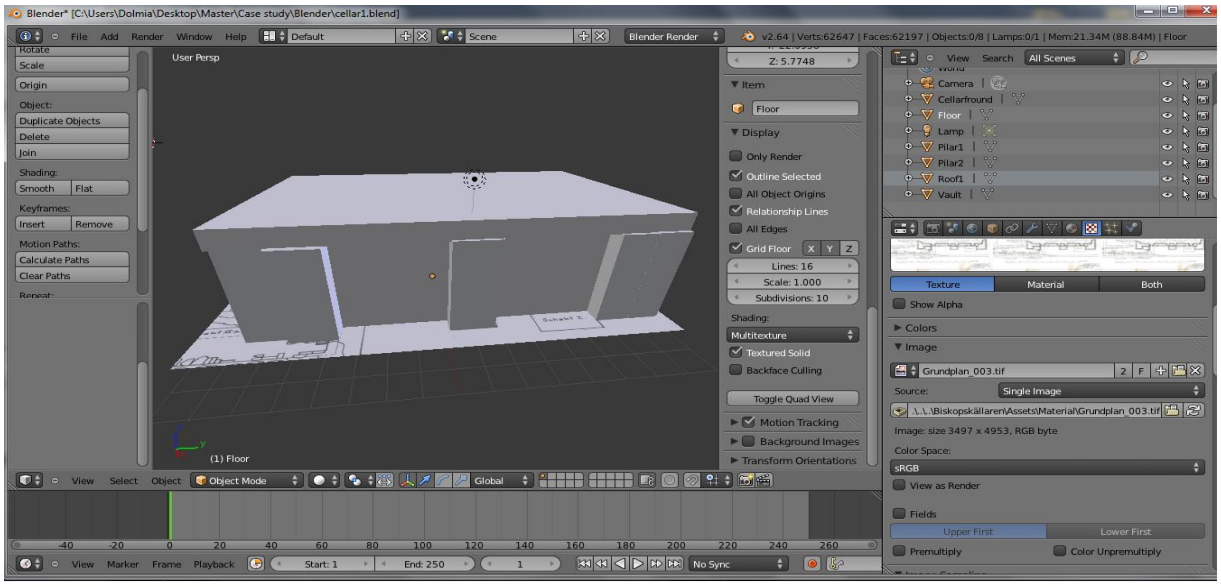


Figure 21. Final prototype of the cellar in Blender

Since the two models are big in size (figure 20-21), I chose to develop them separately. Unity 3D does not allow big sized files and therefore dividing the models are good. The models are now ready for being imported into Unity 3D. Another action needed was to make an opening in the house-model, otherwise I could not get in with the camera in Unity 3D and nothing inside the models would be visible.

10.1 Unity 3D

Unity 3D is a powerful game engine. The developers behind Unity 3D created this instrument so the user could have a clear interplay of features and functionality. Unity 3D allows powerful rendering and the program has a complete set of tools (script and animation), which allows the user to immediately build a virtual system. Projects can be imported directly from other 3D programs or they can be created and animated in Unity. Through Unity's website it is possible to have access to support forums. They also have an Asset Store where it is possible to download (for free or for a low cost) assets, scripts if needed. These assets can be used if the user cannot model certain objects/environments or just to complete a game environment (Unity 3D).

Unity 3D allows projects to become complete games and to be published on the Internet if the user wants to. In the free version of Unity 3D, there are choices such as Standalone game (which is a finished game version only available on your computer) or website games (then the finished result can be shown on the Internet). In Unity 3D Pro you can choose to have the finished game as an application on the mobile phone (Unity 3D).

Unity 3D allows to easily visualize 3D models from different platforms. A virtual scene constructed in Blender can be easily imported and visualized in Unity. This allows the user to work in Blender and Unity at the same time.

Once imported all the models in Unity 3D I could start to create a scene in the game engine. The models were placed on a terrain (which is created in Unity). After placing the models on

the terrain, I had to scale the models. This is sometimes needed, since the models can be very small once place in Unity, and otherwise not visible.

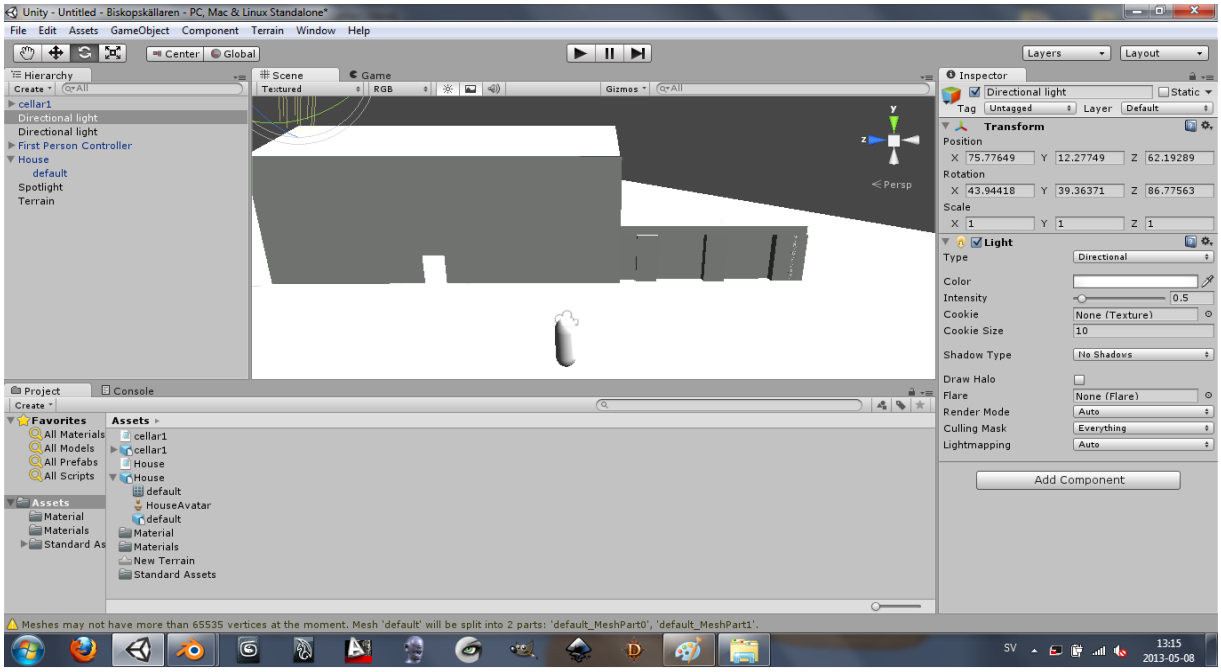


Figure 22. Showing the models on the terrain with only one light, to make them visible. First-person camera is also in place.

To make the models more appealing I created and placed more lights inside the cellar and around the house (figure 22). In order to make it possible for the users to explore the environments, I placed a virtual camera in the project. This camera is called "first-person camera", this means that the camera can be used by the user to explore the virtual site (figure 22).

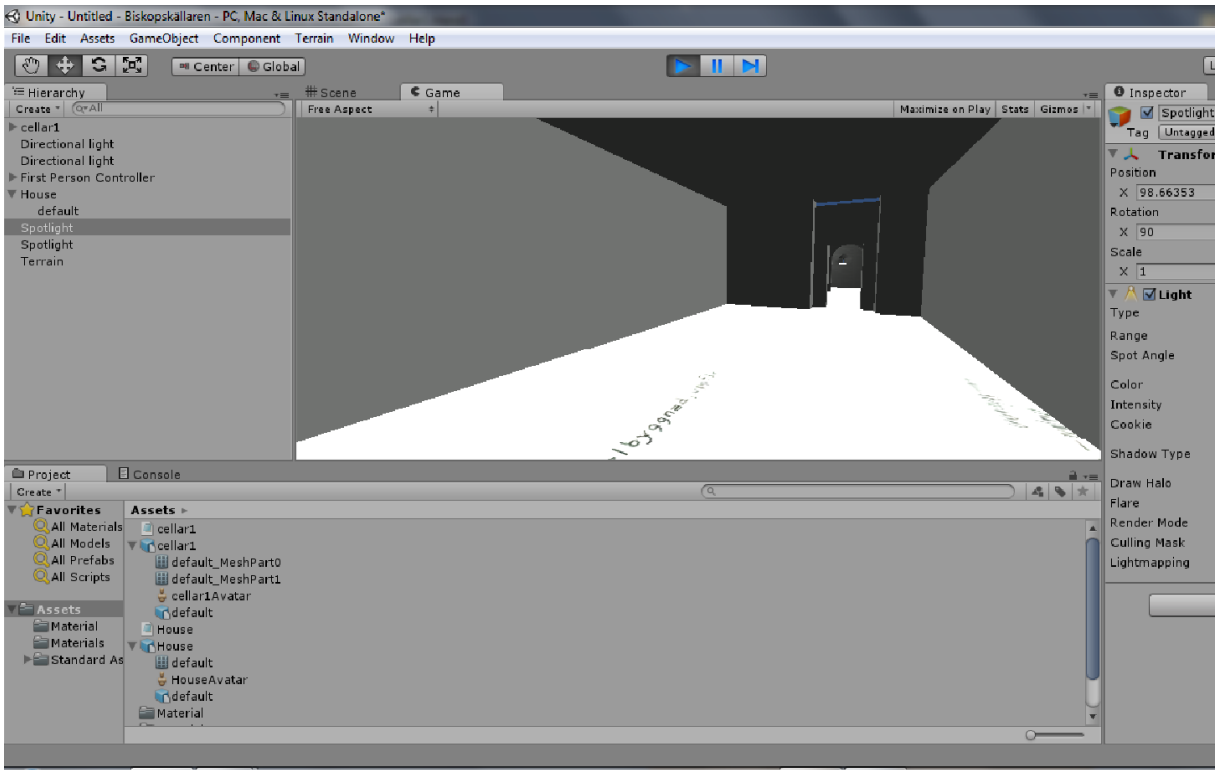
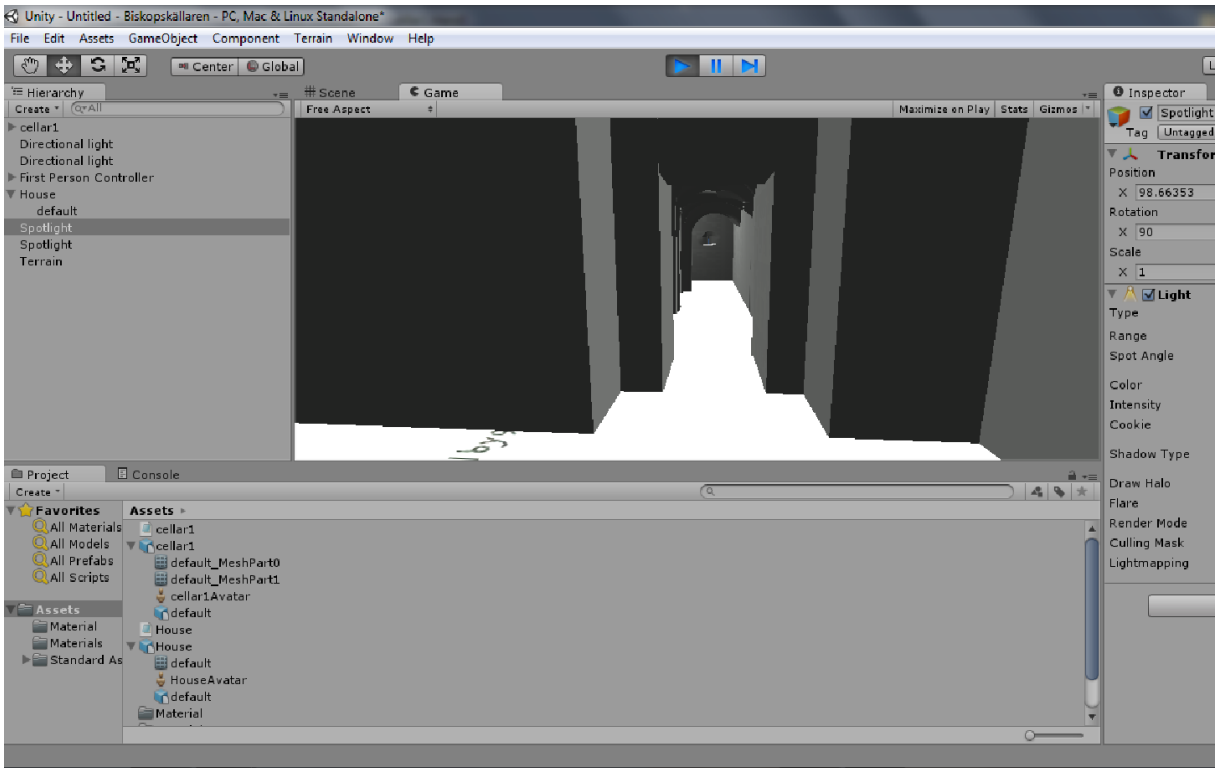


Figure 23 (on top) and figure 24 (on bottom). Snapshot from Unity while walking inside of the model



Figures on the previous page (figure 23-24), are showing the inside of the models while walking around with the "first-person camera". To get into the model I had to make an opening in the house. Moreover I created several "geometric colliders" in order to create a collision between cameras and structures. This implies that if I get to close to a wall or any other architecture I cannot walk through the model. These tools allow increasing the perception of the space using the first person camera.

11. Discussion and conclusion of the case study

The use of transparency to visualize the buildings, make me aware that it is possible to show a model and understanding its geometry without any texture or color information. To apply texture or color accordingly to what it actually looked like before it is required to add information that was not available. By showing a model without this information it still allows interpretations to be made by people visiting the site, since the geometry is in place.

When people are visiting the site, only seeing the transparent model, it could still give them an idea of what it could have looked like. Since the cellar is still intact and visible in both virtual and real world, it will make the interpretation of the house reconstructed on top of the cellar, easier for people to understand and to connect to. An evaluation of this case study would be great to have for understanding peoples thoughts of virtual worlds in a real environment.

My case study was developed with the guidelines from the London Charter. Before I started developing the model, I analyzed the historical sources and archaeological material that I had. This information allowed me to start creating the application and make my own interpretations of the site. By having a research study made of the historical monument and also virtual models, allows for a greater understanding of the site but also of how we as archaeologists are working with historical sites.

The main goal for developing these models was to be able to show the process of creating virtual models based on archaeological material, and to make an interpretation of Iföhus, which is no longer visible. It would also be interesting to develop this kind of application to see if the site would be enhanced by people visiting the site and using the application.

The virtual models were created in collaboration with Skånes Hembygdsförbund and their main reason for wanting virtual models created of Biskopskällaren and Iföhus is for people to understand what the site looked like and to make it a more attractive place to visit. A possible development of this application will be the visualization trough a Pad or mobile phone.

12. Future research

During this work of thesis I had the possibility to visit a company from Älmhult in Sweden. MSE Weibull specialized in developing virtual reality system, for different companies and for the entertainment industries (http://www.mseab.se/).

This company developed a new typology of virtual theatre based on the perception of the space through an *Omni-directional treadmill* (figure 25) floor, motor and controlling computer and a virtual reality tracking system (MSE). The virtual theater is placed in a Dome (Cylinder) which consists of six projectors placed in the roof of the Dome (MSE). The projectors retro-project in virtual environments on to the cylinders walls in order to provide a 360 degree visualization of the site.

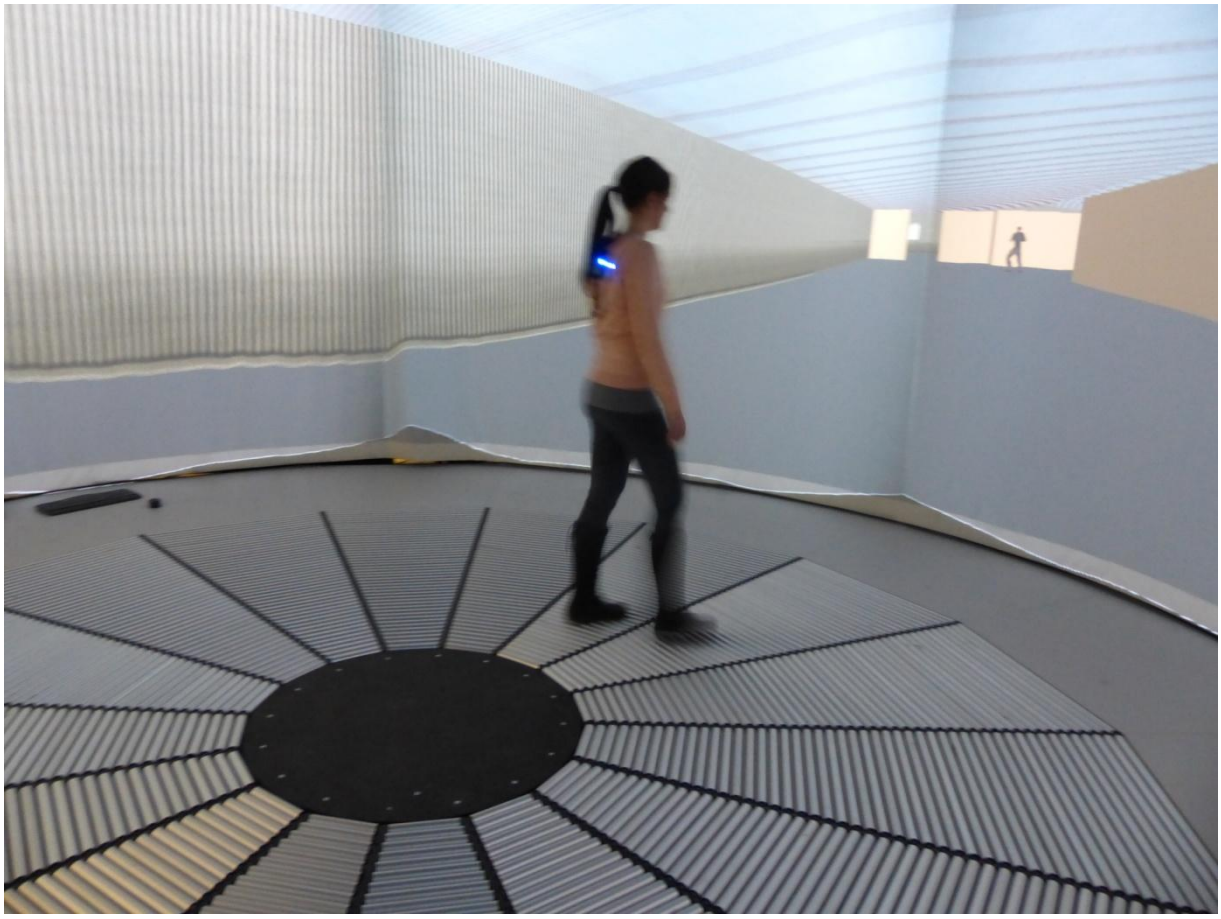


Figure 25. I am trying to walk on the Omni Theater floor. (Picture taken by: Carolina Larsson 2013).

Through the use of the body sensor, which is placed on the neck, the system is able to recognize the position of the user in the virtual space. While walking on the floor allows the user to leave a stronger sensation of embodiment. The floor is constantly moving towards the centre, and there is no chance to fall off the floor or moving outside of it. If the movements stops, the user is automatically move back by the system to the centre of the floor (MSE).

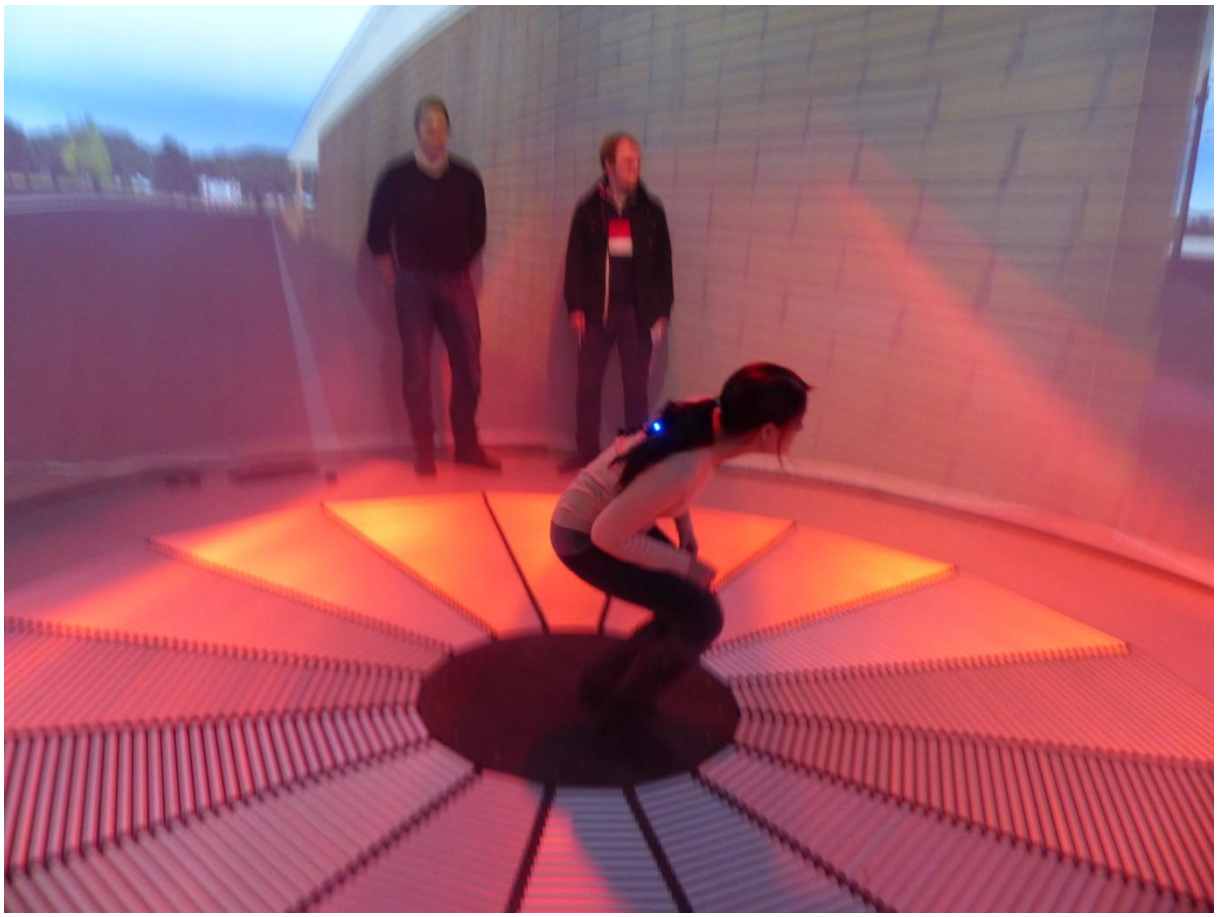


Figure 26. Picture of the Omni Theater floor, where I am trying to peak through the corner of the house (Picture taken by: Carolina Larsson 2013).

Figure 27. Virtual reality glasses connected to a game engine. These glasses could also be applied when using the Omni Theater floor (Picture taken by: Carolina Larsson 2013).

With the sensor connected to the game, we were able to actually hide and peak through the corner (figure 26). In the theater there were also different lights, sounds and also smoke, which enhanced the feeling of being in the game.

Through this thesis I have written about different case studies and their development through time. And it is clear that interaction is a powerful vehicle of communication and knowledge transmission for virtual museums. The use of such technology could represent an important tool to propose and communicate archaeological and historical interpretations (With both the Omni Theater floor and the virtual glasses) (figure 25-27).

But there are still concerns when it comes to these new techniques and the cost of these new techniques is still very high. So even if this instrument could enhance the experience of the application we want to show, there are still aspects to take into account that make the use of such advanced tools far from a real situation.

13. Discussion

In this research work I have focused on how 3D models can be created and visualized through the use of virtual reality techniques. I have also presented how these 3D models have been develop throughout the years and how we as archaeologists can use this technique to publish archaeological data in a different way, and how it can be used for pedagogical purposes. Our main task as archaeologists is to try and interpret the past through material and written sources of our past societies.

Through this work I have tried to focus on what virtual archaeology is all about. Archaeological material, is very often fragmented as Johnson states (Johnson 1999); we have to try and make the best possible interpretations based on this fragmented material. This is to make the public aware that the interpretations archaeologists make are based on this archaeological fact. This fragmented nature sometimes becomes an issue in archaeology, since we never find a complete collection of archaeological material. But in a way, this issue is what give us interpretations and allows all researchers to make their own interpretation. And in the future, it might be possible to gain new data to complete this fragmented nature.

I think it is important to know how the brain reacts to images, or understands the cognitive process that is formed when we get visual information. To understand how the brain creates images, we have to have knowledge of the cognitive process. The human brain has a lot of different boxes containing information of what we learned and what we have seen, which creates different prototypes in the boxes (Abramiuk 2012). A reconstruction could be like a prototype that is constructed from an environment rather than directly extracted from the environment (Abramiuk 2012). This means that the prototype is information from an object in the mind for which a duplicate may not exist in the nature, which almost makes the prototype, or the reconstruction in my case, a manifest of hybridization of attributes. Since part of my work was the reconstruction of a structure that does not exist anymore, it is hard to find a similar example in reality. But trough the connection of all the fragmented information so far investigated, this work could be perceived and recognized by the users as an hypothetical reconstruction, since we have created a cognitive box for it in our mind (Abramiuk 2012:77). It is also fundamental to have knowledge that every interpretation an archaeologist creates, are different, since we perceive the information differently and also see things differently. This work does not explore the implications of cognitive and neuroscience in virtual

archaeology, but it is important to take into account that developments in those sectors are brining an important contribution to the area of communication in archaeology.

The advantages for using virtual reality is to show different explanatory processes and not only as a technique for description (Barceló 2001:578). But Virtual reality also allows us to show different interpretations at a low cost compared to create physical reconstructions, and with virtual reality it also allows changes been made to the model (Teichmann 2009). I think that virtual reality became more important since this a good method that could be used on different sites and artifacts in the field of archaeology. The advantages as a presentation tool is great since you could use it to communicate scientific data to a wider audience (Teichmann 2009:103). Other advantages with a virtual model is that it allows different hypothesis to be tried out at a lower cost than making a physical reconstruction. If in fact the virtual model contains any wrong data it is possible to make changes in the model, whilst in a physical reconstruction it is not (Teichmann 2009).

At Kulturnatten, as I have mentioned in Chapter 6.2**,** I had the impression that people were willing to learn more about archaeology when they had seen virtual interpretations, especially younger people showed a strong interest. In the case study of Skeingeborg, which as created in 2012, I realized that people want to see more virtual environments of archaeological nature. They found it fascinating and they seemed more inspired to learn about our past. People, who looked at the Skeingeborg application, asked a lot of questions, about the process of building the 3D models but also about the site itself. It was important for me to stress that the application of Skeingeborg was based on archaeological data and that it was done to provide still an idea of what it could have looked like. People in all ages seems to have accepted a new way of learning and gathering information of our past, at least this is the impression I was given at Kulturnatten. New generations have a constant interaction with technology and therefore I think it is important that we as archaeologists follow the development in these digital techniques, developing more and more new interpretations of our past.

14. Conclusion

The main reason why I have chosen to work with virtual reality and virtual archaeology is because I find it fascinating and in the future I hope to develop more and more virtual applications to help people with different disabilities. By showing or publishing archaeological data in a virtual context can give the sense of being equal to everybody and at the same time, learning about our past. Even if it is just interpretations archaeologists are creating.

An issue regarding showing a visual model is the accuracy that is achieved from the archaeological data, which is incomplete, by nature (Teichmann 2009). Sometimes it is difficult to have a complete model due to the lack of information. This could be missing information from written sources (Teichmann 2009). And that is why I think it is fundamental to work more and more in defining guidelines based on a strong theoretical assumptions and a strong practical experience, as suggested in the London Charter. To explain the visual model and also the information about how the model was produced. It is fundamental to express to the viewer that a visual model, is an interpretation and it can never be 100% accurate. By creating virtual models with virtual reality techniques, we as archaeologist have the ability to create several hypotheses of the archaeological data. By this we can also reach out to a lot more people. I would stress the fact that we can get several benefits in performing our work if we will introduce more and more digital methodologies in our work.

Virtual reality techniques of the new generation could be a way to develop virtual models of archaeological data in the future. A good example can be found in the work of Pietroni & Alli where tests and experiments that define a new way of approaching the use of visualization techniques are experimented. By examine her evaluation process of the case study, it seems as peoples responses to the new digital techniques are quite fine (Pietroni *et al in press*), I personally think this could be a way of presenting future archaeological interpretations and making people more aware of our past.

15. Summary

This research work is about how we as archaeologists can use virtual reality tools to show and publish archaeological interpretations. By understanding how Virtual reality has been developed in archaeology so far, we can in some extend, assume that this is a good way of presenting archaeological material. The case studies that I have written about in this thesis show that the digital techniques have developed quite fast and also with much better techniques. By creating these virtual models or environments we can make different interpretations of the past but also making archaeology more understandable for people. By making these models, more people can get involved in the process, interact and understanding archaeology and our past better.

My case study consisted of a small application of Biskopskällaren and the house that once was on top of it, Iföhus. This archaeological site is located at the island Ivö, near Kristianstad, was developed in a collaboration with Skånes Hembygdsförbund. Throughout the development of the application, I have used historical sources and archaeological material to complete this application. The archaeological material is not complete, which is why I have chosen to develop the application without any texture or color information. The final result of the model is placed in a game engine Unity 3D, which allows free navigation in the 3D space.

16. Acknowledgements

I would like, first of all, to thank my supervisor, Nicolò Dell 'Unto, for the help with feedback to complete this thesis and also for the good advices to make this a better thesis. And big thank you to Sophie McAulay for helping me correct my spelling.

Thanks to the Humanities Laboratory and MSE Weibull, Carolina Larsson and Stefan Lindgren for advice and also for letting me see the new virtual reality techniques.

I would also like to thank Skånes Hembygdsförbund and Sofia Winge, for their collaboration and for giving me information about the Bishop's cellar.

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And thank you to Jes Wienberg for the feedback on the thesis.

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17.2 Pictures

Figure 1. *The tomb of Queen Nefertari*, virtual reconstruction of the tomb that was to substitute the real tour in the 1990's. Snapshot of the model provided by Nicolò Dell 'Unto

Figure 2 -3. *Capella Degli Scrovegni*, pictures of the hypermedia room that was created in order to supplement the tour to the chapel.Snapshots of the models provided by Nicolò Dell 'Unto

Figure 4, 5 and 9. *Regolini Galassi tomb*, pictures of the virtual reconstructions of the tomb showing the public interaction with archaeological material. Pietroni E, Adami A, Carlani R, I van Kampen, Sannibale M. *(in press).* Natural Interaction in VR Environments for Cultural Heritage and its Impact inside Museums: the Etruscanning Project. VHLAB, ITABC, Roma, Italy. Museo dell'Agro Veientano, Italy. Musei Vaticani, Città Del Vaticano.

Figure 6-8. *Daily life in the Middle Ages in Parma, Italy,* pictures are showing the reconstructions that were created by different experts. Guidazzoli A, Delli Ponti F 2007. Daily Life in the Middle Ages - Parma in the Cathedral Age. Eurographics Italian Chapter Conference 2007. CINECA, Via Magnanelli, 6/3, 40033, Casalecchio di Reno (BO), Italy

Figure 10-11. *Skeingeborg,* pictures are showing an interpretation of Skeingeborg inside a game engine, both inside the courtyard and outside environment. Snapshots from Skeingeborg project inside Unity (2012).

Figure 12. Photograph from the excavation (1938 or 1949). In the picture the Bishops cellar is visible and also a stone with markings. Photograph from Riksmuseets arkiv in Kristianstad.

Figure 13-21. *Bishops cellar and Iföhus,* working progress inside Blender. Snapshots from Blender.

Figure 22-24. *Bishops cellar and Iföhus,* working progress inside Unity. Snapshots from Unity 3D.

Figure 25-27. *Omni theater floor,* photographs taken by Carolina Larsson, 2013 at MSE Weibull.