Interpreting in 3D

Employing 3D modeling in field archaeology from research and public communication perspectives

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Abstract

This thesis investigates the use of digital technology on the border between science and public communication. The author argues for a public archaeology that goes beyond an arranged communication, where only one final truth about the past is presented. Instead arguments are presented for the benefit of letting also non-archaeologists take part of the many ambiguities of archaeological excavations, thus experiencing the process in which knowledge about the past is created. The potentials in using 3D modeling as a way that involve the public in the interpretation process, and at the same time provide researchers with a deeper understanding of the archaeological context is investigated and discussed in this thesis. An experiment of 3D visualization of an archaeological excavation is developed where 3D models representing the excavation area obtained through Computer Vision techniques are combined with modeled 3D geometry representing archaeological interpretations made during and after the excavation. The layout of the models of combined 3D data describes the relation between archaeological features and interpretations of what they represent, which in a communication situation gives the public the chance to follow the reasoning of the archaeologists. From a research perspective, integrating the element of hypothesis visualization in the fieldwork process, provides a deeper understanding of an archaeological context, beneficial for the continuing excavation process. The case study was conducted using a systemized way of accounting for sources and paradata, being the record of the subjective discussions, decisions and choices made that leading to the visualization, thus emphasizing the importance of transparency in virtual heritage.

Key words: 3D modeling, visualization, model, reconstruction, field archaeology, public archaeology, computer vision, digital archaeology, virtual reality, virtual heritage, transparency, paradata, contextual experiment

Contents

1. Introduction

Traditionally, archaeological research and public communication in archaeology have been regarded as two different matters to be kept apart. However, seeing this dividing line as an unnecessary construction, and instead aiming to create a meeting and dialogue between the two fields, has a potential to enrich both of them (Petersson 2011:12). This is my starting point when aiming to explore the possibilities of using digital technology and 3D modeling in the border between science and communication to a wider community.

1.2. Background

The archaeological site of Uppåkra in southern Sweden was discovered in 1934. Since the end of the 1990s, archaeological investigations have been conducted here yearly, revealing traces of an Iron Age central place, with intense religious and economic activity, international trade and superior crafts with a continuity for over a thousand years (Larsson & Hårdh, 2007). During season, visitors come daily to see the ongoing excavations. Science pedagogues, including myself, perform guided tours at the site. Currently, the investigations are focused on the remains of houses once inhabited by the social elite, and as pedagogues we try to explain how the features seen today in the form of post holes and cultural layers relates to the buildings that once stood there and the people connected to them. Much of the challenge of the job is to try telling a story that evokes somewhat more vivid images of past times, of which only fragments remain today. The remains of Uppåkra, as most Scandinavian prehistoric archaeology, are quite scarce, since most organic material no longer remains in its original form. Another reason for the fragmented picture is the fact that only a few percent of this large site has been excavated. Every season, new knowledge is gained and reinterpretations sometimes have to be made due to new discoveries.

In this thesis, ways of using 3D modeling to make the dynamic process of an archaeological excavation more understandable for the public will be discussed. During the summer of 2011, an experiment of 3D documentation of one of the ongoing archaeological investigations in Uppåkra was done, combining the use of Total Station with Computer Vision techniques. The result of this test was a number of 3D models depicting the state of the excavation surface in different stages of the process. The methodology proved to be easy to integrate with the daily work of the archeologists and provided a valuable source of data for interpretation, archival and integration of acquired material (Callieri *et. al.* 2011). This material will be used in this work as the basis for a visualization experiment.

The use of 3D visualization technology for the communication of archaeological environments has increased exponentially in the last years. Despite the possibility to combine and use different kind of technology for data capture, so far, the main use of these techniques have been employed to reinterpret in three dimensions archaeological contexts already investigated. It has been pointed out and criticized that public archaeology often appear somewhat arranged, without possibilities of interpretation, or expressing the ambiguity that is the core of archaeological knowledge (Karlsson & Nilsson 2001:7). Related to this discussion are criticisms directed against how images depicting the past often communicate ”authenticity”, ”truth” and ”fact” (Killebrew 2004:127), when they, by definition, cannot recreate this one true picture. Images representing the past are created within its contemporary context and will therefore always be a biased interpretation, shaped by current conceptions of what the past is. However, what today is seen as ruins were often once impressive decorated buildings, and avoiding visualizing this can be argued to be misleading to a viewer as well (Brush 2004:253). These issues will be considered throughout the thesis.

1.2 Problem formulation

Through this work I will investigate how the use of visualization can be employed for a more transparent communication of the archaeological investigation process. I will discuss the possibilities in using 3D modeling to communicate the ongoing research process of field archaeology. I will also focus on the concept of 3D modeling techniques from a research perspective. I will develop an experiment of 3D visualization of an archaeological site, based on the analysis of geo referenced resolute 3D models that describe step by step the excavation process. In my case study I will investigate the potentials in connecting different typologies of 3D data for the description of the entire interpretation process performed by the archeologists. This work has been developed starting from the following research questions:

- **How can we successfully employ 3D modeling during an archaeological excavation in a way that benefits both research and public communication?**

- **Is it possible to involve the public further in the interpretation process and make archaeology more understandable by using 3D modeling in fieldwork?**

2. Theory and method

2.1 Transparency in heritage visualization

Seeing is believing – the power of visual media in influencing the way we perceive the reality is very strong. The use of computers to visualize interpretations of the past has been done since the 1980s, and along with the improvement of software and hardware, renderings have become more and more realistic and immersive. Criticism regarding these virtual creations has concerned the way they, by being so realistic, communicate a high degree of "truth", when it is in fact no more than an interpretation. A related critical comment concerns the lack of declaration of the level of accuracy contra hypothesis of different parts of many 3D visualizations, as well as the importance of accounting for the sources that influenced the creation of the virtual model (Clark 2010:69-70). The London Charter is a list of principles proposed by a group of scholars, with the aim of establishing internationally recognized principles for the use of three-dimensional visualization in cultural heritage. These scholars critically analyze the impact of computer based visualizations in cultural heritage, with the aim to establish guidelines for the intellectual integrity of the 3D models used to represent the past. In a future where digital communication and visualization technologies will pervade cultural heritage, the contributors to the London

Charter see common ground principles as becoming more and more important. The principles are broadly formulated since they aspire to be valid across all domains in which 3D visualization can be applied to cultural heritage. The authors hope to offer a foundation, upon which specific subject areas can build more detailed guidelines to ensure that the use of 3D visualization coheres with the aims, objectives and methods of their domain (London Charter website). In short, some of the key contents of the charter are: (i) to let the cultural content be central in the visualization and not the spectacular aspect, (ii) to document the interpretation process and account for the sources, (iii) to distinguish interpretation and hypotheses from facts and actual information (Nicolucci 2010:62). A key concept in the discussion leading to the formulation of the principles is *transparency*. If 3D visualization is to be used as a methodology, it must be easy for the users to understand and evaluate the processes and outcomes of computer based visualization. The following principles from The London Charter concern transparency in documentation:

> "Documentation of Knowledge Claims
> 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 a cultural heritage object or site, and the extent and nature of any factual uncertainty."
>
> "Documentation of Process (Paradata)
> 4.6 Documentation of the evaluative, analytical, deductive, interpretative and creative decisions made in the course of computer-based visualization 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 website)

2.2 A reconstructed past?

Many have pointed out how the concept of *reconstruction* can be problematic and inappropriate (Clark 2010, Baker 2012:164, Pletinckx, 2012:203, Rasmussen 2011:152). The term is often used when referring to depictions of the past based on archaeological material and results, either made virtually, drawn, imagined and built in full-scale (Clark 2010, Rasmussen 2011:51). According to Clark, the term is misleading, implying an idea of actually having the possibility of *re-constructing* the past. The core problem thus lies in a misconception of what is actually being produced (Clark 2010:63-64). The concept infers that something is being recreated just as it was, when it is in fact impossible to rebuild that of what only fragments remain. From the perspective of the post-processual approach of *interpretive archaeology,* you are, as an archaeologist, engaged in an interpretive discourse and hermeneutic reading. Your interpretation is biased, theory-laden and subjective, as you interpret the archaeological context from the perspective of your contemporary context, and your own preconceptions and prejudices. From a post-processual point of view, having "the one" reconstruction of an archaeological site is inconsistent with notions of interpretation, context, multivocality and agency (Clark 2010:66). Interpretation is always ambiguous and uncertain, and a recreation of the past is impossible to make, since the information you collect, as an archaeologist is always incomplete. This is best emphasized by using proper terminology according to Clark. Clark finds the term *model* more appropriate, since what you create is to be regarded as another model, similar to mathematical or geographical models. A model is a tool that is able to help us better understand a complex phenomenon, but it is also a simplification. A model is not to be seen as the endpoint of research (Clark 2010:67-68). Baker is also critical to the reconstruction concept, and suggests the term visualization instead. He emphasizes a difference between these terms regarding the aims and ultimate goal using computer graphic images in cultural heritage. The goal of visualization is not to show an accurate image of the past, but to provide the viewer with visual arguments for the hypotheses of the researcher, while as a researcher being aware of and accepting inevitable uncertainty of interpretation (Baker 2012:164). Pletinckx as well points out that the goal of 3D visualization is not to reconstruct the past, since it is not possible to do, but instead to visualize the process of bringing together available sources (Pletinckx 2012:205). Rasmussen, when discussing the building of full-scale physical structures based on archaeological discoveries, also expresses the opinion that the term reconstruction can be inappropriate, and suggests using the term model as well, to show that the building is an interpretation of archaeological features. Rasmussen emphasizes that when a model based on archaeological structure is created, an analogy is made. It is created by our interpretation, which is based on an incomplete archaeological record (Rasmussen 2011:152-153).

2.3 Visualization and archaeological research

Most three dimensional archaeological visualizations have served as means of communicating archaeology to a wider audience, rather than being made for research purposes (Hermon 2012:21). One example is provided by Larsen: the virtual modeling of a Viking Age house from Holsted Overmark, made for public communication purposes in a museum. Even though this was not the purpose, Larsen was able to conclude that the construction of this 3D model also led to unexpected valuable conclusions from a research perspective. Some of the archaeological features had to be reinterpreted as a consequence of the insights gained when making the visualization (Larsen 2007:186ff). This example shows how the process of building a 3D interpretation, connecting all the data that characterized the archaeological investigation, deeply influence the result of the interpretation itself. Building three-dimensional models as a way of gaining insights and inspiration during the archaeological interpretation process is further discussed and developed by Rasmussen and Beck, from the perspective of experimental archaeology, as well as by Hermon, discussing the use of 3D models to interpret the past. Rasmussen considers the visualization as a fundamental starting point for interpretation of archaeological material (Rasmussen 2011:151). Hermon points out that cognitive psychology as well as education research show that a visualization tool, if properly designed, facilitates understanding and perception of information (Hermon 2012:14). In a situation where archaeological data have to be interpreted, three-dimensional models allow a direct and real time comparison between the geometrical characteristics of the investigated context and the different interpretations developed during the investigation (Hermon 2012:21). The process of visualization can to lead to a reevaluation, as in Larsen´s case above, which deepens the understanding of an archaeological material.

In the context of experimental archaeology, the concept of *contextual experiment* has been introduced by Rasmussen (2001, 2007, 2011) as an alternative to what she calls the *controlled experiment*, being the traditional method of conducting experimental archaeology within a positivistic theoretical framework (Rasmussen 2011:6). The contextual experiment instead uses a post-processual approach, where the aim of the experiment is not to systematically record empirical data, but instead to search for questions, inspiration and new perspectives through practical experiments (Beck 2011:186). In a contextual experiment, instead of trying to minimize the influences of modern conditions, it is clearly emphasized that the experiment is situated in the present, and that it is the experimenter who sets up the premises (Beck 2011:187). The benefit of a contextual experiment is the ability to go beyond what has been excavated, in order gain a deeper knowledge of the character of the site and the different features when continuing the excavation process. This might provoke new insights and aspects, or hitherto unknown features in the archaeological material. This process in turn encourages new experiments, thus creating a hermeneutic circle (Beck 2012:187, Rasmussen 2001:5). An example is provided by Beck describing an experiment of a construction of a full-scale Iron Age house. When inhabiting the house, the archaeologists found several draughts that made living inside the building very uncomfortable. The direct experience of this intangible element was the start of a discussion on how to minimize draughts using internal walls. Later on, during an excavation of Iron Age houses, one of the participants in the experiment involved in the excavation found traces of internal walls in the form of faint features, which probably would have been overlooked without the experience of the experiment (Beck 2012:187-188). Hermon in his work explain how these analogies might as well be constructed virtually as in physical form. He provides an example where historical texts and comparisons with other monuments were used to create hypothetical versions in 3D of a mausoleum described in a historical text written by the Roman author Pliny the Elder. As the virtual models were analyzed, features that did not fit into the picture could be identified. The process adopted during the development of this project led to the formulation of research questions, which had not been taken into account before (Hermon 2012:16-19). The example provided by Hermon shows the unique characteristic of Virtual Reality in elaborating and comparing multiple hypotheses using the same visualization platform. Another advantage of this visualization method is that it can be a relatively time-effective way of using a contextual experimental approach and digital tools to build visual experiments. The virtual environment can thus be used as a visual research platform, where both the archaeological data and hypothetical interpretations can be critically investigated. This approach produces a visualization of the archaeological reasoning (Hermon 2012:22).

2.4 Interpretation management

The paragraphs in The London Charter mentioned above stress the necessity of a systematic documentation of sources used, decisions taken and interpretations made when visualizing, thus making the scientific reasoning transparent, and the visualization academically credible, both for research and communication purposes. The term *paradata* is a key concept in this discussion. Baker defines paradata as “describing the processes of interpreting and creating data objects in order to enable understanding and evaluation” (Baker 2012:169f). Compared to *metadata*, which is describing the properties of data, for example height and weight, paradata is more fluid, being a record of the subjective discussions and decisions that led to a certain visualization (Baker 2012:170). As with other publications, the relationship between a virtual model and the evidence that supports it should be clear, so that the interpretation can be understood. The equivalent of footnotes shall be accessible also in the virtual world created (Pollini *et al*. 2005).

There is still little standardization regarding the documentation of sources and interpretation processes leading to the creation of a virtual model, which causes 3D visualizations of the past to still have the connotation of lacking credibility (Pletinckx 2012:204). Finding practical ways to implement the paragraphs of The London Charter, thus making the 3D modeling process transparent, represent an important part of this thesis. I will discuss and orient my case study around the methodology of Interpretation management proposed by Pletinckx (2012). The methodology is a suggestion on how to manage and structure the interpretation process in order to produce a transparent 3D visualization, easy to review and update. The aim of this methodology is also to make understandable the level of speculation, assumption or uncertainty of the different parts of the visualized features and to preserve the data of intellectual efforts for later generations. The use of such methodology will increase the chance of 3D visualization techniques to be fully accepted during activities of research and public presentation (Pletinckx 2012:204 ff.). Pletinckx suggests the creation of a source database initially, and thereafter following the steps of *source assessment*, *source correlation* and *hypothesis trees*:

Creation of a source database. All the sources are collected and recorded in a database. Examples of sources can be recognized in for example iconography, excavation data, pollen analysis, historical sources or oral history. All sources should be identified uniquely (Pletinckx 2012:207).

Source assessment. The source is studied to reach an understanding of its degree of reliability. Assessing the sources means taking into account and reflecting upon sources as already being an interpretation at the time of their creation and in that way being able to spot possible errors in their representation of reality (Pletinckx 2012:208).

Source correlation. Comparing the different sources makes it possible to identify correspondences, differences and inconsistencies. An example could be a comparison of an archaeological source with an iconographic source, to reach an understanding about the correlation between the two (Pletinckx 2012:210).

Creating hypothesis trees with conclusions. The hypothesis tree is a *formalization of the interpretation process.* This part is focused in showing different possible interpretation alternatives in a tree-like structure where the different hypotheses contain *sub-hypotheses* that each are evaluated. The reasoning leading to a certain interpretation is expressed in writing. Even less likely interpretations need to be recorded even if they are not developed. The different time phases of a site and how they relate to each other needs to be taken into consideration in the interpretation. The hypothesis tree can be used in a top-down fashion in the cases where all the sources are available and finalized. However, the method is also suitable for documenting the interpretation process in a bottom-up way of working, which is what archaeologists apply during the excavation process (Pletinckx 2012:213 ff).

Updating. The visualization should be kept up to date. If a new source becomes available or an existing source is reassessed, this might have an impact on the hypotheses and the reliability of the 3D visualization, which leads to the need of changes of the model. Full transparency should be maintained, by recording all the paradata derived from creation and updating of the visualization (Pletinckx 2012:216 ff).

The purpose of presenting this method is to be able to use it as a starting point when discussing how to apply 3D visualization in archaeological fieldwork, and suggesting a framework to develop. During my case study I will use parts of this methodology when structuring the sources of the 3D visualizations created and as a tool for documenting the discussion leading to the different visualized hypotheses.

3 Examples of heritage visualization in 3D

To further discuss the issues raised in the theoretical section, I present a number of examples, of how 3D modeling has been used in cultural heritage contexts. They represent different ways of considering and implementing transparency in the work process and public presentation, and the possibilities of combining research and communication with a wider audience.

3.1 Ename 974

Since 1982, archaeological and historical research has been conducted in Ename, a town situated in the province of East-Flanders in Belgium. This archaeological site lies on the medieval boundary between the French kingdom and the German empire. The site has an open-air archaeological park, with the aim of communicating new insights about archaeology, history and conservation and to make complex and poorly preserved archaeological remains comprehensible to the general public (Pletinckx et al. 2000, Ename 974 website). The archaeological structures at Ename, belong to the foundations of a Benedictine abbey and an early medieval fortress. A trading settlement has also been excavated. As expressed on the Ename 974 website, it can be hard for a visitor to interpret and understand the stone structures, and get an idea of what they looked like in the past. The archaeological park and museum today uses virtual reality to make this more comprehensible. An on-site virtual reality installation called TimeScope was built in 1997, to give the visitors an idea of the past appearance of the site. This virtual reality kiosk is located next to the visible archaeological remains, and lets the visitor navigate on a touch screen, to see 3D models of the sequences of structures that stood on top of the building foundations. A video camera directed at the site superimpose a 3D interpretation of the site directly on top of the archaeological structures, providing the visitor with a virtual infrastructure to perceive (fig. 1, Pletinckx et. al. 2000, Ename 974 website).

Figure 1: Virtual reality kiosk situated next to the archaeological remains of the Saint Salvatore church of Ename, showing the wireframe 3D model concept that visitors can view (Pletinckx et. al. 2000:46).

The archaeological site is also presented virtually from a landscape perspective. In the presentation called TimeLine, the evolution of the landscape is presented, by combining real images together with virtual. This part of the visualization tool aim to show to the visitors the appearance and the evolution of the area during different centuries, by presenting every visible element in the current landscape. The present look of the site is shown from 150 meters above the ground. Roads, remains of the abbey, the old pond of the abbey and parts of the river can be recognized in the images of today, and connected to their past look on 3D images. 36 views on the virtual model are presented, for each of the 12 historical periods (fig. 2). A story can be told of how a place evolved, that creates an understanding and an interest among the visitors to continue exploring the site (Vergauwen *et. al.* 2005:1f).

Figure 2: Present day images combined with 3D models showing the development of the Ename site in 3D during the centuries from medieval times until the present (Vergauwen et. al. 2005).

As expressed in the website, the incapability in understanding the appearance of archaeological remains can lead to a failure in capturing the imagination of the visitors (Ename 974 website). The Ename project provides examples of how visible archaeological remains are connected to computer modeled interpretations. This makes it easy for a visitor to understand some of the basis of the interpretation by seeing the connection between visible remains and 3D models. It also offers the visitor a sense of immediacy and realism, by having real time video of the site serving as background to the model (Ename 974 website). Presenting the church as a wireframe model (fig. 1) also emphasizes the interpretation dimension more clearly, by using a look that puts focus on the shape rather than aiming for a realistic look.

3.2 Augustan Mausoleum Project

In the Augustan Mausoleum Project, developed in a collaborative effort by four researchers at the University of Southern California (Pollini *et. al.* 2005), virtual 3D models were made presenting several suggestions of past looks of the mausoleum of Augustus. This monument was constructed in the ancient Campus Martius in Rome, largely during the earlier 20s BC. Its archaeological remains still stand today. The project developers see a great possibility in using virtual tools when visualizing antiquity, but recognize that the relationship between data, interpretation and representation can be highly ambiguous, making representations of the past rather deceptive. One of the aims of this project was to specifically make the inherent ambiguity of a visualization of the past, explicit in the presentation and the images themselves. By creating the model they also wanted to emphasize the importance of demonstrating the link between the sources and the visual interpretation upon demand, and point out that the equivalent of footnotes should be accessible also for virtual visualizations (Pollini *et. al.* 2005).

The visualization consists of a rendered image of the virtual mausoleum model. Next to it are icons depicting different elements of the monument. By clicking the icons, the user chooses to visualize a certain interpretation of the look of the mausoleum top, middle and bottom. For example, a quadriga or a statue on foot can be selected for the top, since there are sources supporting both interpretations. The selected element is inserted into the entire mausoleum model, together with a presentation in text of the arguments for the chosen feature (see link in section 9.2 for figures). Along with this information there are “reliability meters”, indicating the reliability of the current visualization on a five-grade scale from ”very low” to “very high”. The viewers thus have all the available supporting evidence from the surviving written and archaeological record, and can make their own assessment. Using this visualization model, the user becomes aware of the limitation of evidence and creates awareness that the model necessarily does not represent the past look but an interpretation (Pollini *et. al*. 2005). Presenting the visualization in this way serves as a help for a visitor to imagine the past look of the monument, but it also communicates a fundamental part of archaeological research, namely that there are several possibilities, and no definitive answer to the appearance of the past. The presentation concept instead involve the users in interpretation, letting them take an active role by interacting with the model and having the possibility to draw own conclusions from the presented information. Something to take into consideration is how or if the level of probability or uncertainty shall be expressed in a visualization of the past. Connecting a hypothesis with a scale of its reliability, for example defining it as high, medium or low reliability is one way. Color coding can be used, letting different colors represent different levels of reliability of a feature. A way of indicating uncertainty can also be to use line drawings, black and white images, or watercolor images instead of photorealistic material (Pletinckx 2012:217 ff.).

3.3 Holsted Overmark

A visualization of the excavated Viking Age house from Holsted Overmark in Denmark was modeled in 3D as a part of an exhibition at the Sønderskov Museum. The project was intended for public communication, with a focus both on the original appearance of the house and a presentation of how technology can be used in museums. Using the plan of postholes measured during the excavation as starting point, the appearance of the archaeological remains indicated that the house was constructed according to "the circumscribed ship principle", where the house walls have the shape of a ship if drawn as two semicircles. Starting out from this idea, the architecture of the virtual model was constructed (Larsen 2007).

The modeling work in this case proved to be useful also from a research point of view, even though that was not the initial intention. When building the particular features of the hall in 3D, new insights were gained regarding how to interpret the archaeology and past construction of the house. A suggestion made in the field about two features being postholes from roof-bearing posts had to be reconsidered during the 3D-modeling work, since the dimensions of the hall did not support the hypothesis. The process also evoked a discussion about the symmetry of the building. Modeling the Holsted Overmark hall using the drawn plan as starting point and taking into account the actual positions of the postholes, seemed to indicate a construction with some skewed and asymmetrical lines (Larsen 2007).

At the Sønderskov Museum website an animations can be viewed visualizing the 3D model in different ways. One of the animations shows the 3D construction of the building step by step, starting out from the excavation plan drawing, visualizing the idea of the circumscribed ship principle, putting out the roof-bearing posts over the post-holes, followed by the wall posts, relating them to the post-holes, the walls, interior and roof (fig. 3). Another example of this form of presentation is made by the Norwegian company Arkikon, specializing in the communication of cultural-historical content. This animation uses text, excavation plan and 3D animation to explain and visualize the construction of a three nave building (Arkikon website). The principle of the presentations is thus the same as in the case of the Ename Saint Saviour church discussed above, aiming to make the connection between documented archaeological data and 3D model understandable.

Figure 3: Images from a 3D animation directed to the general public, aiming to show the connection between excavated postholes and roof-bearing posts of the Holsted Overmark house (Museet på Sønderskov website).

Holsted Overmark is a concrete example of the potentials of using 3D modeling in archaeological research. However, what can be noted about the animation presented at the Sønderskov museum website, is that the houses are presented with fairly straight walls, without emphasizing the non-straightness of the walls in the models. Another possibility of presenting the construction process could have been to let the viewer be exposed to the ambiguity regarding how to interpret the structure having these results. This choice would have made the public more involved in the actual issues raised by the researchers during this investigation.

The case examples presented above served as inspiration during the case study presented in the following section.

4 Case study

4.1 Presentation of the experiment

During the excavation of a Neolithic grave at the archaeological site of Uppåkra in 2011, a documentation experiment was performed with dense stereo matching techniques, resulting in a number of 3D models depicting the excavation surface in different stages of the process (fig. 4). The application of this methodology proved to be easy to integrate with the daily work of the archeologists and provided a valuable source of data for interpretation, archival and integration of acquired material (Callieri *et. al.* 2011). By having the opportunity to use this 3D material, I was able to develop a case study where I combined the 3D geometry acquired during the fieldwork, with 3D models created in the modeling software Blender, building hypotheses of the past appearance of this site based on the 3D models generated during the investigation process.
The purpose of this work was to investigate and discuss possible ways of further developing the 3D documentation methodology, by including an additional element of interpretation through the use of 3D modeling techniques in the routines of the archaeological fieldwork. The result was a basis for a final discussion on how this could be beneficial, from a public communication perspective as well as a research perspective.

Figure 4: Archaeological excavation of the Neolithic grave in Uppåkra 2011 (left). 3D model of the same trench acquired through Computer Vision techniques (right) (Photo: Carolina Ask 2011).

4.2 Uppåkra archaeological site

The archaeological site of Uppåkra, located 5 kilometers south of Lund in southern Sweden, has been known since the 1930s, when excavations were made revealing cultural layers with a thickness of more than two meters (Larsson 2007:12). In 1996 the site was further investigated in a large scale metal-detector surveying campaign, resulting in almost 20 000 gold, silver and bronze finds, in an occupation zone of over 40ha. These finds suggested an Iron Age central place with a settlement sequence starting in the late part of the Pre-Roman Iron Age around 100 BC and continuing until the end of the Viking Age in 1000 AD. The metal objects found in an area just south of the Uppåkra church showed the largest technical and chronological variety, as well as very high quality craftsmanship. Excavations in this area started in 1999 and have since then been performed yearly, revealing traces of several house structures, as well as other features. From 2001 to 2005, remains were excavated of an unusually high, timbered building with a stave-wall structure (Larsson 2007:14). The building contained extraordinary objects, including the second largest find of gold foil figures, and a silver and bronze beaker deposited together with a glass bowl. These findings, the unusual construction and a continuity of the house from 200 AD to 900 AD, indicates that the building was a place for cult and ceremonies, a form of temple (Larsson 2007:21). The building was situated in the central part of the settlement, and just west of it, a complex stratigraphy of house remains has been under excavation for the last years, containing several high status objects indicating that the houses were inhabited by a social elite (Piltz Williams 2010:1).

Figure 5: Archaeology students excavating house remains in Uppåkra, watched by school children getting a guided tour (Photo: Carolina Ask 2009).

The excavations in Uppåkra are currently conducted by a number of professional archaeologists and in the form of seminar field courses for archaeology students at the Department of Archaeology and Ancient History at Lund University (Piltz Williams 2010). Investments are made each season in developing the communication of the history of Uppåkra and the results of the ongoing investigations to the public. Open guided tours are offered by science pedagogues six days a week at the site during the whole excavation season. During the autumn period, there are also pre-scheduled tours directed specifically to school children (fig. 5). The science pedagogues update a blog at the Uppåkra website a few times per week, reporting of the developments of the fieldwork, interesting finds and new results. The building of an archaeological science and visitor center at Uppåkra with ongoing excavations, exhibitions, research and education is planned to be completed in 2017 (Uppåkra website).

Ongoing research projects focusing on archaeological method development are conducted using the Uppåkra site as a case study. Geophysical prospections are performed by Ludwig Boltzmann Institute in Vienna (Ludwig Boltzmann Institute website). A project focused on the development of archaeological documentation through 3D technology started in the season of 2011 (Callieri *et. al.* 2011). The results of these projects will be discussed in the coming sections. Digital technology is also being used in the public communication of Uppåkra. An update of the current mobile application will offer a presentation of Uppåkra in 3D (Uppåkra website).

4.3 The excavation of a Neolithic grave

In the season of 2011, an area south west of the church yard in Uppåkra was excavated. The area was chosen on the basis of the results of the large-scale geophysical prospections that had been conducted on the site by Ludwig Boltzmann Institute in Vienna in 2010. The georadar and magnetometer investigation identified several anomalies. One of them was an oval round structure with a rectangular structure in the center which seemed to indicate a grave (fig. 6). In connection with the circle shaped anomaly were initially at least four burial mounds. Two of them are still visible, probably built during the Early Bronze Age or Early Iron Age (Larsson 2007:21). Excavation finds showed that the surface on which the larger of the two remaining mounds was built showed traces of a Neolithic settlement. The excavation also revealed traces of an edge of a now removed mound (Lindell 2001:6). The 2011 excavation was conducted with the aims of increasing the knowledge on graves in Uppåkra, of which there have been very few found, and to be able to evaluate the method of using geophysical prospection to detect anomalies and possible archaeology (Söderberg 2012). Excavating the area proved this hypothesis, a grave dating to the Neolithic was found.

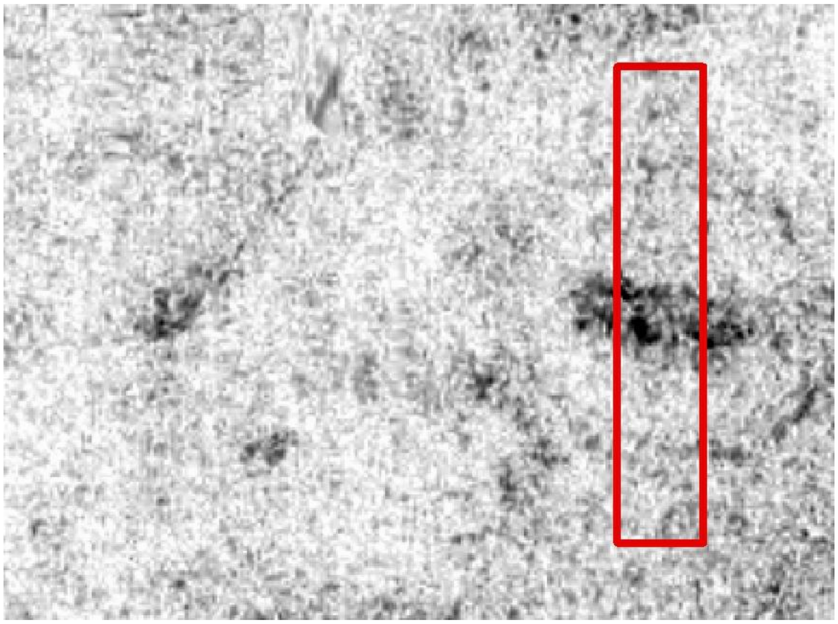


Figure 6: The anomaly discovered through geophysical investigation is visible to the right as a circle shape with a dark center. The red line marks the delimitation of the initial trench.

4.3.1 Excavation procedure

The excavation started in the beginning of may 2011. An eleven meters long and two meters wide trench was dug in a north-south direction through the center of the anomaly. After the removal of the top soil, activity layers were discovered in the south, with a hearth, a comb fragment and pottery which could be dated to Roman Iron Age. Following these layers were connected layers of stone constructions. Ditches were found in the north and south part of the trench, and some of the stone layers appeared in and on the filling layer of the ditch.

A pit was found covering the whole middle part of the trench, with filling containing sherds of pottery from the 18th to 19th century. The bottom showed a stone covered surface. At this stage it could be relatively safely determined that the anomaly represented a prehistoric grave. The central grave had a stone covered surface, and ditches in the north and south indicated that a circle/oval shaped ditch surrounded the central part, also clearly visible in the geophysical images. It was also possible to determine that the grave had been disturbed during the early modern period, when a pit had been dug down to the stone covered bottom of the grave. It was interpreted as representing a stage where the grave had been plundered (Söderberg 2012).

The trench was extended to the east and west in order to delimitate the grave chamber. The western part showed a stone packing covering the ditch. The eastern part of the new trench had the same kind of activity layer with traces of a hearth as found in the south eastern trench. A destruction layer with yellow clay and burnt daub was found directly under the topsoil and might have been a part of an oven (Söderberg 2012).

The modern plundering pit reached all the way down to the well preserved “floor” of the grave chamber, which was covered by fist-sized stones. The eastern part of the grave chamber was the only part that seemed to be untouched by plunderers. Stones covered the edge of this part of the grave. The filling also to a large part contained stones. Under this primary filling, a cranium was found (fig. 7). Teeth was also found, which led to the conclusion that at least three individuals were buried in the grave. The cranium belonged to a young adult, while the teeth belonged to at least two children of different ages (Söderberg 2012).

The ditch east of the grave contained several concentrations of stone, as well as two layers of packed stones, continuing outside of the trench in the east and south. A block of granite was found between the ditch and the eastern gable of the grave chamber. This might originally have had an upright position. A coloring of the soil next to the block might indicate its original position (Söderberg 2012).

Figure 7: The eastern part of the grave chamber is seen to the left with stones covering the edges. A cranium of a young adult was found (Photo: Carolina Ask 2011).

During the excavation of the ditch filling, a charcoal sample was collected and 14C dated, resulting in a date between 2140 and 1878 B.C, representing the late Neolithic period. There are no graves from this period with similar structure with an oval ditch around a central grave earlier found in Scania. The best parallels were found in Jutland in Denmark, ascribed to the Single Grave Culture (Söderberg 2012). The function of the ditch and its relation to the grave was complex and hard to interpret. The recent plundering pit made the investigation of the original complex complicated. The method chosen for the investigation did not allow a full examination of the ditch, which made it hard to get the full picture of the grave construction and reach a clearer understanding regarding the function of the ditch (Söderberg 2012).

4.3.2 Interpretation and division into phases

Phase 1: Cultivation? The area might have been cultivated in the earliest phase.

Phase 2: Building of the grave. A grave chamber was dug as well as a round/oval ditch around it. A layer containing mud has been interpreted as a layer with material from the digging. Apart from that, the material from the pit seems to have been transported away from the area. The bottom of the grave chamber was covered with fist-sized, well wedged stones. The eastern edge of the grave chamber was covered with larger stones, which could indicate that the other edges also were stone-covered in this stage. (fig. 7, Söderberg 2012).

Phase 3: Construction is added to the grave. The filling layer in the ditch, as well as the packed stones connected to the ditch belongs to this phase. The eastern part had a very well preserved stone collection, with an extension from the outer part of the ditch, until the modern plundering pit. Some collections of stones were present in the northern part as well. The whole or parts of the grave could initially have been covered with stones, with the block in the eastern part marking the eastern gable.

The relation between phase 2 and 3 is complex. It is hard to say how long period of time they represent. The results indicate that the grave was something of an ongoing project that changed appearance throughout these initial phases, not representing one event but several. Three individuals or more were buried in the central grave, which means they were either buried all at once or during separate events. Because of the plundering this cannot be fully determined.

Phase 4: Iron Age activities. Layers interpreted as hearths and the remains of a destroyed oven belong to this phase. In 1968, house remains dated to the Iron Age were excavated south-east of the grave, which are most probably connected to this phase.

Phase 5: Cultivation. Scattered layers are connected to this phase, which are classified as cultivation layers from medieval as well as early modern times.

Phase 6: Plundering. The grave seems to have been visible in early modern times. The plundering pit is very well fitted with the central grave. The pit contained pottery which can be dated to somewhere between the 16th and the 19th century. The person performing the plundering seemed to have had knowledge of the shape of prehistoric graves. The location of the grave close to the church makes it unlikely that this undertaking was performed without knowledge of at least the persons connected to the Uppåkra church.

4.4 Archaeological documentation and interpretation with Computer Vision techniques

During the investigation of the grave, a method for archaeological documentation was tried out alongside the conventional documentation, using Computer Vision techniques. These techniques allow you to obtain three-dimensional data starting from a series of uncalibrated pictures, taken with a standard digital camera. The aim of the experiment was to develop and test the potential of using 3D technology during and after archaeological fieldwork (Callieri *et. al.* 2011).

The acquisition process consists of taking a photo every few steps in a path around the area of interest, covering the whole surface and letting each image overlap the previous one. Turning these images into a 3D model is then done in two stages: first by using structure from motion (SFM), where the image matching and camera orientation is calculated and a point cloud is obtained, and then using dense stereo reconstruction to generate a more detailed model. There are several software able to perform this process. In this case PhotoSynth/Bundler and PMVS2 was used, having the advantage of not being based on web-service (Callieri *et. al*. 2011). Algorithms of structure from motion (SFM) are used to estimate the camera parameters associated to each image of the set. Features from each image are extracted and matched, and their corresponding position orientation in space is calculated. At the end of the process, the feature points can be associated to 3D points in space, resulting in a point cloud of a few thousand points. When this is done, algorithms for dense stereo reconstruction are applied. All the pixels of the images are employed using the estimated camera parameters, creating a denser point cloud. This point cloud can be easily transformed into a high-resolution 3D model.

The image acquisition procedure and the post processing of the correspondent 3D model were performed at the end of each day of fieldwork. The result was a collection of geo referenced 3D context of the ongoing excavation (fig. 8). After a short period of training the acquisition and the data post processing was performed by the archaeologists. Once obtained, the model was imported in MeshLab in order to be scaled and geo referenced using a grid previously realized using the Total Station. MeshLab is an open source, portable, and extensible system for the processing and editing of unstructured 3D triangular meshes (MeshLab website). This software provides tools for visualize and analyze the data. Through the use of this software the 3D model of the excavation area can be studied in plan, rotated and viewed from any chosen angle. Meshlab allows visualizing all the models previously realized in the same window, giving the opportunity for the researchers to time travel back and forth during the investigation comparing the different features and their relation in space and time. This also makes it possible to take more complex measurements *across* the different layers by using the “measuring tape” tool and switching between the time stages. Other useful visualization tools provided are the possibility of simulating different light conditions or applying shaders, thus allowing for emphasis of specific characteristics of the geometry or features that are difficult to note when the color are projected on the geometry. Features can be highlighted using the painting tools and MeshLab also allow attaching notes on the model, drawing on the surface, and creating orthoimages to integrate into any GIS system raster based (Callieri et. al. 2011).

Figure 8: 3D models acquired in different stages of the excavation process (Callieri et. al. 2011).

The experiment proved the potentialities in using these technologies during fieldwork activity. 3D documentation and visualization was useful during the interpretation of the ongoing excavation, and increased the capacity to interpret the site after the destruction of the stratigraphy. The acquisition and processing was time-effective, low cost, and possible to do directly on site. The documentation method was easy to integrate with the methods already used, and opened up new possibilities in the study of the site (Callieri et. al. 2011).

The methodology will be used in Uppåkra the coming season of 2012, to further develop the methodology of data acquisition.

4.5 Experiment with 3D visualizations

My experiment consisted in investigating possible ways of further developing the methodology described in the previous section, by developing 3D interpretations of the possible layout of the grave structure starting from the 3D geometry acquired by Computer Vision techniques. With the help of the excavation staff, I created a number of 3D models representing interpretations of the earliest phases of the grave. The function of the circular ditch and its relation to the central grave was complex and hard to interpret. For this reason the phases 2 and 3 described above, when the ditch was dug and manipulated serve as a good example to visualize and discuss.

Parts of the methodology of Interpretation management presented in chapter 2 was used as a way of systematically accounting for the sources and paradata behind the visualizations, by organizing a source database, and presenting the sources, hypotheses and visualizations in the form of source sheets and hypothesis sheets, as suggested by Pletinckx (2012:233). In my case I found it more suitable to include the source correlation and assessment stages in the hypothesis sheet. The visualizations should be seen as representing the current stage in the interpretation process concerning the grave, based mainly on source material gained during the archaeological investigation, compared with a number of additional sources. A more thorough analysis of sources and comparisons is not possible to include in this specific study, since that would require a deeper investigation, which is not the goal of this thesis. The sources presented below are the start of a discussion of possible interpretation alternatives, which might well be updated with new hypotheses following the ultimate Updating step of the Interpretation management model.

4.6 Implementing transparency and paradata through Interpretation management

Source sheet 1:

Short description:

Excavation plan of excavated grave ascribed to Single Grave Culture.

Conclusion:

Shows a grave with a stone filled ditch.

Reference:

(Hübner, 2005:1402-1405)

Description:

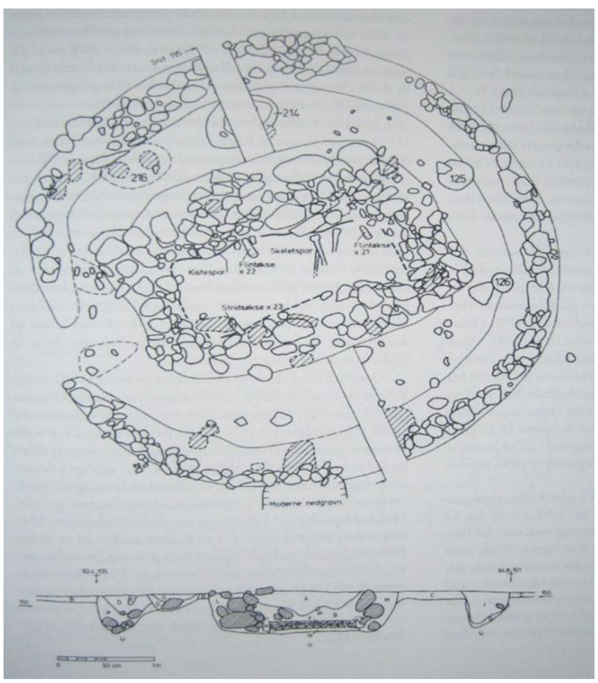


Figure 9: Plan and section showing a grave excavated in Jutland, ascribed to Single Grave Culture.

Context:

Bakkegården. Ksp. Rødding, sb 23. Ham 1787. Nm Journ. Nr. 6826/88. Jutland. Denmark.

Analysis:

Example of a parallel to the grave found in Uppåkra. It has a stone filled ditch and a central grave.

Source sheet 2:

Short description:

Excavation plan of east part of the ditch in Uppåkra.

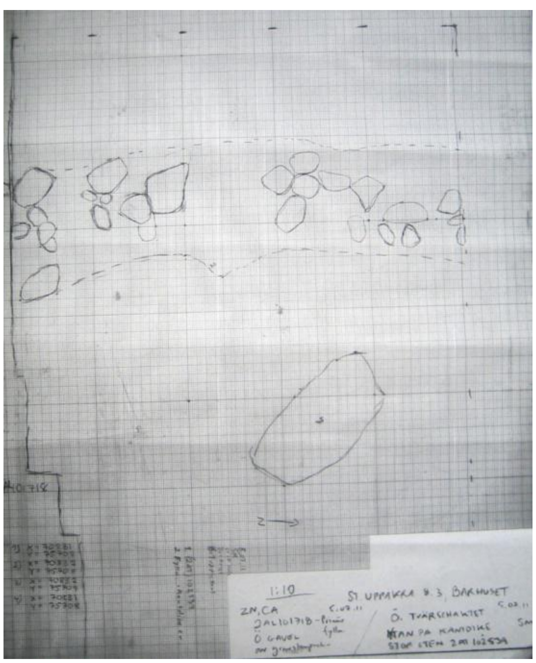
Conclusion:

Shows the position of the stones found in the eastern part of the ditch of the excavated grave in Uppåkra.

Reference:

(Söderberg 2012)

Description:



Figur 10: Drawing showing the stone filled ditch in plan. The pattern of the stones could indicate that they supported wooden posts.

Context:

Excavation season 2011.

Analysis:

The positions of the stones could indicate they were once supporting posts of a wooden structure built around the central grave.

Source sheet 3:

Short description:

Section drawing of the eastern trench wall. Uppåkra grave.

Conclusion:

The section shows the northern part of the ditch.

Reference:

(Söderberg 2012)

Description:

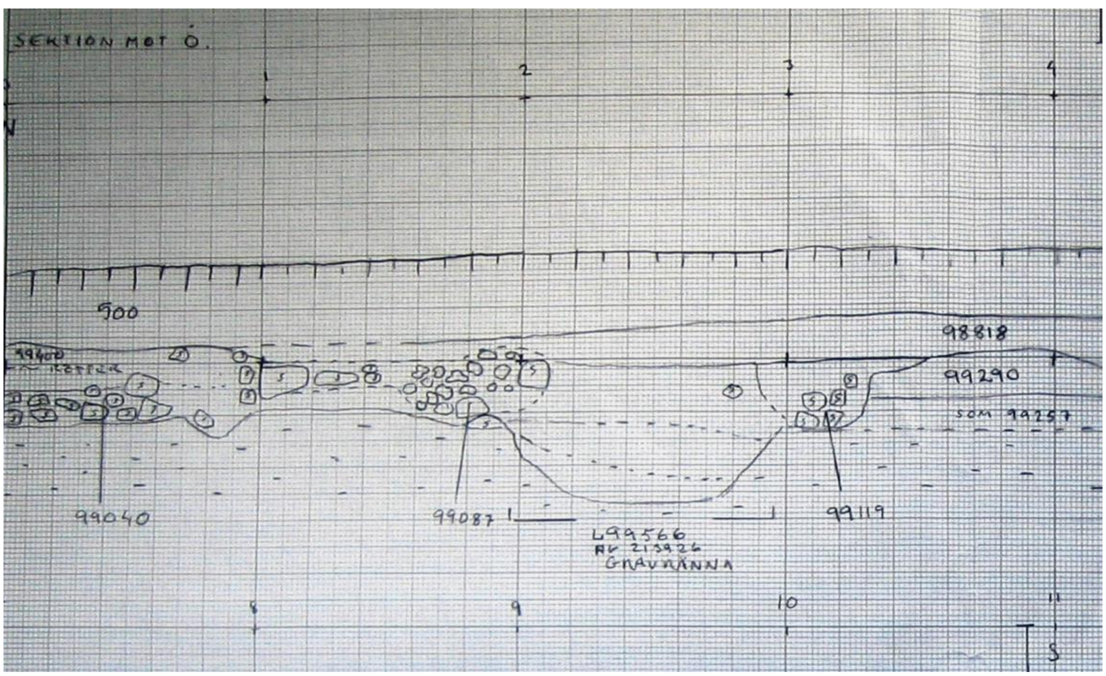


Figure 11: Section showing the ditch with a stone filled layer stretching north of the ditch itself.

Context:

St. Uppåkra sn. St. Uppåkra 8:3. 2011.

Analysis: There were layers of stones north of the ditch that were not present outside the ditch on the other sides. This might indicate a stone paving to a form of entrance.

Source sheet 4:

Short description:

Excavation plan showing a grave mound ascribed to Single Grave Culture.

Conclusion:

Shows postholes indicating that the mound once were surrounded by wooden posts cut in half.

Reference:

(Hübner, 2005:1086-1087)

Description:

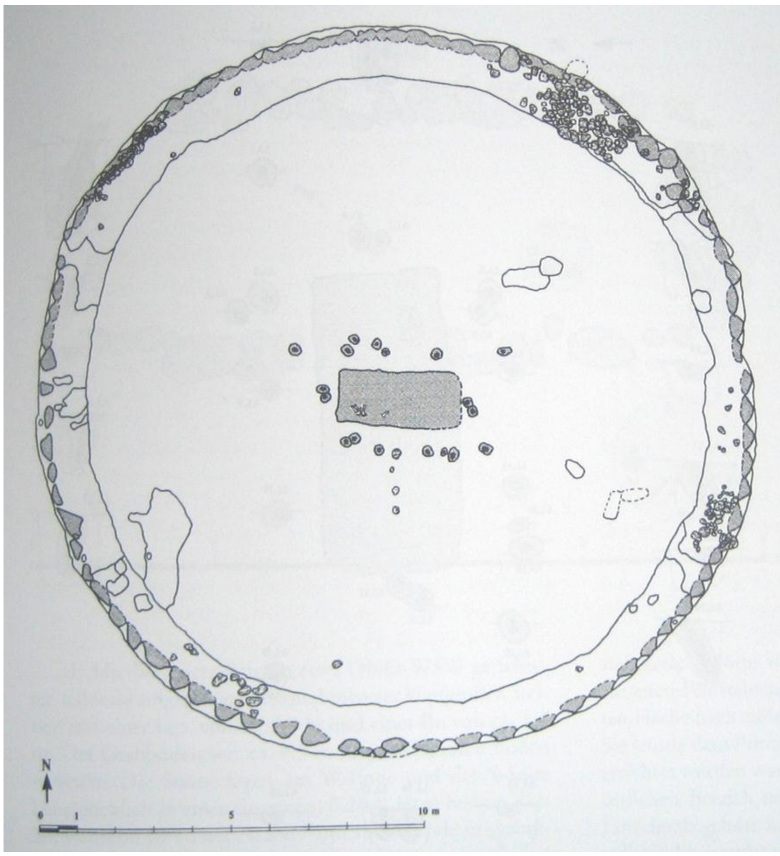


Figure 12: Excavation plan showing the central grave and a circular ditch. Along the edges of the ditch were clearly visible remains of a palisade constructed with tree trunks cut in half.

Context:

Gantrup. Ksp. Voerladegård, sb. 61. Hom 319. Jutland. Denmark.

Analysis:

The grave belongs to the Single Grave Culture on Jutland, and shows an example where the central grave and the area around it have been separated by a ditch supporting a wooden palisade.

Hypothesis sheet:

Visualization hypothesis 1:

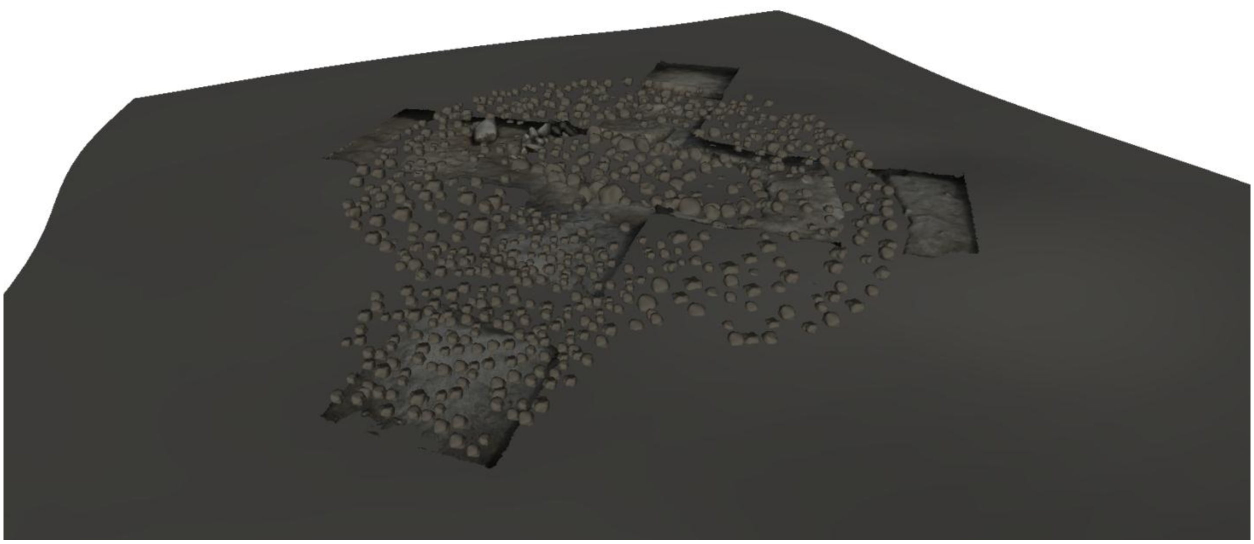


Figure 13: Hypothesis 1: The grave was marked above ground having the form of a flat stone construction. Snapshot from MeshLab.

Visualization hypothesis 2:

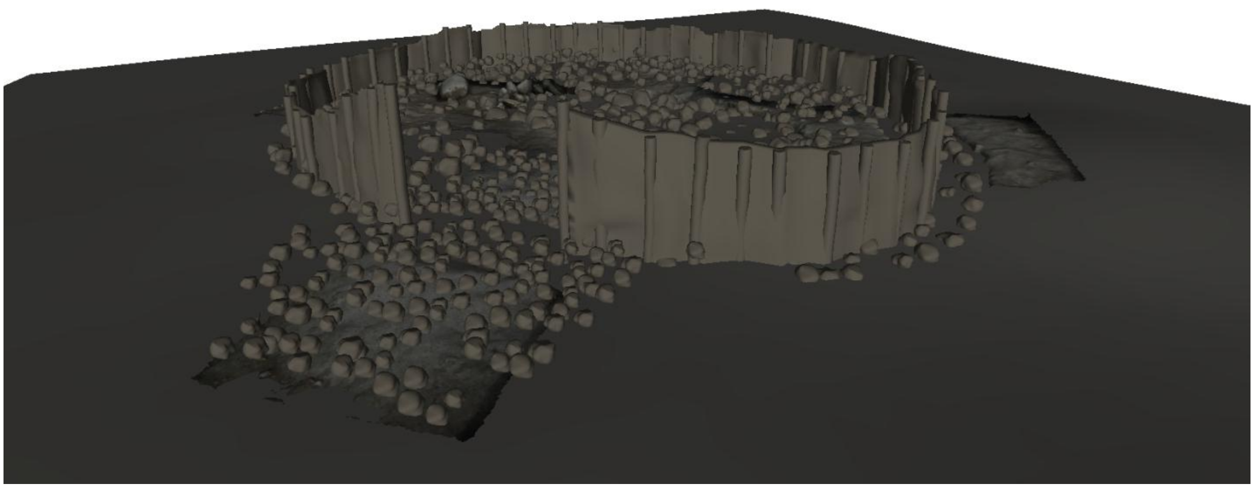


Figure 14: Hypothesis 2: The ditch and the stones in it supported a wooden fence delimiting the grave area. It had an opening in the north with a stone paved entrance. Snapshot from MeshLab.

Hypotheses:

1. The grave was marked above ground having the form of a flat stone construction.
2. The ditch around the grave chamber was dug and filled with stones to support a light wooden palisade structure around the grave chamber.
3. The grave had both these structures during different phases.

Introduction:

Hypothesis 1: The grave was visible above ground in the form of a flat stone formation. What supports this hypothesis is that stones were present all over the grave structure, especially in the ditch, which could have had the function to mark and separate the area of the grave from the area around it.

Hypothesis 2: The ditch seems to have been built in one stage. In a later stage it was filled with soil and stones. The ditch could have been dug with the purpose of supporting a wooden structure around the grave. Source sheet 4 shows an example where the ditch of an Single Grave Culture grave contained traces of a palisade structure. In the case of the Uppåkra grave however, the ditch seems too shallow for having been able to support any robust posts. Neither could archaeological traces in the form of darker soil indicating post holes be found during the excavation. Stones were found in many parts of the ditch however, especially in the eastern part. One possible hypothesis is that a lighter wooden construction was built, where the stones supported smaller wooden branches, possibly braided together. A pattern in the position of the stones in the eastern part of the ditch could possibly show positions of posts supported by the stones around them (source sheet 2).
The layers with packed stones in the north part of the trench reach outside the ditch. The stratigraphy shown in the section (source sheet 3) indicates that the ditch was covered initially with stones. This has been interpreted in the 3D model that this part was a stone paved entrance.

Hypothesis 3: Much of the excavation results indicate that the grave was rebuilt and changed in different phases, thus a kind of ongoing project. Skeletal material from at least three individuals was found, which could indicate that the grave was reused for new burials in separate stages. The ditch in the northern part seemed to have been re-dug.

4.7 Technical procedure

The reality of most archaeological excavations, with limited resources and a tight schedule, requires a consideration of how to integrate the 3D modeling procedure as smoothly and time effective as possible. The software used, Blender and MeshLab, are both open-source cost-free alternatives to similar, often expensive programs. The process of creating and presenting the visual interpretations, are presented below.

4.7.1 Blender

Blender is an open-source software for 3D modeling, animation and rendering (Blender website). The use of this informatics instrument allows building complex models in 3D. In this case study, the three-dimensional geometry representing the excavation surface was imported into Blender, and used as starting point in the modeling process. Geometry was then constructed starting from the previously imported models in order to build the different 3D interpretations (fig. 15).

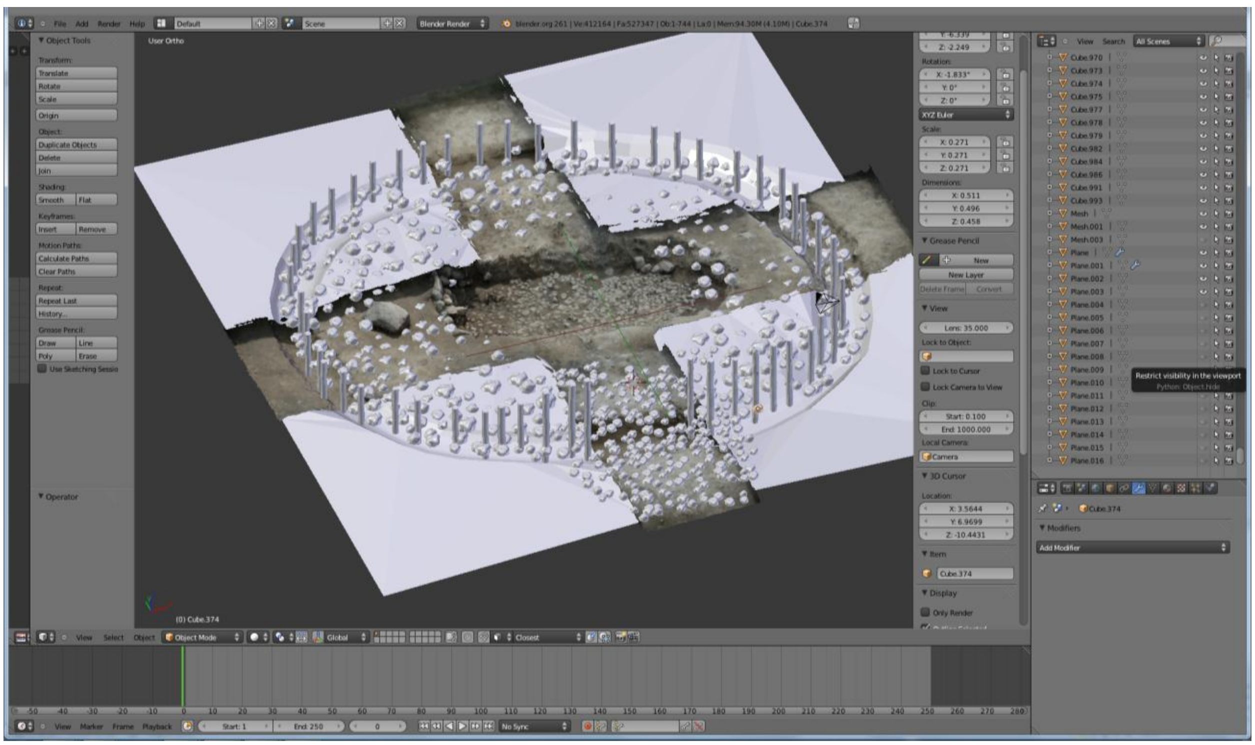


Figure 15: 3D model acquired by Computer Vision imported into Blender. The edges of the original model were removed, to be able to model interpreted elements of the first phases of the grave. A"snap tool" in Blender lets you connect the imported 3D model with the geometry modeled in the software.

4.7.2 MeshLab

The three dimensional geometry created in Blender was imported into MeshLab. The interface of MeshLab allows organizing the geometry in layers, where the visualization of a specific feature can be switched on and off (fig. 16-19). The interface of MeshLab can thus be used to show the 3D models to the public in order to increase the knowledge of how an archaeological context is investigated and interpreted.

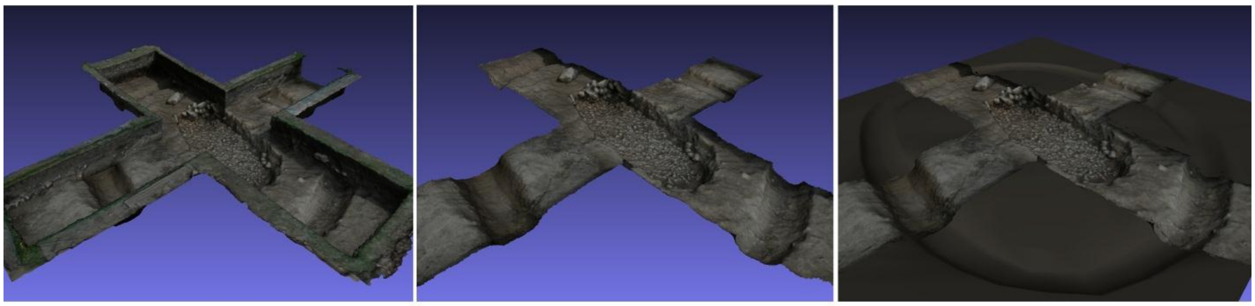


Figure 16: Layer-by-layer visualization in MeshLab. Original model acquired in the field (left). Edges have been removed from the model (middle). Parts of the ditch modeled in Blender visualizing the character of the grave in its initial phase with the round ditch (right).

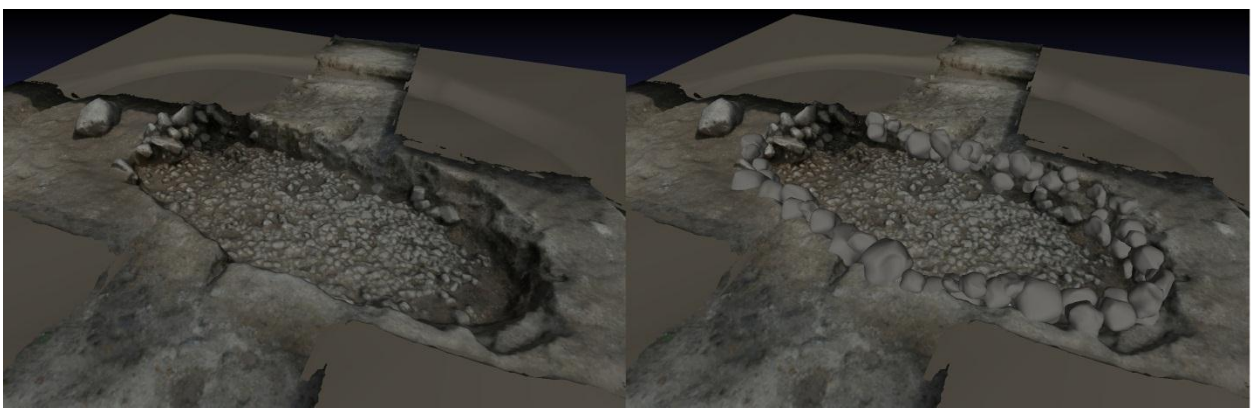


Figure 17: The eastern part of the central grave (left in the model) were interpreted as the only part containing original filling, untouched by plunderers (left). The edge is covered with stones which was probably originally covering all the edges. Modeled stones have been added around the edges of the central grave (right). A distinction in texture is made between the preserved stones and the Blender modeled interpretation, by letting the modeled stones have different color and structure. The same color tone is kept however creating a sense of a complete structure.

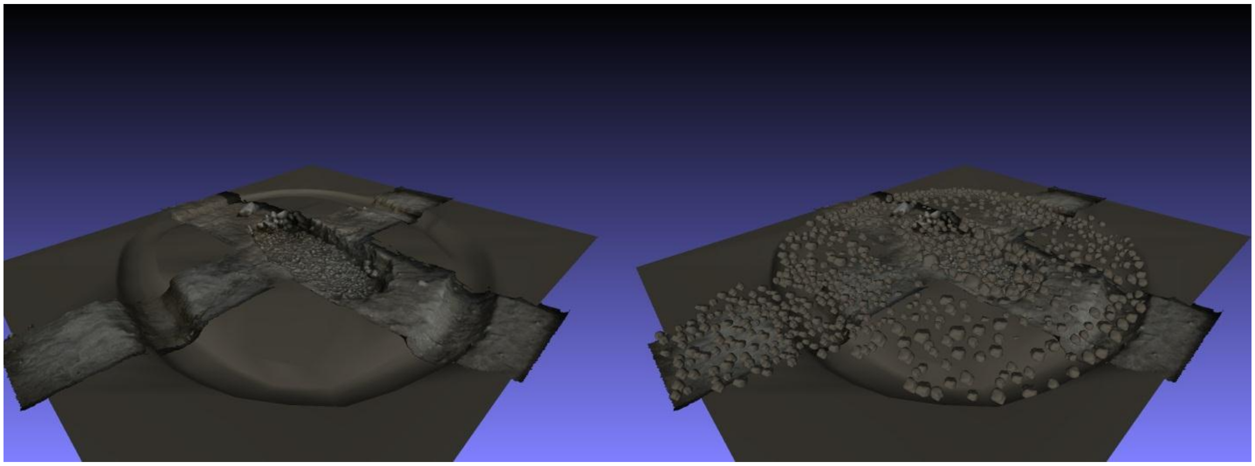


Figure 18: Visualization in MeshLab of Hypothesis 1 with the ditch (left) and layers of stones covering the area inside the ditch, the edge of the central grave as well as the inside of the central grave (right).

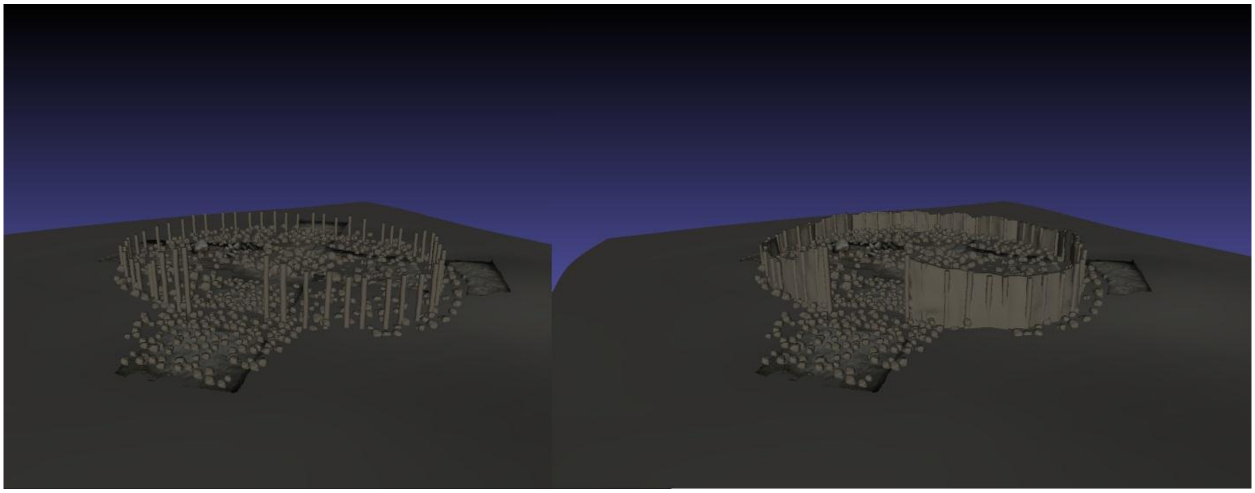


Figure 19: Visualization in MeshLab of Hypothesis 2 with different elements added in layers one by one. To the stone covered grave has been added a fence of small posts (left), and a braided wooden structure with an opening in the north, where the layers of stones, interpreted in this visualization as a pavement in connection to the entrance (right).

5 Analysis

The aim of this thesis was to discuss the use of 3D modeling techniques in an archaeological fieldwork situation in a way that could benefit both research and public communication. I investigated the questions by combining a 3D model of the excavation surface acquired through Computer Vision techniques; with 3D interpretations of how the investigated context could have appeared in the past. Together with the excavation staff, we used the 3D models realized during the excavation as a starting point for a discussion on how to visualize the initial phases of the grave, forming a number of visual interpretations. This approach proved to be very useful for the development of this work and for a deeper analysis of the site.

By using the Interpretation management methodology, a systematic way of accounting for sources, arguments and choices made when creating a 3D visualization could be established. The sources were presented one by one in the form of source sheets. Accounting for the sources through an organized system let them become footnotes to the visual argument that is the 3D model, thus a step in the interpretation process.

5.1 Integration with Computer Vision acquisition

My case study is a suggestion of how documentation through Computer Vision techniques during archaeological fieldwork could be developed to include 3D visualization in the interpretation process. The 3D visualization step can be integrated with the Computer Vision documentation, but requires basic knowledge in a 3D modeling software. During the modeling process, a visualization form was developed where emphasis was put on creating the models relatively quickly, with the aim of clearly expressing the connection between 3D excavation surface and the hypothesis.

5.2 Public presentation

The geometry representing the excavation surface was visualized with the original texture acquired in the field. I chose to separate the characteristics of the modeled features, letting it become easy for the viewer to know the difference between replica and interpretation. An argument for avoiding a fully detailed and realistic depiction of the past is that there is a risk of undermining the imagination and interpretational skills of the viewer, not encouraging the ability to bridge the archaeological data and the vision of what the past was like (Kantner 2000). To leave the visualization open, clearly communicating that the image does not aim to present a complete past reality, but to provide the viewer with some additional visual information regarding the past appearance of the site, let some elements be open for further interpretation or added later.

In a situation where these data are presented to the public, the paradata have to be communicated in connection with the presentation of the models, in order to make the audience understand the interpretation process. In the context of Uppåkra, the visualization could be presented to visitors by the science pedagogue. In a situation where there are no pedagogues to explain the site, a version with a movie could be made where the work in Meshlab could be digitally recorded, and presented to the public in combination with speech or text. An element of interactivity would also be possible to include in the presentation, since MeshLab's way of turning the model is through a simple click and drag of the computer mouse.

My case study started out from an already finished excavation. However, this method might as well be done as a part of the excavation, and as an extended part of the post-processing of the Computer Vision 3D documentation. Thereby an argument is visualized immediately and the visitor can follow the development of the excavation and better understand how features can be related to past structures.

6 Discussion and Conclusion

An archaeological excavation is a dynamic situation where different operations are performed simultaneously, and new knowledge about the past is formed step by step. I have discussed and argued for different ways of inviting an audience of non-archaeologists to follow this process, by using visual digital media.

By using the terms *visualization* and *model*, instead of *reconstruction,* a different approach to the creation of images representing the past is used as well as communicated. Baker describes the distinction between the two concepts as subtle but important both for the creator and the audience. It means moving away from the idea of recreating an object "accurately", towards a *process* of visualization, which is rather the creation of a visual research narrative and a visual argument for a hypothesis, while accepting the inescapability of human interpretation (Baker 2012:164). McCarty argues for letting computational models be understood rather as "*temporary states in a process of coming to know"*, than representing fixed knowledge (McCarty in Bentkowska-Kafel 2012:248).

In an excavation situation, this process of coming to know typically involves the discussion of multiple hypotheses. The realistic renderings obtainable with 3D modeling, has been criticized for being deceptive, expressing the one closed "truth" about the past. With 3D modeling multiple hypotheses can be expressed visually, as exemplified in the case study. A person visiting the excavation could thus find it easier to become involved in a discussion about the site investigation, precisely through using the directness that is the power of the image to its advantage, as a tool to explain something complex, which could be overwhelming for a non-archaeologist to grasp if explained only in words. Letting the public follow the interpretation process in this way, instead of hiding the ambiguity inherent in the archaeological process, could enrich the experience for a visitor of an archaeological excavation. Beard argues for this approach from her experience of writing about history for a wider audience. Her impression is that readers prefer when the author shares her uncertainties instead of trying to impose a "truth" on the reader (Beard in Bentkowska-Kafel 2012:246).

Concretizing a hypothesis by letting it take visual form, gives the possibility to scrutinize it further and testing the reliability. 3D modeling has the potential to benefit also the archaeological research. This is a less explored field than its use in public communication, but the examples and arguments presented in this work show that there are advantages in using 3D visualization also in a research situation. To integrate 3D modeling in archaeological research with the purpose of creating a new dimension in the understanding of the archaeological context can result in new inspiration or in new ideas to bring back when continuing the excavation process. However, an archaeological excavation is usually under a lot of time pressure and with a limited budget, which means that the implementation of an additional step in the fieldwork process must be integrated in the workflow as smooth as possible. The integration of 3D modeling activities during the excavation process from a research perspective would demand extra resources, not always available. At a place like Uppåkra however, where specific resources are spent on communication to the general public, an opportunity opens up for experimenting with new approaches where communication and research are performed as a more integrated activity. A situation where the archaeologists gather to discuss and transform their thoughts into 3D geometry for public visualization have the potential to result in a deeper understanding of the area under investigation, thus benefiting also the field of research.

It is clear that there is a need of systemizing the documentation to make visualizations of the past become fully accepted as important scientific contributions to both research and communication. The principles expressed in the London Charter aim to set standards when it comes to making the sources and reasoning behind visualizations of the past transparent, through the documentation of paradata. This makes the visual creation reach a complexity and substance to be compared with a narrative in traditional print form (Baker 2012:164). Applying the method of Interpretation management in the 3D visualization process builds up a database of systematically arranged sources, presentation of paradata and hypotheses. In a context where this method is implemented during the work process, the database grows in a way that allow sources to be re-used when a similar feature is built in 3D, increasing the ability to create additional 3D interpretations. Building an organized database of sources facilitates the uploading and updating of the 3D models every time a new source is found. The 3D visualization should be seen as an object to be updated, as a part of an ongoing research project.

Resources spent in communicating with a wider audience about archaeological contents are investments in the cultural growth of the community. New and more efficient communication systems can increase the involvement of a wider community, having them understand what kind of knowledge can be gained by excavating. The meeting between the archaeologist and visitor of an archaeological excavation is a platform where a dialogue can be created, regarding knowledge about the past and the importance of cultural heritage. This strengthens the role of archaeology in society. I see big potentialities in using virtual tools as instruments for helping and inspiring the researchers in the interpretation process, as well as a way of giving the public the chance of understanding archaeological methods, thus have a more active role in the research process.

7 Summary

This thesis aimed to work with digital technology on the border between science and public communication. The goal was to investigate the possibilities of using 3D modeling to communicate the ongoing research process of field archaeology, and focus on the concept of 3D modeling techniques from a research perspective. A key concept in the discussion of using 3D visualizations in cultural heritage in a sustainable way is *transparency*. If 3D visualization is to be used as a methodology, it must be easy for the users to understand and evaluate the processes and outcomes of computer based visualization. Paradata is a concept that describes a record of the subjective discussions and decisions made that led to a certain visualization. If transparency pervades the use of computer based visualizations, virtual reality can be used in a sustainable way both in research and public communication. The terms visualization and model was used instead of reconstruction throughout the thesis. The reconstruction concept infers that something is being recreated just as it was, when it is in fact impossible to rebuild a replica of a past structure. Instead an argument was developed for the use of the term visualization or model, as these concepts are better suited for what is produced, emphasizing the interpretation dimension, and the possibility of multiple solutions.

The purpose of this work was to investigate and discuss possible ways of further developing 3D documentation methodology through Computer Vision techniques, by including an additional element of interpretation through the use of 3D modeling in the routines of the archaeological fieldwork. During the excavation of a Neolithic grave at the archaeological site of Uppåkra in 2011, a documentation experiment was performed with Computer Vision techniques, resulting in a number of 3D models depicting the excavation surface in different stages of the process. As this documentation methodology proved to have many advantages beneficial for archaeological fieldwork, my case study consisted in investigating an additional step, where this 3D data was combined with 3D models created in the modeling software Blender, where hypotheses of the past appearance of this site were visualized. The result was a number of 3D visualizations representing multiple hypotheses of the layout of the site in the past, emphasizing visually the connection between archaeological feature and interpretation. The virtual environment could thus be used as a visual research platform, where both the archaeological data and hypothetical interpretations could be critically investigated. This approach produced a visualization of the archaeological reasoning, that the public can take part of in a presentation situation, thus letting the public be involved in the process where archaeological knowledge is gained.

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9.2 Online sources

Arkikon
http://www.arkikon.no/

Blender. The free open source 3D content creation suite.
http://www.blender.org/

Ename 974
http://www.ename974.org

London Charter for the computer-based visualization of cultural heritage.
www.londoncharter.org

Ludwig Boltzmann Institute. Archaeological Prospection and Virtual Archaeology.
http://archpro.lbg.ac.at/birka-and-uppakra-%E2%80%93-iron-and-viking-age-rural-and-early-urban-landscapes

MeshLab. An open source, portable, and extensible system for the processing and editing of unstructured 3D triangular meshes.
http://meshlab.sourceforge.net/

Museet på Sønderskov
3D animations of the Holsted Overmark Viking Age house
http://www.sonderskov.dk/3D_animationer.aspx?ID=161

Uppåkra
www.uppakra.se