It’s unbelievable, feels like you’re diving:

– Potential benefits of Virtual Reality for documentation and analysis in underwater archaeology

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Reading guide

This master’s thesis is in the form of an article with several appendices.

The main article has the following content:

1. Abstract
2. Introduction
3. Background & Related work
4. Method
5. Results
6. Discussion
7. Conclusions
8. References

The following appendices with more in depth details and background material are also included:

- More in depth material which did not fit in the article
  - Appendix: Background & Related work
  - Appendix: Process
  - Appendix: Results
    The results appendix includes questions answers and notes from the workshop plus thematic analysis of the gathered information.

- Reference material.
  Note, the interviews are in field note format and include the questions, the answers and in some cases other notes by the author.
  - Appendix: Interview with Brendan Foley
  - Appendix: Interview with Kristin Ilves
  - Appendix: Interview with Niklas Eriksson
  - Appendix: Interview with Riikka Tevali
  - Appendix: Interview with Senior forensic technician, National Forensics Centre
  - Appendix, Interview with Veronica Palm
  - Appendix: Accessing the Deep (Information about the workshop Accessing the Deep)
It’s unbelievable, feels like you’re diving:
Potential benefits of Virtual Reality for documentation and analysis in underwater archaeology

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ABSTRACT
This study examined questions around the scientific validity of using digital 3D models in underwater archaeology and the potential benefits of using virtual reality (VR) as a way of working with said models for documentation and analysis. A workshop with underwater archaeologists at the Swedish National Maritime and Transport Museums was conducted and the results indicate that depending on the research question being examined, there can indeed be validity in using digital 3D models, even if they are at a somewhat lower resolution. The results furthermore indicate that VR might give a better spatial understanding and overview of a site and provide a more familiar and intuitive interface for the archaeologists when working with the digital models. Several design openings were also identified and design suggestions for features in a potential VR tool were created.

INTRODUCTION
In 2015 UNESCO included cultural heritage, the protection of it and the research around it, in their sustainable development goals (UNESCO, 2015). In their online material, they specifically acknowledge the importance of maritime and underwater archaeology by stating “The Oceans are the Past and the Future of Human Life” (‘Underwater Archaeology, UNESCO’, 2017, Highlight).

Shipwrecks have long intrigued people (Adams, 2013), the fact that they are underwater in a world most people have no access to, makes them kind of mysterious and hidden. Most people can only glimpse snippets of these mystical places through salvaged items, photos or perhaps video recordings. However, photos and videos which actually give a good view of a sunken artefact are rare. Due to the often poor underwater visibility where these wrecks are located, even trained eyes may struggle to make sense of what is being shown.

However, with methods and technologies like Photogrammetry and Multibeam and Sidescan sonar, becoming more mature and accessible in recent years, digital 3D models can now be made of shipwrecks and provide us with much clearer views of these sunken objects and sites.

Furthermore, with Photogrammetry and software such as Agisoft Photoscan (‘Agisoft Photoscan’, n.d.) which generates digital 3D models by analysing large numbers of photos of an object, becoming more accessible and no longer being something only specialised experts with highly expensive equipment can do, an influx of digital 3D models of shipwrecks from around the globe has been seen (McCarthy, Benjamin, Winton, & van Duivenvoorde, 2019). This has led to the maritime archaeology community now being at a stage, where the initial excitement over the fact that these things can be done, is subsiding and the questions turn to, what should, and can these digital 3D models be used for? Can they even perhaps be used for actual documentation and analysis? And if so, how should one best view and interact with them? This is for example shown in the statement by McCarthy et al. in their recently published chapter “There will always be a need for research into technical improvements in 3D survey techniques but research into new analytical techniques founded upon these 3D survey datasets is just beginning.” (McCarthy et al., 2019).

As an attempt to start answering some of these questions, the following research questions have been selected for this study:

- Are the digital 3D models that can be created by most underwater archaeologist without highly specialised knowledge and equipment, detailed enough, to be of archaeological value?
• What potential benefits might Virtual Reality add to documentation and analysis in underwater archaeology?
• Design openings: What features might be beneficial in a basic VR tool for underwater archaeologists?

BACKGROUND & RELATED WORK

Accessing sunken or flooded archaeological sites is often problematic and demanding. Low visibility, cold water and nitrogen narcosis from breathing compressed air at depth, are just some of the challenges facing the underwater archaeologists.

Historically, written records, photos, videos and sketches have been used as documentation. However, just as with accessing the sites themselves, there are challenges around these methods. For example, photos and video are highly affected by the visibility in the water on the day they are taken. Another potential issue with methods like these is that they are rather subjective (Drap, 2012), viewers of the documentation do not have any control and can only view or read what the person who initially performed the documentation included. This can be frustrating if the focus of the researcher who created the documentation does not align with that of the later viewer, as some things might not have been included or glanced over (Al, 2019; Tevali, 2019). These problems will most likely only be amplified in the future as sunken shipwrecks are found at greater and greater depths and archaeologists increasingly have to rely on remote operated vehicles (ROVs) or hired specialised deep divers, for documentation (Tevali, 2019).

However, as mentioned in the introduction, the creation and use of digital 3D models have over recent years become more prevalent in maritime archaeology and the use of such models can now potentially be used as a complimentary documentation method to counteract some of these challenges. Still, there are potential issues to overcome also with this method. One problem being, that when using a 2D screen to view 3D data, as is the most common way today, much information is lost (Ebert et al., 2014) and hence a better way to view these models is needed. The concept of using Virtual Reality (VR) in the field of maritime and underwater archaeology is not new but previous studies have mainly focused on public outreach, education, tourism, technical feasibility and data gathering (Bruno et al., 2016, 2017; Chapman et al., 2006; Liarokapis et al., 2017; Rowland & Hyttinen, 2017; Sundén, Lundgren, & Ynnerman, 2017), rather than the potential benefits of VR for documentation and analysis.

Having searched ResearchGate, Google Scholar and the electronic catalogue available through the university library for various constellations of the terms “Virtual Reality”, “VR”, “Immersive visualization”, “maritime archaeology”, “marine archaeology” and “underwater archaeology”, no previous work specifically regarding the potential benefits of using digital 3D models with VR for documentation and analysis in underwater archaeology was found. Hence, research in other fields, where this technology has been studied was mainly examined and used. The related fields identified were; Terrestrial (land) archaeology, Forensic science and Architecture. Research in the field of immersive visualisations and VR is also taken into consideration when looking at the effect of immersion and presence in a VR experience (Slater & Wilbur, 1997).

Research in these related fields has shown that VR can be an effective way of viewing and working with 3D data. Not only does it provide the possibility of working with digital assets at scale 1:1 (Angulo, 2015) but it also provides a better understanding of scale and spatial information (Angulo, 2015; Ebert
et al., 2014; Landeschi, 2018; Milovanovic, Moreau, Siret, & Miguet, 2017; Portman, Natapov, & Fisher-Gewirtzman, 2015).

From a critical point of view, Portman et al., however, raise the question of “How real must real be?” (p3, 2015), they go on to discuss how realistic and detailed a VR experience needs to be, to be of value. This is also a question, currently fervently debated in both terrestrial and maritime archaeology, and was one of the big discussion points at the international workshop Accessing the deep, in Helsinki, Finland 26-27th Feb 2019, which focused specifically on the use of digital 3D models in maritime archaeology. The participants were clearly divided and no consensus was found. This chasm was further seen in the interviews for this study and rather widely varying opinions on the topic were noted (Foley, 2019; Ilves, 2019).

METHOD

As this study was done in a field with a relatively low number of practitioners on a topic where no to little previous research has been done, an empirical qualitative method was used and an exploratory research style was chosen. The literature review was done mainly on related or similar fields where the use VR has been studied, the fields used were; terrestrial archaeology, architecture and forensic science. The majority of the data was gathered through semi-structured interviews and a workshop with a focus group.

The process used for the study was inspired by the Double Diamond design process model (Tschimmel, 2012), where there are four stages of divergence and convergence, Discover, Define, Develop and Deliver.

The first phase; Discover, which aims to get a broad understanding of the subject matter, included a literature review and six one-hour-long semi-structured interviews with six experts (Appendix: Interview with Brendan Foley, 2019; Appendix: Interview with Kristin Ilves, 2019; Appendix: Interview with Niklas Eriksson, 2019; Appendix: Interview with Riikka Tevali, 2019; Appendix: Interview with Senior forensic technician, National Forensics Centre, 2019; Appendix, Interview with Veronica Palm, 2019). It further included participation in a number of events around the topic of maritime archaeology, including; Accessing the deep, Helsinki, Finland, Feb 2019, which focused around the use of digital 3D models in maritime archaeology and two separate seminars on the general topic of Maritime archaeology, Vrakprat, Sept 2018 and The MAS Konferens, Apr 2019, at the Maritime Museum in Stockholm, Sweden.
The information gathered was then analysed using thematic analysis in the second phase (Define), and the study converged into the definition and formulation of the research questions and design openings to focus on. The third phase; Develop, diverged again going wide to explore various ideas and developing ways of answering the research questions.

The two main activities of this phase were, firstly; a semi-structured interview session with an experienced maritime archaeologist regarding the potential use and benefits of VR in underwater archaeology which also included a discussion around the idea of a workshop to explore these questions further.

Secondly, that workshop was realised and held at the Swedish National Maritime and Transport Museums (SMTM) in Stockholm Sweden, which is a public agency under the Swedish Ministry of Culture. The participants of the workshop included 5 of their staff, whereof all were qualified archaeologists and 4 were specialised maritime and underwater archaeologists.

Practically, the workshop was split into individual sessions with semi-structured interviews and a practical part. In the practical part, the participant got to first view and interact with a model of the shipwreck.
Bodekull (also known as The Dalarö Wreck) (‘The Dalarö wreck/ Bodekull part 2, 3D model’, n.d.) via keyboard, mouse and a flat 2D computer screen. They then got to view and interact with the same model via VR. While interacting with the model in VR, the participants were asked questions regarding the differences between the two interaction modes and they were also encouraged to “Think out loud” (‘Think Aloud Testing | Usability Body of Knowledge’, n.d.). To minimise the technical setup but yet have comparable environments, the web-based Sketchfab platform was used (‘Sketchfab platform’, n.d.). The Sketchfab platform makes available interfaces both for viewing a model in 2D full screen via a web browser (see Figure 3) and in VR via a WebVR interface (see Figure 4). In the Sketchfab environment, the models are displayed against a neutral grey background and basic but comparable interaction controls, for zoom and movement, are available in both modes.

In the fourth and final phase; Delivery, the information gained from the interview and workshop during the third phase was analysed and answers to the research questions together with design openings and initial design ideas were formulated.

RESULTS

The conducted interviews show that maritime archaeology is a very diverse field, even to the extent where some of its’ own practitioners, raised questions around the validity of it being its own field. As put by one of the interviewees, -Maritime archaeology is somewhat odd, why is there even a field called maritime archaeology? Archaeologists who work in mountainous areas don’t go around and call themselves Mountain Archaeologists…

Large multiplicity is also found in the areas of research within the field, where some researchers focus on specific details around ship construction and the tools that were used, others might look at how ships and coastal settlements influenced societies and the daily life of their citizens. Further signs of this diversity are also evident when discussing questions like reconstruction or how to depict shipwrecks. Some maritime archaeologists prefer looking only at the raw photos or scans to draw their own, uninfluenced conclusions, whereas others, might prefer seeing the interpretations of others before making their own deductions.

How detailed do the models need to be

Hence perhaps it is not so surprising that the opinions vary widely among the interviewees on the topic of how detailed the digital 3D models need to be, to be of scientific value. Some researchers like B.Foley (personal communication, April 2019) feel that the level of detail and the precision must be extremely high to be classed as scientific, where K.Ilves (personal communication, March 2019) feels that even rather rough models can be very useful.

Out of the archaeologists interviewed, the clear majority expressed opinions equating to, that the level of detail needed in the models, was directly related to the research questions being studied.

Viewing model on a 2D screen versus in VR

For the data in Table 1, some grouping has been done where two or several things mentioned were very similar to another. Furthermore, although, the item about it feeling real and being there, could possibly be grouped with the one about it being more natural and like what underwater archaeologists are used to, they were kept separate as they were mentioned in separate contexts and at separate times.
Regarding the statement; Seeing and experiencing shapes better, one participant said that seeing and experiencing the shape of the bow of the wreck in VR, was totally different than seeing it on a screen and that you just did not get the same experience via a screen.

<table>
<thead>
<tr>
<th>Differences mentioned by participants</th>
<th>Number of participants who mentioned it</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feels like you are diving / Feels like being there / Feels real</td>
<td>5</td>
</tr>
<tr>
<td>Better overview / better field of view / better perspective</td>
<td>4</td>
</tr>
<tr>
<td>Better feeling for scale</td>
<td>2</td>
</tr>
<tr>
<td>More natural and like how underwater archaeologists are used to working</td>
<td>2</td>
</tr>
<tr>
<td>Gives a better connection to the ship, feels more real and you really feel that it sailed once</td>
<td>1</td>
</tr>
<tr>
<td>You see things which you might not think to look for on the flat screen</td>
<td>1</td>
</tr>
<tr>
<td>Less risk of erroneous measurements</td>
<td>1</td>
</tr>
<tr>
<td>Seeing and experiencing shapes better</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1. Differences between viewing the model in VR compared to on a flat screen, reported by participants.

Regarding the statement; “Less risk of erroneous measurements”, one participant told of having measured something in a 3d model of a shipwreck in the 3D spatial data software Agisoft Photoscan (‘Agisoft Photoscan’, n.d.), using a mouse, a keyboard and a flat-screen. Without realising, the interviewee had put one of the measurement points too far back on the Z-axis, resulting in an obviously erroneous result. The participant told of having retried several times before finally trying to rotate then model and then realising the mistake. The participant reasoned, they only discovered the problem as they had physically visited the wreck and knew that the measurement reported by the software could not be correct. They further reasoned that this mistake would not likely have been made in a VR environment(VE) as you there have a better sense of depth and position.

However, when discussing the potential problems of taking measurements in Agisoft with another participant, who had extensive experience in the IT field including the use of CAD software, they did not experience it as a problem. Though, the participant did acknowledge that measuring in 3D can be problematic if you are not experienced working in 3D environments.

Tasks being imagined done

For the data in Table 2, just as in Table 1, some grouping has been done, a statement about “taking notes”, was included in the “Observe/Document” category. Furthermore, one participant who didn’t explicitly say they could imagine taking screenshots, later asked for that specific functionality when being asked what tools they would like or need. Thereby showing a clear thought process, where they imagine using that type of functionality.

<table>
<thead>
<tr>
<th>Task mentioned</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring</td>
<td>4</td>
</tr>
<tr>
<td>Observe/Document</td>
<td>3</td>
</tr>
<tr>
<td>Analyse hull/ship constructions (thereby also giving a rough age)</td>
<td>4</td>
</tr>
<tr>
<td>Take screenshots / images</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2. Things mentioned by participants, when asked, what they could imagine using the VR setup for.

Tools an archaeologist would need

The archaeologists were asked, what feature or tool they would need or want in a VE, to make it useful from a maritime archaeology point of view. As previously some grouping has been done in Table 3, e.g. requests like “Note-taking”, has been included in “Tools for documentation”. However some items have purposefully been left separate, “Measurement tools”, could possibly have been grouped into “Tools for documentation”, however as it was specifically mentioned by such a high number of participants as a separate thing, is has been included as its own entry.
Regarding the “Tools for documentation”, different things were mentioned;

- The ability to have a predefined list of measurements to measure and record, including the ability to add more posts in that list while in the VE.
- Ability to “Take notes”, however it was also suggested that this could be in the form of voice recordings.
- The ability to save and export screenshots or take pictures of what you are seeing.
- Ability to link notes to items or areas of the model.

The majority of the participants also mentioned how using this method takes away the pressure and limitations of working underwater. However, as this is a feature of using 3D models, rather than a difference between viewing a model in VR and on a flat-screen it was not included.

Although the questions focused on VR from a documentation and analysis perspective, it was mentioned by the interviewees and participants, numerous times how a large part of archaeology and any research, is to communicate the findings to the public. And how they believed that viewing these 3D models in VR would create much greater engagement and interest from the public.

## DISCUSSION

### Potential benefits using VR

The majority of the participants, expressed, that they could see things better or that they could perceive scale better when viewing the model in VR compared to on the 2D screen. This could possibly be due to the increased spatial perception and understanding which has been found when using VR in architecture (Milovanovic et al., 2017; Portman et al., 2015). However, it could also possibly be a case of information being lost when generating 2D projections from a 3D dataset (the model), and that information being available when viewing the model through VR (Ebert et al., 2014).

In the VE used for the workshop, a generic grey environment with the model of the wreck and a small portion of the seabed was used where nothing had been done to simulate an actual diving experience. As such it was somewhat surprising that all the participants with diving experience, and particularly the experience of diving the wreck being used in the test, expressed a feeling of it being quite like or a lot like real diving. Presence, or the feeling of being there, is something which has been researched.

<table>
<thead>
<tr>
<th>Tool / Ability</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale indicator/set scale</td>
<td>2</td>
</tr>
<tr>
<td>Measurement tools</td>
<td>4</td>
</tr>
<tr>
<td>Tools for documentation</td>
<td>3</td>
</tr>
<tr>
<td>Connected reference library (text, photos, video etc.)</td>
<td>2</td>
</tr>
<tr>
<td>See the photos, which were the Photogrammetry raw material the model</td>
<td>1*</td>
</tr>
<tr>
<td>Functionality for showing, what is original/raw and what has been manipulated/reconstructed</td>
<td>1*</td>
</tr>
</tbody>
</table>

Table 3. What tools or features the archaeologists would like or need in a VR experience, to make it useful from a maritime archaeologist perspective. *Included as these are things which also came up during earlier interviews outside of the experiment.
in VR for quite some time and Slater & Wilbur (1997) discuss Immersion and Presence in VEs based on a number of key concepts. Slater & Wilbur reason that Immersion is the first step towards Presence and that Immersion is dependent on four key factors; Inclusiveness, Extensiveness, Surrounding and Vividness. Inclusiveness, measures to what extent the physical reality is shut out, Extensiveness, deals with sensory modalities, Surrounding is the extent to which the VR is panoramic rather than limited to a narrow field of view (FOV) and Vivid is concerned with the resolution and quality of the display. Beyond, these four key concepts they also point to, what they call Matching, being of great importance for the immersion of the user, which relates to how well the users’ physical movements are matched in the VE.

Considering the research by Slater & Wilbur, perhaps it should not be so surprising that the participants felt a large degree of presence, most of the factor stated by Slater & Wilbur related to Immersion, were accounted for in the workshop, thanks to the use of a relatively high-end head-mounted display (HMD) (‘VIVE | VIVE Virtual Reality System’, n.d.). The HMD in question fully encloses the users’ vision, while at the same time providing a relatively high field of view (FOV) and resolution of the digital world, it is also highly responsive and matches the movements of the user in near real-time by using trackers in the HMD and in the hand controllers.

According to Slater & Wilbur, following the concept of Immersion is Presence, which is the general idea that the users feel more like being present in the VE than viewing pictures of it. However, Slater & Wilbur also state that a limiting factor on the level of Immersion or Presence is the user themselves and how they construct their internal world model and what task-contexts they are faced with.

**The importance of task-context**

Without purposefully designing the workshop for this, the setup used in the workshop might unintentionally and by a stroke of serendipity, have become a very good setup to explore the concept of task-context.

In the context of tasks to perform the participants could use the simple navigation controls (small amount of walking, “teleportation” and scaling of the model, which gave a zoom like effect), to place themselves in almost any position in the VE and get the point of view from that location. This is in fact very much like the diving experience for an experienced diver. By using a buoyancy control device and their fins, an experienced diver can move around largely effortlessly in 3D space and place themselves at any location around a wreck or site. This could be; close, far away, above or underneath (assuming there is a way of getting underneath parts of the wreck). In this way, free-swimming divers who work in an underwater environment are somewhat unique and can perhaps only be compared to astronauts who work in a weightless environment.

Hence, adding to the previously stated factors leading to a sense of Immersion and Presence, it could be speculated, that due to a high degree of similarities in the task-context, activities done by free-swimming scuba divers might be almost uniquely suited for replication in VR. This concept could furthermore be seen as supported by two of the participants in the workshop, stating that they felt the VR experience being closer to how underwater archaeologists normally work, compared to using mouse and keyboard and the 2D view of a flat computer monitor.

**Intuitive viewpoints**

Looking at this from a slightly different but yet seemingly related viewpoint, Ebert et al. (2014) state that one of the benefits of using VR when viewing 3D information, is that it allows for an intuitive choice of viewpoint. This seems to match well the concept of scuba divers being used to free 3D movement and therefore suited to a VE with a similar navigation experience. In regards to the
underwater archaeologists, if they feel using VR is more similar to the diving experience they are used to in their daily work, they might be able to use their previous knowledge in finding those intuitive viewpoints.

These things could be seen as a transient thing, which will pass once people have learnt the CAD-like computer interfaces for working with digital 3D models. However, if VR might provide a more intuitive and familiar way of working with digital 3D models, then why force people to use the less intuitive interfaces. One participant during the workshop went as far, as stating, that archaeologists are often not people with a strong technical interest, as an explanation to why some find the Agisoft software challenging. This notion also seems to be corroborated by Eriksson(2019) stating in an interview, that he was hoping the maturing of technologies like Photogrammetry and VR, would mean that there could be less focus on the technology and methods and more focus on the actual understanding of the people and the humanist side of archaeology, which he sees as the core of archaeology.

Level of detail needed in the models

The digital 3D model of Bodekull(‘The Dalarö wreck/ Bodekull part 2, 3D model’, n.d.) used for the test in the workshop, was created by one of the curators at SMTM, who although having some experience at creating digital 3D models from Photogrammetry, is not an expert in Photogrammetry or 3D modelling and has not had extensive specialised training in those subjects. The potential use and value of this type of digital 3D models were exemplified by one participant, speaking of how in the digital 3D model of Bodekull, the angle of the mast could be measured with relative ease, which is something which had not been possible before with traditional methods. The participant further told of how looking at the digital 3D model of another wreck which SMTM has created a model of, Anna Maria(‘Anna Maria’, n.d.), it had been discovered that the shape of the bow was rather special for the type of vessel it was, which was something which had not been seen before, although numerous dives had been done on the wreck and it had been documented with traditional methods.

This together with the discussions had with the participants and the discussions recorded between some of them indicates that although not the highest possible resolution or level of details, the digital 3D model can be used for analysis and as a way of documenting an underwater archaeological site. One of the participants made the statement that it is not real, it is just a representation and as such, the level of detail needed is purely determined by the research question being explored, this is a opinion which was voiced by several of the interviewees in this study.

A higher degree of details and resolution is, of course, better as it allows a model to be used for a wider range of research questions and there are things which can not be researched with these lower-resolution models as they simply lack the details. One example being, details around the tools which were used to construct the ships, as such research often includes the examination of tool marks on the timbers which are not visible in lower-resolution models.

However, when considering the creation of higher resolution models, there are several technical challenges to take into consideration and a balance must often be found. Capturing highly detailed raw data can be hard due to underwater conditions, available equipment and the skills of the person collecting the data. Furthermore, storing the datasets is often a challenge as they are very large and can require extensive IT infrastructure to store and manage in an efficient way.

The idea of the full model being of lower resolution while certain items or areas of interest, being of higher resolution, was brought up during the workshop. However, that idea is not compatible with the concept of having the models, in as high as possible resolution, to accommodate a wider range of
research questions, as only the areas of interest of the person who captured the data would be of high resolution. One potential solution to this problem is the proposed functionality of additive creation of digital 3D models over time and by separate contributors, proposed by Ilves (2019) as part of a digital wreck repository. Various contributors would therefore be able to contribute their own pieces of raw data which would get merged into the master model and over time increase its’ quality and level of detail.

**Design openings**

To answer the question regarding design openings, a thematic analysis of the needs and requests of the participating archaeologists was done using the data from the interviews and the workshop. The analysis resulted in a number of design openings and suggested features for a potential VR application for documentation and analysis in underwater archaeology.

As the main focus of this study was the potential benefits of using VR and the questions around the level of detail needed, this section is limited to the basic tools and features identified. Further work together with active underwater archaeologists would be needed to realise them fully.

**Intuitive controls**

Following the earlier discussion around task context and intuitive viewpoints. Care and effort should be taken to create, for the underwater archaeologists, intuitive controls which enhance the feeling of familiarity, presence and immersion and lets them draw from their previous knowledge and experience with diving.

To achieve this, the workflow and procedures underwater archaeologists use to perform their work should be studied together with their equipment to see what can be learnt and which concepts are suitable to be applied to the controls the archaeologists would use to control their movement and their interaction with the various tools available to them.

**Setting scale and scale indicator**

Much of both the documentation and analysis work is dependent on the scale of things, hence the user must be able to set and know the scale. Having a rough scale setting, to imitate a zoom effect is, as seen in the workshop, useful for navigation and for quickly getting an overview and then be able to zoom in on a detail. The rough setting could be done by using the buttons on a controller. For example, based on the tests in this study, the scaling up and down with the right and left side of the thumb pad on the HTC Vive hand controller, seemed to work well and the participants took to it quickly with minimal instructions. However, for taking correctly scaled measurements and images, there is also a need for the ability to set the exact scale, which might be more appropriate to do in a menu type interface.
Recordings, notes and screenshots

The ability to save the image of what they were seeing and to make notes was a requested feature by several participants in the workshop. As a comparison, the ability to take screenshots, which equates to images of what the user is seeing, is something used to great effect by the technicians at the Swedish National Forensic Centre. In their case, they often use this functionality when preparing material for investigators or court hearings (Appendix: Interview with Senior forensic technician, National Forensics Centre, 2019). For the underwater archaeologists, it would mean that they could freely create images from various vantage points and perspectives for their documentation. This, while feeling confident in that the result will be the same they are seeing in the VE, no particles in the water obstructing the view or bad lighting confusing the results. The interface should be something simple and quick to use, such as a dedicated button on the controller.

Regarding the note-taking functionality, typing longer texts in VR can often be somewhat cumbersome, however, as mentioned by one of the participants in the workshop, underwater archaeologists are used to using voice communication via radio, to describe what they are seeing and finding. Hence, it would be a natural fit, to include the ability to record their voice in the Virtual Environment (VE) as a way of documenting their explorations. An extended option to this could be to do a full recording of what the user is seeing both seeing and saying as a way of creating detailed documentation. The interface, to start and stop a recording would again need to be easy and quick to access. If the option to also record what is seen, is used, a selection of which type of recording to do, would be needed when the recording is started. A clear and noticeable indicator should be included in the users FOV, so that it is abundantly clear when a recording is being captured and which type it is.

Tools for measurements

The most requested tool from the underwater archaeologists at the workshop was the ability to take measurements. As it is speculated in this study, that the underwater archaeologists can use their previous knowledge in their use of the VR experience, the design work for this feature should be done in close collaboration with the archaeologists. The recommendation would be to do this with the help of codesign/co-creation sessions, to ensure that the tools are as intuitive to use as possible for the underwater archaeologist. However, some basic features of a measurement tool can be identified already here, based on the data from the interviews and the workshop.

The ability to measure:

- Distance, this may be the most basic however yet very useful measurement tool. It would allow for the measurement of the length and width of an intact hull or of a broken-up site. However, furthermore, it would allow for the measurements of details like the thickness of various objects. Of course it would also allow for measuring how far away from each other objects are.
- Diameter, when finding circular or tubular items like canons, grinding stones or bottles, it is an important aspect to find out the diameter, as this helps with dating and identifying the objects.
- Angles, one participant mentioned how one of the benefits of working with digital 3D models was the ability to measure the angles. The participant used the example of measuring how much a mast was inclined, as a measurement which is very hard to do with traditional methods when physically diving on a wreck but relatively easy on a digital 3D model.
Lists and reports
When discussing notetaking and measurement recordings, one participant in the workshop requested the ability to have a predefined list of measurements to record and then possibly export. There was, unfortunately, not enough time to fully discuss this at the time, hence further investigation would need to be done. If there are standardised documentation formats and reports, they should be considered and included in the tool.

The concept of a list with tasks to do or information to gather could be further expanded and could include other things than measurements. A task could, for example, be to locate and record images of a specific item or a section of the site and the data input could be an image or a recording of the object, using the recording tool as described earlier. In addition to the predefined lists, it might also be useful, to dynamically be able to add items to the list and to create new lists from within the VE.

The interface for this list functionality would need to be easy to access but also have some flexibility. One potential would be the ability to turn on and off a semi-transparent list of tasks in the users FOV in a heads up display(HUD) style of interface. The list could get more definition when the user starts interacting with it and selecting a task, would bring up prompts for the data input.

A critical discussion of the method
As maritime and underwater archaeology is a very diverse field of research, it is challenging to draw generalised conclusions based on such a small study as this.

Furthermore, as very little to none, previous research on this specific topic has been found, this study is grounded in research from other fields which is not ideal. However, those other fields are all related or otherwise strongly relevant. Furthermore, as the field of underwater archaeology is quite small and specialised, finding participants who had the time and willingness to participate in the workshop, was challenging. Hence the sample size for that part is smaller than would be ideal, however, with the profession being relatively small, with a limited number of practitioners, the number of participants was deemed a good enough representation.

The risk of affecting the results through the order of which the visualisation and interactions techniques were introduced to the participants was considered. However, the fact that the participants at the SMTM were already familiar with the digital 3D model used was deemed to negate any effect the order might have had.

Further research
This study is an initial small step in this field. With the technology around both VR and digital 3D underwater models becoming constantly more and more mature and accessible, the potential for research into how to use these technologies to best further underwater archaeology is very high.

Familiarity with the model
In the workshop for this study, the participants were primarily shown and asked to explore a wreck, well known to them, it would be interesting to investigate if using a, to the participants, unfamiliar wreck or site, affects the results.

Presenting the results
This study focused solely on the documentation and analysis part of underwater archaeology, however, many of the archaeologists contacted during this study mentioned how a large part of archaeology, is to present the results of their studies to the public. Many of them furthermore spoke
of how well, they imagined VR would be suited to show their finding to the public. For this purpose, it would be interesting to look at the concept of Exploranation, where the same data and tools the researchers are using, are adapted for public use in museums or science centres (Ynnerman, Lowgren, & Tibell, 2018).

**Collaboration**

Several of the archaeologists mentioned in interviews, that they often need to consult with others but that it sometimes can be challenging as their colleagues often are geographically dispersed. At the workshop Accessing the Deep, Helsinki Finland, the VR remote support and training system Elements (CTRL Reality Ltd., n.d.), was being shown with a shipwreck model loaded into it as a proof of concept. That system was however not built or meant for archaeology and research would be needed to fully realise the potential of such a system.

Another interesting area is the potential collaboration between users of different visualisation technologies or in groups. At one point in the workshop, an archaeologist who was waiting their turn was viewing a mirror image of what the person in the VE, was seeing and an archaeological discussion spontaneously started up regarding what could be seen on the screen and what it meant. Another interesting area is group collaborations using immersive visualisation techniques more suited to groups, like CAVE (DeFanti et al., 2009) or 360 DOME experiences.

**CONCLUSIONS**

Effectively no previous research has been found regarding the potential benefits of using digital 3D models with VR for documentation and analysis in underwater archaeology. However, the technologies around this are rapidly becoming more mature and accessible which has led to an upswing in the creation of digital 3D models of underwater archaeological sites. Hence more research is needed around how these technologies can be used to further the field of underwater archaeology.

The research questions posed in this study were:

- Are the digital 3D models that can be created by most underwater archaeologist without highly specialised knowledge and equipment, detailed enough, to be of archaeological value?
- What potential benefits might Virtual Reality add to documentation and analysis work in underwater archaeology?
- What features might be beneficial in a basic VR tool for underwater archaeologists?

The results from the data collected indicate that the level of details of the generally available digital 3D models of shipwrecks, and in ones which can be created by underwater archaeologists without having highly specialised knowledge or equipment, are sufficient to be used for a variety of research purposes. The results indicate that the level of details needed are strongly related to the research question being studied and therefore even relatively low-resolution models can be relevant and potentially valuable from a research perspective, depending on the research question.

The results further indicate that there are tangible benefits for underwater archaeologists in using VR to view and interact with digital 3D models, instead of using keyboard, mouse and a 2D screen. Using VR seems to give both a better overview and detail view, however, the potentially largest benefit, seems to be that VR might provide a way of working in a, to the underwater archaeologists, more natural and intuitive way, as many found the VR experience similar to the actual diving they are used to.
Furthermore, as part of the work in this study, the following basic features were identified as design openings for a basic VR tool for underwater archaeologists.

- Intuitive controls which enhance the feeling of familiarity for the underwater archaeologists and lets them draw from their previous knowledge and experience with diving.
- To see and set the scale of the VE.
- To take and save measurements.
- To record images, voice and video from within the VE.
- To create lists with tasks and data to collect and then export the data as reports.
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Appendix: Background & Related work

Ola Karlsson
Background

Archaeology as a science, aims to study the human cultures, their origin, development and societies, this is done through the historical traces they have left behind.

In 2015 UNESCO included cultural heritage, the protection of it and the research around it, in their sustainable development goals (UNESCO, 2015) and in their material, they specifically acknowledge the importance of maritime and underwater archaeology by stating “The Oceans are the Past and the Future of Human Life” (‘Underwater Archaeology, UNESCO’, 2017, Highlight).

Maritime archaeology, being a subdiscipline of archaeology, share the goals of archaeology as a whole but looks specifically at archaeological things related to bodies of water and waterways. This can be anything from a sunken warship from the 17th century to the remains of a stone age settlement by a lake. Underwater archaeology, which is the field this study is related to, is in itself, a subdiscipline within Maritime archaeology which studies submerged sites and artefacts.

With various high-quality underwater recording technologies becoming more and more common, a larger number of deep wrecks are found and the underwater archaeologists are finding themselves in situations where they cannot physically visit the sites due to limitations in training, equipment and sometimes laws around working conditions. They then have to hire the help of specialised deep divers or use Remote Operated Vehicles (ROVs) with both still video cameras to record the wreck (Tevali, 2019).

The use of technology to create visualisations and digital 3D models on underwater sites or artefacts is not new, however as it has with the developments over the last few years become accessible
enough, for adoption to become more mainstream (McCarthy, Benjamin, Winton, & van Duivenvoorde, 2019). Using Virtual Reality (VR) in this field is also not new but has in the past most often focused on public outreach, education, tourism and technical feasibility and data gathering methods rather than the design of and potential value of the visualisations (Bruno et al., 2016, 2017; Chapman et al., 2006; Liarokapis et al., 2017; Rowland & Hyttinen, 2017; Sundén, Lundgren, & Ynnerman, 2017). Note, that when VR is discussed in this study, it is the use of a Head Mounted Display (HMD), displaying a virtual/digital reality to its wearer.

Having searched ReaserchGate, Google Scholar and the electronic catalogue available through the university library for various constellations of the terms “Virtual Reality”, “VR”, “Immersive visualization”, “maritime archaeology”, “marine archaeology” and “underwater archaeology”, no previous work specifically regarding the potential benefits of using digital 3D models with VR for documentation and analysis in underwater archaeology was found. Hence, research in other fields, where this technology has been studied was mainly examined and used. The related fields identified were; Terrestrial (land) archaeology, Forensic science and Architecture. Research in the field of immersive visualisations and VR is also taken into consideration when looking at the effect of immersion and presence in a VR experience (Slater & Wilbur, 1997).

It is evident that just as J. McCarthy et al. (2019), notes, this is still a very new topic and very little to no research has been done into the use of VR for actual analytical and documentation in underwater archaeological work.

**Level of detail and accuracy**

To consider using the digital 3D models (hereafter referred to just as 3D models) created by various recording and scanning technologies, for archaeological purposes, one must consider if the 3D models are actually detailed enough to be of use and value? This is something fervently discussed in the maritime archaeology community currently. This was reflected in the fact that this was one of the big topics of discussion at the workshop Accessing the deep, in Helsinki, 26-27th Feb 2019 (Appendix, Accessing the deep info, n.d.). This workshop was specifically arranged to discuss the potential use and value of 3D models and VR in Maritime archaeology.

The question on how detailed the 3D models need to be, seems to divide the Maritime archaeology collegium, which is evident in the various interviews conducted with active underwater archaeologist and it is also mentioned by J. McCarthy et al., where they also discuss that the rising use of digital 3D models in underwater archaeology has led to

“...interesting debates on the tensions between capturing the most accurate and objective surveys possible and the archaeologist’s ultimate goal of cultural interpretation” (2019, p2).

Furthermore, to understand where we are going and why we might want to look to use 3D models and VR in the first place, it is useful to look at how underwater archaeological sites, and in particular shipwrecks have traditionally been documented and visualised.

**Traditional documentation and visualisation**

Historically the most common ways to document and visualise underwater archaeological sites such as shipwrecks has been with notes, photos, sketches and eventually video (Ingelman-Sundberg, 1985). Geophysical techniques such as various acoustic systems, magnetometry and submersibles have also been used as compliments but these are most often used for surveying and positioning and the resulting visual material is not part of the final visualisation of the site and when an overview of a site is needed, photo mosaics or hand-drawn sketches have been created (Bowens & Nautical Archaeology Society, 2009).
The use of hand-drawn sketches is prevalent in underwater archaeology and has in places like around the Baltic a strong tradition which is today carried on by archaeologists like Niklas Eriksson (Adams, 2013), this has historically been the only way of creating a representation of a shipwreck which includes perspectives and a perception of depth unless a physical model was built. The sketches, together with photos and video of a shipwreck are often used to create a more clear and conclusive picture, which cannot be gotten from the raw material alone (Adams, 2013; Ingelman-Sundberg, 1985). Adams further argues that sketching is an important tool for cognition and helps the understanding and internalising of an underwater site like a shipwreck. However, as Adams also mentions, and as discussed with Eriksson (2019), sketches are not objective means of documentation but rather an interpretation by the artist or the archaeologist who created them. As also discussed with Eriksson, this means that the person creating the sketch is looking at the site through the lens of their research questions and are creating the sketches based on that. Hence some information, which might be of interest to someone else might not be included in the sketch.

This could potentially be seen as an indicator that a technical recording system might be superior as it would record everything objectively, however, Eriksson does not agree. His argument being that if a person is using a camera to record a wreck, to then turn it into a 3D model, they are, just like a person doing a sketch, likely to pay more attention to things which are related to their research than other things and thereby not provide a truly objective recording.

Caraher (2016) is also a proponent of sketching and touches these topics when he discusses it in relation to the concept of Slow archaeology, saying “… illustration is the product of an explicitly interpretive process, and it reinforces careful observation and decision-making while excavating” (p. 436). One might say that of course, he is going to say that, as he is taking inspiration from the larger Slow concept (Honoré, 2005). However, at the same time as he is an advocate of Slow, he does not necessarily reject the use of modern tools and technologies in archaeology all together, but he cautions archaeologists to consider what the use of these tools and techniques mean to their work and their results, he points out

The removal of the time-consuming illustration process from excavation work does not necessarily guarantee the de-skilling of the excavator, but it certainly transforms a crucial step in the documentation process from one requiring detailed and careful knowledge of the features in a trench and of the conventions of illustration to one requiring the understanding of a digital camera and relevant software. The former is vital to the archaeological process whereas the latter is not. (Caraher, 2016).

Where Caraher is discussing terrestrial archaeology and is using the point of view from the Slow movement, some underwater archaeologists like Adams (2013) and Rönaby (2013), also bring up sketching and spending time at the site as an important part of understanding a wreck. Rönby even takes an almost experiential stand and says that the personal experiences of visiting a shipwreck, can change the perspective of an archaeologist and help them in their reflections and understanding of the people who once used to crew these ships.

But what about the level of detail? These sketches, although they are produced using actual measurements, are most often not fully accurately depicting the wreck but the measurements are instead used to get the proportions right (Adams, 2013). Adams actually mentions this exact issue, saying “But what about accuracy? Can they be valid archaeologically if they are freehand? In fact many are produced with the aid of measurements, but these are used more to assist in achieving realistic proportions rather than accuracy of projection.” but he also goes on to state somewhat later, that “In fact today, recognition of the role these images have, and particularly the process of
making them described above, suggests they can be both an active and legitimate component of archaeological practice” (Adams, 2013, p 92). This shows that the question about accuracy and level of detail in visualisations of shipwrecks is older than the new technology of using 3D models.

The importance of 3D

Information and site management
According to Atkinson, Campbell-Bell, & Lobb (2019), it is only in the last 10 years 3D surveying has become more used in the recording of historic maritime objects like ships. And only in the 5 last years, it has started to be used in a more complex way, like looking at information modelling using, for example, the Building Information Modelling (BIM) approach for looking at the management of historic heritage assets. They also discuss how 3D data is helping in various ways when working with the management of heritage sites and artefacts, providing richer models and more in-depth ways of working with the information. In a similar fashion but yet quite different, Dell’Unto (2014), discusses how 3D data can be incorporated with Geographical Information Systems (GIS) in terrestrial archaeological excavation sites, to gain a better understanding of relations within the excavation intra-site and also create what he calls 3D temporal references of the work being done.

The human perception
Where Atkinson et al. (2019) and Dell’Unto (2014), look at the gains in information from using 3D data, others are looking at how we as humans perceive things differently looking at 3D objects and data rather than 2D, Ebert et al. (2014) look at in their work, how data and information lost when transforming 3D objects and datasets, to 2D projections.

This brings up the question of how then to view these objects or data. Both Adams (2013) as well as (Sutcliffe et al., 2019) mentions the use of a CAVE immersive visualisation system (DeFanti et al., 2009), Adams, stating:

The CAVE therefore utilises human perception not just as the medium for visualising and auralising the results of research but in opening up new pathways for engaging with and understanding the source material. This form of multidimensional communication has particular potential for visualising, exploring and coming to understand shipwreck sites. (p. 94)

And Sutcliffe et al, say:

In interviews, users commented that the application was a useful research tool because it enabled them to view and examine complex and visually rich data with ease and from new vantage points. (p. 7)

However building full rooms with immersive visualisations systems is often prohibitive, both in cost and space used and a Head-Mounted Display system for Virtual Reality, is in many cases a more realistic way to explore 3D information.
Although the CAVE technology, was not the focus of this study, the work by Sutcliffe et al. (2019) is however possibly relevant as it does pertain to the building of a virtual environment (VE) and an application specifically for underwater archaeologists.

Virtual Reality - VR
As VR is one of the more accessible ways of viewing and experiencing 3D information and has been used in other fields, such as terrestrial archaeology (Landeschi, 2018), forensics (Ebert et al., 2014) and architecture (Angulo, 2015; Milovanovic, Moreau, Siret, & Miguet, 2017; Portman, Natapov, & Fisher-Gewirtzman, 2015), to increase the ability to understand 3D information, it was decided for this study to focus on it as the technology for immersive visualisation.

For public outreach and education
There has been work done, both with VR and Augmented Reality (AR) to create experiences for divers and non-divers alike around underwater archaeological sites and even attempts to build more general tools for this, where also underwater archaeologists are mentioned but realistically, they have to large extent been aimed at tourism and education (Bruno et al., 2016; Chapman et al., 2006; Haydar et al., 2008; Magrini et al., 2015; Rowland & Hyttinen, 2017) or more general public outreach and they focus more on the method and the how rather than the why.

For Underwater Archaeological documentation and analysis
Both Adams (2013) and Rönnby (2013) place a relatively large focus on being present at an underwater site. This would make underwater archaeology a great case for using VR and immersive visualisations, as being present without actually physically being in a place, is one of the strong points of VR (Slater & Wilbur, 1997), however it turns out that the collegium of underwater archaeologist do not necessarily agree about it being a great benefit to being present or having been present at the site (Eriksson, 2019; Foley, 2019; Ilves, 2019), therefore that specific area was not further pursued.

Some previous project were found where 3D models had been used to create a VR experience. Liarokapis et al. (2017) state that their goal was to provide an experience, which partly was aimed at underwater archaeology researchers and partly at the public (Liarokapis et al., 2017), however reading the paper, the project seems to have more focused on the scuba diving simulation and the technology around the creation of the VE than archaeological documentation and analysis. The only benefit mentioned for researchers to use the system is that it prolongs the time which can be spent exploring the site. Another project where these technologies were used was the VENUS project (Haydar et al., 2008) which was a large European project spanning over several years where the main goal was to provide both the public and archaeological researchers with digital tools to explore underwater archaeological sites which are too deep to physically reach diving. Although a very interesting project, the published materials that were found from the project mainly deals with the technology around creating the VE and VR experience (Chapman et al., 2006; Conte, Zanoli, & Scaradozzi, 2010; Drap, 2012; Haydar et al., 2008).

Lack of previous work
The literature review for this study failed to find basically any previous work on using digital 3D models with VR specifically for documentation and analysis in underwater archaeology. Hence
previous research in other fields, where this technology has been studied, was mainly examined and used. The identified related fields were; Terrestrial (land) archaeology, Forensic science and Architecture. Research in the field of immersive visualisations and VR is also taken into consideration when looking at the effect of immersion and presence in a VR experience (Slater & Wilbur, 1997; Sutcliffe et al., 2019).

The sources which were searched included the online resource ResearchGate (‘ResearchGate’, n.d.), Google Scholar (‘Google Scholar’, n.d.) and the electronic catalogue of academic publications at the Library of Linköping University (‘LiU Library’, n.d.). The search terms used included

Related fields

Forensics
In the case of forensic science, digital 3D models of crime scenes are becoming more and more used, for example in the work of the Swedish National Forensic Centre (NFC) (Notes from meeting with Senior forensic technician, National Forensics Centre, 2019). There, laser scanning is the main way of scanning but also photogrammetry is used for documentation of crimes scenes. The information from the scene is then stored in its point cloud format and can thereby at any time later (Barazzetti et al., 2012), give the possibility to either look at a crime scene in its raw point cloud format, or to create full digital 3D models of the crime scenes. This information can be used by investigators or prosecutors as material or as visualisations in court, doing reconstructions of events (Ebert et al., 2014). Another benefit noted compared to traditional documentation is that with this material the user has full control over the navigation and can interact with the environment (Robey et al., 2000).

Architecture
Research around using VR in architecture education has shown that although experienced architects often have the ability to internally translate 2D drawings and material to 3D information about how a room or a building will look and work, students most often do not have this ability. It has also shown that using VR and presence (Slater & Wilbur, 1997), provides a better understanding for space and spatial experiences in architectural design (Angulo, 2015; Milovanovic et al., 2017; Portman et al., 2015).

Terrestrial Archaeology
In terrestrial archaeology, research has also been done around how 3D can help in understanding sites and information better. One example is the Master thesis work done by (Stöhr, 2017) looking at how 3D modelling of the Late Bronze Age settlement of Corneşti-Iarcuri, can help in understanding the site better from a spatial perspective. Researchers at the Digital Archaeological Lab at the Lund University in Sweden (‘Laboratoriet för Digital Arkeologi DARK Lab, Lund University’, n.d.) are also looking at this and have also found that 3D data increases the understanding of archaeological sites and the workflow of excavating (Dell’Unto, 2014; Dell’Unto, Landeschi, Apel, & Poggi, 2017; Landeschi, 2018), they have also done work around reconstruction of sites and used 3D data for
analysis of Lino Of Sight regarding what would have been visible and not in a Pompeian house and what the might have meant from a social standpoint (Landeschi et al., 2016). Work with VR at the DARK Lab has also been done looking at how it can increase the accessibility of heritage sites (Karlsson, 2013) and how heritage sites can be experienced digitally in an immersive way (DARK Lab Lund University, 2016).

Other technologies for immersive visualisations
As previously mentioned, Sutcliffe et al. (2019) performed some research where they among other things built and tested a VE application using a CAVE system, for underwater archaeologists. However, their focus was mainly in the design of VEs and although they include some remarks like the quote:

In interviews, users commented that the application was a useful research tool because it enabled them to view and examine complex and visually rich data with ease and from new vantage points. (p. 7)

They mainly focus on design guidelines for VE and VR applications.

Summary
Research in related fields has shown that VR can be an effective way of viewing and working with 3D data. Not only does it provide the possibility of working with digital assets at scale 1:1 (Angulo, 2015) but it also provides a better understanding of scale and spatial information (Angulo, 2015; Ebert et al., 2014; Landeschi, 2018; Milovanovic et al., 2017; Portman et al., 2015; Sutcliffe et al., 2019).

From a critical point of view, Portman et al., however, raise the question of “How real must real be?” (p3, 2015), they go on to discuss how realistic and detailed a VR experience needs to be, to be of value. This is also a question, currently fervently debated in both terrestrial and maritime archaeology, and was one of the big discussion points at the international workshop Accessing the deep, in Helsinki, Finland 26-27th Feb 2019, which focused specifically on the use of digital 3D models in maritime archaeology. The participants were clearly divided and no consensus was found. This chasm was further seen in the interviews for this study and rather widely varying opinions on the topic were noted (Foley, 2019; Ilves, 2019).
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Appendix: Process

Ola Karlsson
What follows here is a roughly chronological account of the process and journey I went through as part of my master’s thesis project and a summary at the end with some of the main learnings.

As this is an account of the process and my experience, I have chosen to write this part in first person and in a fairly personal style.

Inception
I already in the later stages of 2018, started thinking about what the topic for my master’s thesis might be and one of the ideas was to merge my interest for diving, with my design interests.
Hence I early on contacted my old diving acquaintance Ingemar Lundgren at Ocean Discovery (‘Ocean Discovery’, n.d.) who is a deep diver, underwater photographer and also works with 3D computer modelling. He was part of the team who found the wreck of the Swedish Warship Mars in 2011 (‘Mars Makalös | Västerviks Museum’, n.d.) and has since then been working on the digital 3D model of the wreck and the wreck-site around it. Speaking to Lundgren, he mentioned how they after nearly 8 years of work on gathering information and modelling had a very good and detailed model of the Mars shipwreck. But one of the big problems was that they had no good and easy way of letting the maritime archaeologist involved in the project, view the model. He also mentioned how there was an effort underway, to create a Virtual Reality (VR) application for use in museum and education purposes but that this VR experience did not have any tools or features for maritime archaeologists. We went on and discussed how it would be interesting to create a VR experience with for example measuring tools for the maritime archaeologists. Being a scuba diver with an interest in and rather extensive experience of wreck diving, myself, the idea of creating a design for a VR experience including sketches and possibly some prototypes, specialised for maritime archaeologists, seemed like an interesting project and quite straightforward. I also got access to an early version of the VR dive simulation experience for Mars, which I was rather impressed by.

Deciding on the topic and forming the research question
In early 2019, I decided to go with the topic of using VR as a tool in maritime archaeology. From my discussions with Lundgren, I already knew that VR was being used in some places to display shipwrecks to the public but also that there seemed to be a shortage of VR tools for the analysis part of the archaeological work.

Having dived on numerous shipwrecks through the years and being excited when coming across various ship details, speaking to Ingemar Lundgren about the high level of details in the Mars model, visiting various museums seeing rows of glass cabinets filled with historical artefacts and seeing the popular culture icon Indiana Jones chase around the world for exiting finds (Strong, 2007), I felt I had quite a strong, clear notion about what archaeology and underwater archaeology was about.

I also early in my research read some material by Adams (2013) and Rönnby (2013), who place great importance of visiting a shipwreck, to be able to better document the details and get a better understanding of it. This fitted very well with the idea of using VR as a tool for the maritime archaeologists as one of the strong points of VR is to give the user a sense of immersion and presence (Slater & Wilbur, 1997). Taking inspiration from the field of design and research through design, I wanted to use a fairly open research question and the initial research question, I settled on was “What might a VR tool aimed at marine archaeology, look like?”.

With these ideas in my mind, I steamed ahead with my literature review, while in the back of my mind already planning the design of the VR experience for maritime archaeologists and everything seemed to be right on track.

Information gathering

Literature review - Terminology matters, a lot...
The next step in the process was information gathering and already here things started to get challenging. In Swedish the term for archaeology related to underwater objects is, “Marinarkeologi”, doing a literal translation of the word, I started searching for information about ”Marine archaeology”, especially in relation to VR, however, I found very little to nothing on that specific topic. I then started reading about marine archaeology in general to get a better understanding of the problem area I was going to be working with. However, I after a while realised that the term Marine archaeology, which I was using, was not
necessarily the most correct or most used term in English for this field of science. Instead in English the term maritime archaeology is much more widely used. But there are still some people who use the term marine archaeology and to further complicate things, within the larger field there are also sub-fields of study, like underwater archaeology. This was at first rather confusing but after a while I learnt that Maritime archaeology is much bigger than just the study of underwater shipwrecks, which is what I was looking at. Maritime archaeology as a research field actually includes all studies of historical heritage on and around bodies of water, hence the remains of Prehistoric (another term I learnt, pre-historic time being before there were written records and historic time being after we started using writing) fishing equipment in a small Finnish lake (Ilves, 2019), equally falls within in the boundaries of maritime archaeology as famous shipwrecks like the Swedish warship Vasa or the English, Mary Rose.

This use of different terminology by different researchers, in different geographical areas and for different topics made the literature review part of the thesis rather challenging and time-consuming. From what I could find, there doesn’t seem to have been done much in the field of using VR for documentation and analysis work in maritime and underwater (Appendix: Background and Related work, n.d.).

Attending workshops and doing interviews
As preparation for my thesis and as part of my research into maritime archaeology, I attended several workshops and events and conducted a number of interviews.

**Vrakprat - November 2018**
Doing something digital around the Mars wreck had been on my short list of topics for my Master’s thesis and hence, I already in November 2018, I attended a workshop at the Maritime Museum in Stockholm, called Vrakprat (Wreck talks, in English) (The Swedish National Maritime and Transport Museums, 2018). At the workshop I, among others spoke to Tanel Saimre from the Estonian Ministry of Culture, who through later contact, gave me the tip about another upcoming workshop at the Helsinki University (see details below) and also Jim Hansson at the Swedish National Maritime and Transport Museums, who gave a presentation on how he was experimenting with digital 3D models as a way of documenting and showing shipwrecks as part of the European Baltacar project (‘Baltacar’, n.d.) which also Tanel Saimre was involved in.

**Västervik Museum - February 2019**
Around the middle of February 2019, I visited the museum in Västervik, where the Mars exhibition is being exhibited. There I further spoke to Ingemar Lundgren, who works part-time for the museum with the exhibition and with Veronica Palm, the deputy director of the museum and a terrestrial archaeologist.

We discussed the digital 3D model of Mars and also their plans for the exhibit, they both felt that the Mars model is superior in quality and level of detail to most other digital 3D models of shipwrecks they had seen. I also interviewed Palm (Appendix, Interview with Veronica Palm, 2019) about archaeology in general and her views on digital tools etc.

**Accessing the deep - February 2019**
Through Tanel Saimre, I had met at Vrakprat, I found out about the upcoming workshop Accessing the deep at the University of Helsinki (Appendix, Accessing the deep info, n.d.) and after contacting the organisers, I got an invitation to attend, which I did, 26-27th February 2019. It was a workshop specifically around the idea of creating a digital repository of wrecks in the Finnish part of the Baltic sea, using citizen science. However, digital 3D models of the wrecks should be included as part of the repository and large parts of the workshop focused on the creation and use of such models in both terrestrial and maritime archaeology.

**3D models and VR in Forensic Science – February 2019**
As it was becoming more and more clear that there had not been much previous academic work around the use of VR for documentation and analysis. I started looking at possibly related fields where these techniques were used, one such being forensic science. As I had previously attended a presentation by
Philip Engström at the Swedish National Forensic Centre, about their use of digital 3D models and VR, I set up and did an interview with him (Notes from meeting with Senior forensic technician, National Forensics Centre, 2019). Although not exactly the same as the use in maritime archaeology, it was enlightening to hear more details around how these techniques are used. Especially the motivations for why they are being used and any what the largest challenges are.

Interviews

As another part of the information gathering process, I did five interviews via the teleconferencing tools Skype and Zoom, and I attempted another one.

The first interview I attempted, to set up, was to be with Jim Hansson, from the Swedish National Maritime and Transport Museums (SMTM), Hansson had held the presentation at Vrakprat about using digital 3D models and we had spoken briefly at the event and agreed to be in touch later. It was quite a challenge to arrange the interview as Hansson was very busy and things kept getting in the way. When we finally had a time arranged, we, unfortunately, had technical difficulties and could not get the Skype call to work due to the fact that he was using Skype for business and I, the standard personal version. Hansson was going to consult with the IT department and get back to me about a solution but unfortunately this never worked out and the interview got put off a long time. As will be discussed in the section about my learnings, had this not happened as it did, the process might have gone very differently.

From the issues around the interview with Hansson, I learnt to ask if, the person I wanted to interview, was using the non-business version of Skype and otherwise suggest that we’d use the Zoom system, which Linköping university uses and the other interviews went somewhat smoother.

The people I interviewed were four active maritime archaeologists, Assistant Professor in Maritime Archaeology Kristin Ilves, University of Helsinki (Appendix: Notes from interview with Kristin Ilves, 2019), Riikka Tevali, University of Helsinki and the Finnish Heritage Agency (Appendix: Interview with Riikka Tevali, 2019), Docent Niklas Eriksson, Stockholm University, Dr Brendan Foley, Digital Archaeology Laboratory Lund University (Appendix: Interview with Brendan Foley, 2019) and Dr Daniel Löwenborg, Uppsala University, who is a researcher in terrestrial archaeology and also works with digital 3D reconstructions of historical sites.

As I was using a qualitative approach to the project and I was still somewhat new to the field, interviewing experts, where I would most likely need to ask follow up questions and also ask them to elaborate on various points, I choose to use a Semi-structured interview (W. C. Adams, 2015) style. Using questions like, “What is the main purpose, of archaeology for you?”, “In your opinion, what is the difference between having visited the site or using photos and video of a site?” and “What is your view on….?” Aiming for qualitative data together with the Semi-structured interview style also allowed me to adapt my questions to these experts, as I was finding out more information. After each interview I would write up and summarise my notes from the interview and also reflect on take-aways from that specific interview.

The more you find out, the less you know

There is an old saying, to the effect that the more you find out about something, the more you realise how little you really know, this was very much the case in this project.

Initial narrowing the scope and redefining the research question

One of the first realisations was as previously explained, that the field of maritime archaeology is much bigger than I first realised and that I needed to narrow the scope of the thesis. As I previously mentioned, I was mainly interested in creating a tool for the archaeologist’s analysis work, not the display of the findings to the public in museums or the like. The wish to focus on that side of things was further strengthened by the apparent lack of previous research in the area. However, having found out the immense scope of
maritime archaeology as I whole and wanting to possibly use the Mars wreck as some kind of case study, I also realised I needed to narrow the scope even further. Hence, I decided to redefine my research question to “What might a tool for analysis in underwater archaeology, look like?”

Analysing the data and almost losing heart
Although I had just redefined my research question, looking at all the information I had gathered, I started realising that the research question I had, was too simplistic and that there was actually a very important underlying question, which had to be answered. The question was along the lines of, “Is there actually any added value in using VR for underwater archaeology analysis research?”.

Figure 7. Whiteboard with information regarding different types of immersive visualisations and their relevance to the study.

Figure 8. Information gathered from the first phase mapped out for an analysis on whiteboard.

My initial plans on simply designing a VR experience with measurement tools, had all but been crushed by the fact that when interviewing the maritime archaeologists and asking them, “What is the main point of maritime archaeology to you?”, they had almost unanimously said, that it was all about understanding the people of the ancient times, their society and their culture. These wrecks on the bottom of the sea, were
just objects and only really served to help the understanding of historical and pre-historical times. None of them had mentioned that it was about analysing the size of a hull or the diameter of a cannon muzzle.

Also, many of the underwater archaeologists I had come in contact with, did not necessarily agree with the ideas of Rönnby (2013) and Adams (2013) that there was a great added value to being present at the wreck site. Then what was the point in using VR?

On top of these things, I had read material around the value of using digital 3D models for documentation and analysis in archaeology, however, quite a few of the quite prolific archaeologists and maritime archaeologists, I spoke to, did not feel that most of the existing digital 3D models of underwater sites or wrecks, were of high enough quality or level of detail, to be of scientific use.

These things, pretty much caused me to question the whole idea of my thesis, yes, I could change my research question to be about, “What, if any, value might VR be in underwater archaeology?” but at the time, it pretty much felt like the answer would be, that there was no value, which felt very disheartening as my whole idea was built around designing VR for maritime archaeology.

**Redefining the research question, again**

All this rather spread out information, left me in a rather confused and weary state, I had done extensive reading, spoken to numerous experts and the attended several events in person and also analysed the material I had gathered through putting it all out on whiteboards to group things and get an overview of the material. However, after all this work, I did not seem to be any closer to finding a clear way forward in my research.

At this point, luckily, my supervisor came to the rescue. He pointed out that what I had done was the first half of a study using the double diamond approach, even if I had possibly been too quick in the beginning and tried to formulate a specific problem a bit prematurely. So, what I needed to do, was simply to redefine and probably again narrow the scope of my research question based on my new insights, to have the specific problem and move into the ideation phase.

Hence, I yet again changed my research question, this time splitting it into two parts, covering the fundamental questions I had:

- Are the digital 3D models that can be created by most underwater archaeologists without highly specialised knowledge and equipment, detailed enough, to be of archaeological value?
- What potential benefits might Virtual Reality add to documentation and analysis in underwater archaeology?
Moving into the ideation phase

Developing a method to answer the research questions
Following the double diamond approach, I now needed to go wider again and come up with a way of answering my questions. I had already started to gather a hint of the answer to the question regarding the level of detail in the models used or created, through my analysis work but to formalise my answer I needed some more direct input in the matter. Furthermore, as most underwater archaeologists do not have experience in using VR, there is no use in just asking them their opinions on if it might be useful or not. Hence, to be able to answer the question of “What potential benefits might Virtual Reality add to documentation and analysis in underwater archaeology?”, I had to let some underwater archaeologists try it and get their opinion.

Attending the annual conference of the Swedish Maritime Archaeology Society
Around this time I attended the annual conference of the Swedish Maritime Archaeology Society and again met Jim Hansson, who I had tried to interview early on in the project and this time we actually managed to find time to sit down and have a bit of a longer talk. I believe that Hansson had previously not really understood, what I was doing and trying to achieve. When he did, he was very excited, as it fitted well in with his own interests in using digital 3D models and offered to help in a more active way. We decided, that rather than trying Skype again, I would come up to Stockholm and we would have a meeting to further discuss ideas and possibilities.

A meeting of hope, and redefining the research question yet again
At this point I was still somewhat unsure about my idea of using VR for underwater archaeology and if there was really any point in it but had resigned to the idea, that even if the answers to my research questions, was that the models were not good enough and that there was no point in using VR, those were also valid and useful findings.

I then had my meeting with Jim Hansson at SMTM in Stockholm and finally found someone who had relatively extensive experience in creating digital 3D models of wrecks, saw great potential in their use and could also straight away come up with at least one potential benefit of using VR instead of flat screens, keyboard and mouse.

The meeting, then turned into somewhat of a co-design session around the idea of running a workshop at SMTM with some of their underwater archaeologists, to get direct input and data for answering my research questions.

I walked away from that meeting with new hope, there seemed that maybe using VR for underwater archaeology was not such a bad idea after all.

As I now felt more confident in the topic and after discussion with my supervisor, I added a third section to my research question, regarding design openings, to bring more of the design aspect into the picture.

This left me with the following three research questions:

• Are the digital 3D models that can be created by most underwater archaeologist without highly specialised knowledge and equipment, detailed enough, to be of archaeological value?
• What potential benefits might Virtual Reality add to documentation and analysis in underwater archaeology?
Design openings: What features might be beneficial in a basic VR tool for underwater archaeologists?

Delivery
Going further in the double diamond, it was now time to implement or deliver a solution to my problem of how to answer my research questions.

Workshop at the Swedish National Maritime and Transport Museums
What I had come up with and suggested to Hansson in our meeting, was to run a workshop with him and his maritime archaeologist colleagues at SMTM. SMTM was an almost ideal organisation to work with on this, as it is one of the major employers of active underwater archaeologists in Sweden and they have already started experimenting with creating digital 3D models.

I refined the ideas from the meeting with Hansson into a workshop where the participants would get to view the same digital 3D model of a shipwreck on a normal computer screen and interact with it, through the keyboard and mouse and then they would get to view the same model using VR. During this, I would again use a semi-structured interview approach engaging the participants in conversation, around how they experienced the two modes of viewing and interacting with the digital 3D model and what the differences were. To cover the question, regarding if the details were good enough, I came up with questions along the line of “As a maritime archaeologist, what do you think you might use this for?”

With the help of Hansson, I scheduled a day at SMTM and conducted the workshop with 5 participants. The sessions with the participants were recorded via video so that I as the researcher was free to interact with the participants without worrying about taking notes.

Analysis and discussion
The final stage of the project and the master’s thesis was to collate and analyse the data from the workshop and write up the findings.

I watched the recording from the workshop and typed out notes and then analysed and extrapolated the data into categorical results (Appendix, Results from SMTM Workshop, n.d.).

For the discussion part, I went back to the material I had found during my information gathering, tying my findings to previous or related work and contemplate what it might mean.

As previously mentioned, there was very little to no, previous work in the exact field of using VR as an analysis of documentation tool for underwater archaeology, so most of my discussion became based on material around VR itself and its use in other fields such as forensic science and architecture and how that might relate to my results.

This was certainly on of the most challenging parts of the thesis, as it required a lot of analysis and supposition. Another challenge in this part, was to remember where and when I had read various pieces of information, to be able to go back and consider how it might fit in with my results and to reference or cite the material, this made the process extra time consuming and laborious.

Design openings
In discussions with my supervisor, regarding design openings, it was decided, that the bigger contribution of the thesis was the theoretical side and the questions regarding the validity of the 3D models and the use of VR. However, as the programme, is a design focused programme, it would also be beneficial if I could find some design openings and basic design suggestions for those openings. We agreed that, as they were not the main focus, rather simple text based design solutions would be sufficient.
To find suitable design openings, the participants of the workshop were both asked to explain how they would normally go about their work but also, while in the VR experience, what tools and features, they imagined needing to actually use the VR app in their work. Later, as part of the analysis work, design openings were defined and prioritised based on the responses (Appendix, Results from SMTM Workshop, n.d.).

Writing the thesis article
I chose to write my thesis in an article style, as I felt this might open the possibility of later submitting it to various places and also increasing the chance of my thesis actually being read. My reasoning being that a 10-15 page article would be much more accessible than a 50-100 page report style thesis. Writing in this style, however, proved also to be quite a challenge. As the program MSc Design is a new cross-disciplinary programme which in many ways is breaking new ground in how things are done, this way of writing a thesis is not the standard way of doing things at Linköping University. This meant that there was little to no information about how to structure this style of thesis, even my examiner and supervisor had differing opinions on what needed to be included or not.

Learnings and reflections from the process
It was a long and laborious process and here I have attempted to pull out some main points I have learnt along the way.

The organisation of source material
I found that I should have been more careful about noting down interesting quotes and parts of information in my literature review/information gathering process. As it was, I had to in later stages go back and reread a lot of material to find exact quotes and parts of reference materials, which I knew I had read somewhere but was unsure about where and I needed to find the exact spots to reference it or cite it when tying my conclusions to previous or related work.

Asking the right questions
In my bid to understand maritime archaeology and the drive of maritime archaeologists, I was asking a lot of why-questions, which were good for creating and understanding of the underpinnings of the subject. However, as my early goal was to design a tool for the archaeologists and to find out if VR would be beneficial to them in their work, I should also have asked more questions around how they perform their work.

As previously stated, I was rather disheartened when finding out that the main interest of many of the archaeologists I spoke to, was to understand the ancient civilisations and their societies and how that affects us today, rather than being fully engrossed by the objects they might find. What I only realised later was that they are actually very interested in the objects, as they are the things which help build an understanding of those old societies and people. But to put it plainly, the objects are not the goal, they are merely tools to help the researcher get closer to the goal.

However, at the same time, those questions and discussions did give me a deeper understanding of the field of maritime archaeology and the people who work in the field. It turns out to be a very diverse field of study, some researchers focus on the details of historic ship construction, while others look at what prehistoric fishing equipment might tell us about the people and the societies of that time.

Following up
Based on the issues around my experience trying to arrange my first interview with Jim Hansson, I learnt the importance of following up and not leave it to the other person. Hansson turned out to be one of the
key people for me to talk to in my project as he was the one that in the end showed that yes there might
indeed be value in what I was proposing and he was instrumental in arranging the workshop at the SMTM.
But because our first interview never happened due to technical issues and I then didn’t follow up directly
afterwards, it was not until much later in the project I regained contact with Hansson.

Flexibility
Planning is good but many times, being flexible is better.

Remote interviews
Not everyone is familiar and or comfortable with video calls, having previously worked remote and having
used teleconferencing rather extensively during the program at the university, I feel that it is vastly superior
to other forms of distance communication such as emails or phone calls. The fact that you can see the
other person and their body language, makes a very big difference. However, as I found when conducting
my remote interviews, there were several of the interviewees, who were obviously not used to using this
form or communication and there were several technical issues. I also felt that there was some trepidation
from some of the interviewees about it and looking back at it, being able to have the video and body
language might not have made up for the issues it caused. Giving the interviewees, the option of doing it
over a teleconferencing platform or via the phone, might have been better way to do it.

Workshop planning and execution
For the Workshop at SMTM, I had left it to my contact there to take care of the details on site. We had
discussed how many participants were available and needed and I had given the time slots for each session
I was planning. I had also specified the size of the room I needed for the VR setup and had been told it was
all ok. However, getting there on the day, the room was really too small for what was needed and although
a number of people had been asked about participating, they had not been given any information or any
times. Furthermore, over the day, others in the office heard about what was happening and was told by
some of the participants that they “just had to try this VR thing” and therefore turning up, asking if they
also could try.

Although stressful, it all worked out in the end and the necessary data was collected, even if not necessarily
in the exact way I had planned it.

One might argue, maybe it would have worked better if I had direct contact with the participants and more
control of things before turning up on the day but at the same time, I’m not sure the workshop would have
happened at all if I had tried to do that, at least not on as short notice as it now did. Hence, planning is
good but being flexible saved the day.

Not locking onto an idea too early in the design process
The biggest takeaway of the whole project is probably, not locking onto an idea too early in the design
process, be open and be prepared to shift focus based on where the project takes you.

As described earlier, I had a very clear picture in my mind of what I was going to do, already going into the
project, which caused me a lot of problems and stress when things didn’t seem to be heading the way I had
envisioned it. As it turned out some of those initial ideas actually made it into the design suggestions but
only after the data collected as part of the process, called for it.
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https://doi.org/10.1002/9781119171386.ch19

Appendix, Accessing the deep info. (n.d.).

Appendix: Background and Related work. (n.d.).

Appendix: Interview with Brendan Foley. (2019, April 4).


Appendix, Interview with Veronica Palm. (2019, February 18).

Appendix, Results from SMTM Workshop. (n.d.).


Notes from meeting with Senior forensic technician, National Forensics Centre. (2019, February 20).


Appendix:
Results

Ola Karlsson
Regarding the level of details needed for a model to be of scientific value

It’s good enough today or dependent on the research question

Most models produced today are not of enough level of detail

Results from the workshop at SMTM in Stockholm

Summarised Results Tables

Differences viewing the model in VR

Things you can imagine using this for

Tools you would like to have in the VR experience

Notes - Jim Hansson

Notes - Mikael Fredholm

Notes - Pernilla Flyg

Notes - Patrik Höglund

Notes - Marco Alí

References

Introduction

In this document are the summarised results and the raw field notes from the workshop conducted at the Swedish National Maritime and Transport Museums in Stockholm 23/05/2019. The results presented in the earlier part of this document are based on thematic analysis of the data in the field notes included in the latter part of the document but also the information from the interviews conducted as part of the study(Appendix: Interview with Brendan Foley, 2019; Appendix: Interview with Kristin Ilves, 2019; Appendix: Interview with Niklas Eriksson, 2019; Appendix: Interview with Riikka Tevali, 2019; Appendix: Interview with Senior forensic technician, National Forensics Centre, 2019; Appendix, Interview with Veronica Palm, 2019)

Regarding the level of details needed for a model to be of scientific value

Having examined the interview results, here is a summary of the opinions on the matter.

It’s good enough today or dependent on the research question

The following interviewees, state that the level of details that can be achieved today without highly specialised equipment or knowledge is sufficient or that it fully depends on the research question and hence even models with quite rough details might be valuable.

Workshop participants or interviewees who expressed this opinion:

Jim Hansson, Marco Alí, Kristin Ilves, Mikael Fredholm, Pernilla Flyg, Patrik Höglund
Most models produced today are not of enough level of detail

The following interviewees have either straight out said or expressed opinions aligning with the sentiment that digital 3D models need to be highest possible level of detail and most of the ones produced today are not high enough.

Workshop participants or interviewees who expressed this opinion:
Brendan Foley, Veronica Palm

This was also the case for Nicolo Dell’Unto, who is the head of the Digital Archaeology Lab (DARK Lab) at Lund University, when he presented and also partook in the discussions at the workshop Accessing the deep, even though there is currently no published material from that workshop. This general opinion is also confirmed by his colleague at the DARK Lab, Brendan Foley, however, Foley also acknowledges, that they are somewhat of purists in this (Appendix: Interview with Brendan Foley, 2019).

Several people mention how the documentation should be done with the highest possible level of details as you can always “scale down” when rendering models which do not require high all the details to be there but you can never “scale up” if you do not have the details in the raw material.

Results from the workshop at SMTM in Stockholm

All these people are used to these wrecks, diving on them and discussing them.

It is clear that they can easily see things and relate to how things are in the real world. They note that there are details missing but at the same time they seem to be able to pick out even distorted things as tools or handles and boxes etc. And when having several people in the room they very organically discuss details of the wreck, while one person is in the experience and the others view what the person with the HMD can see on the screen.

Considering that Patrik, has never dived Mars and has very little knowledge of the wreck, he could look at the model in the experience and directly start-up an engaged archaeological discussion with Marco about what it was they were seeing and what it would and could not be.

Summarised Results Tables

<table>
<thead>
<tr>
<th>Differences viewing the model in VR</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit mentioned by participant / observed by test leader</td>
<td>Participants</td>
</tr>
<tr>
<td>Feels like you are diving/being there/Feels real</td>
<td>Jim, Mikael, Pernilla, Patrik, Marco</td>
</tr>
<tr>
<td>Gives a deeper connection with the site/ship</td>
<td>Pernilla</td>
</tr>
<tr>
<td>Better overview / better field of view / better perspective</td>
<td>Jim, Mikael, Pernilla, Marco</td>
</tr>
<tr>
<td>See things you might not think of when viewing on screen</td>
<td>Mikael</td>
</tr>
<tr>
<td>Better feeling for scale</td>
<td>Mikael, Pernilla</td>
</tr>
<tr>
<td>Better feeling for shapes, Can perceive things which you can’t on a flat-screen</td>
<td>Mikael</td>
</tr>
<tr>
<td>Not limited by being underwater/onsite</td>
<td>Jim, Mikael, Patrik</td>
</tr>
<tr>
<td>Natural interactions, pointing and gesturing when discussing</td>
<td>Jim</td>
</tr>
<tr>
<td>-------------------------------------------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Natural way to work for an underwater archaeologist</td>
<td>Jim, Marco</td>
</tr>
<tr>
<td>Less risk of erroneous measurements</td>
<td>Jim</td>
</tr>
</tbody>
</table>

**Things you can imagine using this for**

<table>
<thead>
<tr>
<th>Task mentioned</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring</td>
<td>Jim, Mikael, Pernilla, Marco</td>
</tr>
<tr>
<td>Observe / Document</td>
<td>Jim, Mikael</td>
</tr>
<tr>
<td>Analyse hull/ship constructions</td>
<td>Jim, Mikael, Pernilla, Patrik</td>
</tr>
<tr>
<td>Analyse events leading to sinking</td>
<td>Pernilla</td>
</tr>
<tr>
<td>Take screenshots/images</td>
<td>Mikael</td>
</tr>
<tr>
<td>Note-taking (speaking)</td>
<td>Mikael</td>
</tr>
</tbody>
</table>

**Tools you would like to have in the VR experience**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale indicator</td>
<td>Mikael, Pernilla</td>
</tr>
<tr>
<td>Ability to set the scale</td>
<td>Mikael</td>
</tr>
<tr>
<td>Measuring tools</td>
<td>Jim, Mikael, Pernilla, Marco</td>
</tr>
<tr>
<td>Take screenshots/images</td>
<td>Mikael, Marco</td>
</tr>
<tr>
<td>Note-taking (including spoken) linked to items</td>
<td>Jim, Mikael</td>
</tr>
<tr>
<td>Predefined lists of for example measurements to take and populate the measurements in VR</td>
<td>Jim</td>
</tr>
<tr>
<td>Connected reference library (multimedia, text, photos, video etc.)</td>
<td>Mikael, Pernilla</td>
</tr>
<tr>
<td>See the photos, which were the raw material in the Photogrammetry to create a part of the model</td>
<td>Pernilla</td>
</tr>
<tr>
<td>Functionality for showing, what is original/raw and what has been manipulated/reconstructed</td>
<td>Pernilla</td>
</tr>
<tr>
<td>Ability to control lighting</td>
<td>Marco</td>
</tr>
<tr>
<td>A specific platform for research/museums with full-resolution models</td>
<td>Marco</td>
</tr>
<tr>
<td>Ability to see if two items fit together (did they use to be one item which is broken)</td>
<td>Marco</td>
</tr>
</tbody>
</table>
**Notes - Jim Hansson**
Curator, Archaeology Unit, SMTM

Education: Masters in Archaeology

Years as Maritime archaeologist: 13 years

Experience with the tools: Using Agisoft for creating and analysing 3D models, never used VR before.

Other: SMTM Also very interested in using VR for analysis and documentation.

**Viewing on Screen:**

How using models today? Increase interest - forbidden diving, using models for dive planning with trained guides

Contract Arch: short time – photo, seldom video, take tests. Seldom stage 2, not enough reason/money to come back. Gather as much material as possible. Make 3D models is very good documentation method, analysis, including measuring and figuring out profiles of the hull can be done back at the office. Once, did a rather quick 3D model as part of stage 1, kind of as a test, then when came back for stage 2, the developers had made mistake and dropped large concrete foundation blocks had been dropped right on top of the wreck. Hence the 3D model was the only material to go by and document/analyse what kind of ship it was.

Challenges so far, find a suitable level of detail when taking the photos, not to create too much raw material and make it easy enough that most uw archaeologists can do it.

Problems with flat screen – when working with the analysis of the ship which turned out to be Sceptre, was taking measurements on the 3D model in the program Agisoft, the measurement seemed off, having been on site, knew that it couldn’t be right. Re tried several times but kept getting the same erroneous result. Jim then rotated the models and realised that his measurement had been at an angle (he shows with his hands) with one point further away in 3D space. “I thought I was measuring straight from the top to the bottom but I wasn’t”. He says it’s a very easy mistake to make and that it would be interesting to find other was of doing it.

Another use is to show decision makers and developers, - “it creates a different understanding...”, “instead of just seeing fragments, it gives a picture of the whole thing”.

**Which RQ can we answer with todays quality?**

Using still photos for better quality than video. Better take the best possible straight away as you can always downgrade the quality with the tools but you can’t upgrade if you have bad raw-data. And retaking, is expensive with divers, boats etc. This makes up for the fact of getting rather large amounts of raw-data which has to be stored.

The Bodekull wreck model has been in the top 10 models on Sketchfab for the category, historical artefacts, so Jim feels that they have found a good level of details. [Note by Ola, it also turns out that they have higher resolution models than what’s on Sketchfab – Which means that maybe the question about what these models can be used for is not appropriate, maybe that needs more tests on the full resolution BUT at the same time, maybe it is interesting to include what the models can be used for in the state they are on Sketchfab ].
The model is correct to the centimetre.

Jim was also involved in the initial traditional documentation of the Bodukulll wreck. Difference against traditional methods, you have to swim around with large tools for taking measurements and write all the measurements down while under water —“It takes forever and you have to be good at drawing”, the material gathering for the 3D model of this wreck too “4 divers 1 week instead of 10 divers 7 weeks”.

You can now do analysis of hull profiles, you can see the “joining points”? (skarvar in Swedish) and other details.

However Jim doesn’t believe that you can get away from looking at the really fine details IRL.

This like tool marks can be hard to capture and see but if you do find areas or items of interest, you can document those in closer/higher detail.

You can see and measure angles, with the traditional methods, they had no knowledge of for example the angles of the masts, which can be relatively easily measured on a digital 3D model.

Use the model, to see how things change over time, easy to compare models from two different points in time.

Anna Maria and Jutholmsvraket a bit special, it’s a Dutch Flute ship, very common in the 1600s, one thing that became apparent when looking at the model is that the bow of the ship is “angled forward and rounded but also a bit squared”, which Jim hadn’t realised before, even though he’d done very many dives and been involved in the traditional documentation. “This has not been seen neither on video or other ways of documentation.”, These things are seen once you get the full picture and also you get away from the distortions being under water.

To start with it was a challenge, how to work with analysis this in Agisoft as it’s not made for this, they had to come up with some of their own methods but got there in the end.

VR-viewing:

“This is really cool!”

“I didn’t think it would be like this”

“You can even look under deck”.

“You can just skip diving here anymore”.

“Damn this is soo cool”

“It’s unbelievable, feels like you’re diving”

“Feels like I could fall off the edge here”

“This was well over expectations.”

Took to the controls quite quickly, even though the controls where sometimes a bit problematic due to technical issues with the webVR interface.
What are the differences, between this and flat screen?
“This is just like being under water but you get the full perspective”

As a Maritime archaeologist, what do you think you would be able to use this for?
“Measuring distances, here we can twist and turn as we want.”
“I’d like to say, you could do a full documentation” joints, metal rivets.
“Here you can see the details, the joining on the planking and the metal fittings”.

How does this compare to when you view a 3D model in Agisoft?
“It’s night and day, here it feels like it’s for real”

Jim mentions that in a certain place, things are a bit unclear, they are not in focus and that with a lower resolution model, things might not work so well.

“As an outsider this all looks a bit low resolution, is it good enough to use for professional use?”
“Yes, with this, we could do a lot of documentation and anybody can do it, you don’t need to be down there.” “You can for example measure anything you’d like”

What else, beside measuring, what do you as a maritime archaeologist do on a wreck? Or what do you want to be able to do?
“Observe, which we can do here, I can see the canon, I see chests, the back of a rifle, and yes I know what these are but you can see the details.”

“Lets see if you can see the rigging details, yes you can, I’m here standing in a box and here’s a [Block], and over there is a [Block], you can even see it from a distance. Over there is a sharpening stone.” [Here he wants to go and find the Figurehead on the bottom and finds it.] “Here’s the lion”, he then goes on to point out various details about it. “Over here is the anchor [Stockankare]”.

Next Jim starts talking about how you might use this for measurements, would you need to keep taking the HMD off to write down the measurements?
I mention it could be built into the experience, you could have a menu where you create measurements.
Jim would rather see a pre-defined list with measurement points which you populate, while in VR.
He mentions things like “Spanntavstånd”, “dimensions, length, width”, “dokumentationstabell”, “Miscellaneous, describing other, maybe unexpected things”.
Jim asks about recording the info by voice?
Jim starts talking about how, here you are not limited by having to follow dive times and feel forced to interrupt what you are doing, here you can take all the time you need.

“Did, I miss something? Just go back and check..” “On this side, the joint is here, is it the same on the other side, easy to check”.

“Hull profiles might be hard in VR”, I then talk about how tools can be developed and added. Jim then starts talking about adding lines in several places to “slice the hull/wreck”.

Jim then comes across a gun port and starts talking about it and describes it, that it used to sit on the wreck but has fallen down. He then goes on to show and describe more things/details on the wreck.

We then finish off; Jim re-iterates how cool it is and that he definitely sees a lot of potential and that not much would be needed to make it very useful. “The things we talked about, including a pre-determined table, which can be added to, which then gets made as a report output”.

“But needs to be simple, most archaeologists are not technical people”.

From that point of view, how does this compare to using for example Agisoft?

“Here, you’re standing in it and it’s more like doing it for real…” Jim re-tells about when making the erroneous measurement in Agisoft.
Have briefly tried VR before but long ago.

What do you use 3D models for today: Ortophoto, recifying with GPS and measurements, then using it in GIS program, thereby adding a grid of coordinates on the wreck.

GPS on bouyes on Stern and Bow, then also measurements sticks on the wreck for corrects scale.

Don’t need centimetre precision on the positioning of the wreck. Having the front and back position and the measurement sticks usually is accurate enough.

Example, small wreck done recently, tape measurements put it at 10m long, Agisoft, put it at 10.1m, close enough for what we were doing. Also measured the frame (Spant) and it also was close enough, even if it wasn’t always exact on the centimetre.

Note from researcher: The above answer shows an opinion that the models don’t need to be exact and lower level of details is acceptable.

**Looking at flat 3D models in Sketchfab**

Starting with Anna Maria, then looking at Bodekull.

**Tasks that can be done:**

- If the hull is intact, like Anna Maria, Hull profile and thereby identify which type of ship it is. The shape of the hull can be quite hard to see under water. It can be done by measuring and then drawing the hull/wreck but that would probably take longer time.

- You can analyse construction details, maybe not always on the Sketchfab versions as they are lower resolution but you can on the original models in Agisoft.

The Sketchfab model (Anna Maria), something like this can be used for a somewhat simpler description of the wreck, it’s type, how it’s built and the measurements.

- The purpose of the project, these models were made for, was to bring more attention to the underwater cultural heritage, and for that these models are definitely good enough.

- In some areas we have done, more detailed 3d models of certain aspects or details of the wreck.

- Can use the models for “Kulturmiljöbevakning”

**Looking at the existing Bodekull model on Sketchfab, what kind of RQ can be answered?**

- Standard question for their work: Is this a wreck a “fornlämning” according to the law?

- Look at items, for example what type is the anchor, what type is the winch for the anchor,

By looking at items like that you can then start to roughly get an idea of the age of the
ship/wreck. Mikael is saying that by the things he can see in the model, he can roughly estimate, this wreck to be about 300 years old.

-Length, width, how the hull is constructed, also helps with dating and determining type of ship.

- He then points out in the model, some things which, he says in reality are ceramic vessels, which are often good for dating, due to shapes. You can’t see the items clear enough in the Sketchfab model but Mikael says, that if you could see the photos or a higher resolution model, that would help.

**Talking about time and resource constraints.**

Mikael says, it’s seldom or never in the daily contract work do they have the time and resources to create the models of large intact wrecks. Usually they do a dive, determine, if the wreck is old enough or special enough to be classed as a cultural relic (fornlämning) according to the law and then do a simple description of the wreck. Usually, this documentation methods are photos and video. Sometimes samples are taken from the wood for dating.

The creating of 3D models of larger intact wrecks are so far, only in internal research or public outreach projects.

But smaller more flat wrecks, they have done 3D models of also in contract work.

“It would definitely be good for the archaeological science and research if we could document all the wrecks in detailed 3D but, that’s not reality at the moment”.

**Looking in VR:**

“Imagine if the visibility was like this in the Baltic, it feels rather impressive to be able to stand here and see the wreck like this. It actually really is darned cool.”

“Lets look at the anchor, and see if we can do some dating, ooh, there’s the “floater” for the anchor line”

“Feels like I’m walking around with my diving shoes”.

“Here’s the measurement stick, so then I can measure things based on its scale”

**What is the difference between this and when we looked on the flat screen?**

“Looking at the item, it feels like we can see them better here, like they are somehow bigger, and we can probably describe them better from looking at them like this.”

When Mikael is describing, how he would like to be able to take screenshots/pictures, he says that it feels much easier to look at the things and analyse them because they are big and you see the whole thing.

This feels like a kind of substitute for diving, because here you can look around.

Mikael describes how, when diving a wreck for the first time, they use voice communication to describe and document what they see and take pictures. With this, you could do that after the fact, without stress ("I lugn och ro").
“I hadn’t actually thought that this could be something but, yes. I first thought that this was just some cool thing, but there is actual use in it. You can actually return to the wreck and do further research, construction, details, and items.

Now that I’m standing here, I actually think it could work. But it would need to be a bit higher resolution [Note, Mikael is wearing glasses and the HMD hasn’t been calibrated and precisely fitted for him, he mentioned it’s a bit like walking around with glasses which aren’t quite strong enough. This is something I have myself experienced with my glasses; more adjustment can sometimes make it at least a bit better].”

“Damn, this was super cool! Really!”

“You don’t have to contend with the 5 meter visibility [Note, 5 meter visibility would be considered relatively good in the Baltic].”

**Is this easier than looking at it in Agisoft?**

-I would like to do this and be able to take notes at the same time. When working in Agisoft, you can have the wreck on one monitor and take notes on another.

“This gives a very good overview and it’s big, the screen is so small. There are things that you might not think of when looking at a screen”.

Mikael talks a bit more about scale and how it would be good to have the ability to set the scale, he approximates the scale he currently have to maybe be half scale. [Note. Interesting that there is still a scale perception which is not mentioned when looking at the flat screen].

“Seeing the shape of the bow, here in VR, how it is bowing and everything, is a totally different thing, than seeing it on the flat screen, it is very hard to experience on the screen.”

“Gives a totally different overview, than the screen”

**What tools would you as a underwater archaeologist, wish for in this environment?**

- Be able to measure
- Take screenshots/take pictures of certain things
- Indicator of scale
- Take notes – ability to link to the pictures/screenshots
- Voice recording, when diving a wreck for the first time, they use voice communication to describe and document what they see.
- Set the scale
- Hand lamp
- A “reference library”, where you can see other wrecks from around the world, to be able to compare

If you had access to this kind of equipment, how can you see yourself, using this in your role as UW archaeologist?

“Yes, actually”.

After some prompting, Mikael then talks about that if there was a reference library of 3D models, one could go there to do research and compare models. Things like, where has similar wrecks been found, etc.

“You put this [the HMD] on and dive down on those wrecks, maybe the people there have done cataloguing and dating etc., like we today sometimes do with reference literature. “. I’ve never thought of this at all, but I could actually imagine doing that”

Cooperation around the Baltic, looking at what other have found.
Notes - Pernilla Flyg
Curator, Maritime Museum, SMTM

Have tried a little VR before
Archaeologist - 20 years
8 years in the IT field

Not specialised maritime archaeologist but works at the Swedish National Maritime and Transport Museums as a project manager. Working on among others, the Baltacar project where creating digital 3D models of shipwreck has been a large part of the project, to help with awareness regarding the underwater cultural heritage.

3D models – How is the wreck right now, state
Being able to look at the wreck, without having to dive and be limited by time etc.
Likes the idea of using this as a tool for documentation.

What kind of RQ can you imagine trying to answer with this?
Ship construction but also the events leading to the ship sinking (förlisningsförlopp), e.g. by seeing how the parts are spread and looking at the marks on the seabed.

How detailed/good do the models need to be?
This is a balance, that we haven’t necessarily found. We’re trying to make them as good as possible but sometimes limited by technology and resources.

However, Pernilla feels that the models they are creating at SMTM today are good enough.

Discussing, the ideas around how much the models are allowed to be manipulated.

Pernilla is very focused on the experiential side of things.

Pernilla has a technical background and thinks that measuring and similar tasks, might be done very efficiently in a flat screen environment. But at the same time, she acknowledges that you have to be experienced in, thinking in 3D otherwise measuring in 3D space can be hard.

In VR:
“This is really fun!”
“It’s not supposed to be like for real, that’s what we have VR experience professionals for.”

Differences from flat screen?
“Scale, perspective, you can get a reference of scale.”
“I like to be able to measure things”
“Feels like this has actually been real, you start feeling present, this is a ship which actually sailed once”

What tools would be good to have?

- Something to show, what is raw material and what is “manipulated”
- Measure things
- Have a scale indicator
- Add photos of the items
- Mix in all other forms of documentation, if there are drawings or other material, be able to see those in the experience
- Add in archive material
Notes - Patrik Höglund
Curator, Archaeology Unit, SMTM

– Co-worker to the others and experienced maritime archaeologist, who wanted to quickly try VR while we had the setup there.

Had seen the Dome version of the Mars wreck experience.

In VR
- “Here I’ve been hovering for real, and it’s a bit like this”

Note: The sketchfab experience crashed quite quickly and I could not get it to work, so by suggestion from Marco, Patrik got to see the Mars dive experience, also Marco who’s had extensive experience with the Mars wreck model was in the room.

Considering that Patrik, has never dived Mars and had very little knowledge of the wreck, he could look at the model in the experience and directly start up an engaged archaeological discussion with Marco about what it was they were seeing and what it would and could not be.

What can you imagine doing with this?
Look at ship construction.

How detailed does the model need to be?
Details in general of Bodekull, is ok for the public but the hull is great. He mentions that there is a loss of details but then he goes onto discuss and point out different parts he sees.
He points out the "Ränna" and states "You can do some archaeology here".
Note by researcher: Hence it can obviously be used.

We talk about what you can see in real life versus on the models and Patrik tells about how he found “the second canon” on the Dalarö wreck Bodekull, on his 50th dive on that wreck. That it was almost by chance, looking at just that point, from the right angle and having the knowledge and understanding to be able to see what it was, although it had growth on it etc.

And we talked about that having a tool like 3D models and VR, gets away from having dive time restrictions. Patrik says that such a tool like this would indeed be helpful.
Notes - Marco Alí  
Curator, Cultural Heritage Unit, SMTM

Has used the Mars VR experience rather extensively and also looked at Bodekull in VR.

Marco, didn’t feel that he needed (wanted) to look at the wreck again in VR, there and then. Hence, we just sat down and had more of a semi structured interview/discussion.

Video versus 3D model, you have to watch a video many times to create a mental picture of how everything is connected and create an overview in your mind.

Flat versus VR

In VR, you get to move around like you are used to, it is more like diving, which is natural for uw archaeologists.

Marco feels like VR is better but struggles to put the exact reasons into words, he says things like – “3D models are better than other documentation methods and looking at the models in VR is the best way”. When queried why, he answers, “It’s a richer experience, it’s more real, but I’m not sure, it just feels better and more real.” After some more reasoning, he compares it to controlling a ROV (Remote Operated Vehicle) and he says you get a bigger field of view in the HMD/VR.

How good do the models need to be, to be useful?

“Depends on the RQ, if the question is about the hull shape of Bodekull, then the models they have are perfect.” At least the higher resolution models, Marco mentions that the models they have in Agisoft are much higher quality than the SketchFab version.

If we have a platform, where we can have all the lighting on and we can move around unhindered.

“You get the dive perspective which you are used to, not have to spin it on a screen”.

“You get frustrated, watching ROV videos, you spot something in the periphery, and you can’t go there. With 3D model and VR, you can do like in real life and swim over there”

Tools you would like to have:

- Control lighting
- Take measurements
- Screen Captures, export images
- Platform for making all the material available. Biggest problem at the moment is that there is no such platform.
- Be able to see if two pieces, which are separate, fit together? Where they once, one object?
References

Appendix: Interview with Brendan Foley. (2019, April 4).


Appendix: Interview with Senior forensic technician, National Forensics Centre. (2019, February 20).

Appendix, Interview with Veronica Palm. (2019, February 18).
Appendix:

Interview with Brendan Foley

Ola Karlsson
Dr Brendan Foley, Lund University

Considered 360 video for the Greek site but decided against it as it is just so flat, however mentions that some plane wrecks he’s worked with in the past, might have been good to do in 3D/360 video.

From a scientific point of view - biggest benefit with 3D or 2.5D – In the Greek project, using AUV (Autonomous Underwater Vehicle) to scan and then use SLAM (Simultaneous Localization And Mapping) to build a very detailed and accurate map. This map was later used with iPads in housings and with positioning modules, to plot out things under water and mark where things are etc. Huge time saver at 50-55m depths, so the divers don’t have to work with tape measures etc.

Otherwise big help in showing people.

The general view at DARK Lab (Brendan mentions himself and Nicolo having this view at least), is that it needs to be exact and precise, otherwise it is not science.

However he can also agree that it might to some degree depend on the research question and especially that there is a difference in science and outreach. He again mentions that at the DARK Lab, they are somewhat of purists. Also mentions that you can always downgrade the quality for public viewing but you can upgrade, hence the documentation should be done at highest possible quality.

On being there or not, he says it’s nice from a social point of view to be on the project site but not necessary from a scientific point of view. So much more can be done with AUVs and ROVs (Remote Operated Vehicles), places which are otherwise not accessible can be reached. Sensors of different types can be added. If you’re in a sub looking at something or if you’re using telepresence on a robot on site, is there a difference?

Also comparing to terrestrial arch, often the people doing the analysis is not the ones doing the digging.

On the other hand, often you have the experience that you realise when you get back to office “Why didn’t I...”, for example, turn that rock, look closer at the thing e.t.c and also find that you are missing details.

Speaking about VR experiences, he says that of course it’s not the same as diving or viewing it on a computer but if it is made clear, that it’s not supposed to be the same but something else, maybe there is some value.

Brendan compares the equipment and even the artefacts sometimes to a telephone, it is not the telephone which is interesting, it is the conversations you can have via that telephone, same in archaeology, it is the conclusions and the bigger questions which are interesting.

3D models can be very interesting when looking at artefacts, like amphoras, different ones are styles different depend on where and when they came from but also what the they were supposed to have in them. There were however certain standards, being able to compare these amphoras could open up for new interesting questions.

Brendan some years back suggested an archaeological 3D repository, however holding not just the 3D models but also the raw material, however it takes too much space it was too expensive at the time.

Speaking of level of details again, depending what you do – if you are working with change detection of the degradation of a wreck, then the details must be very precise, so that you don’t claim degradation, when it’s really just flaws in the documentation method.
Researcher take away:

The question on how detailed the models need to bee, seems to split the archaeologists, Brendan is obviously on the side, it needs to be very detailed.

Brendan says there might be some value in viewing in VR as long as it is clear that it is not the same as being there or viewing on computer, it is something else. He seems unsure and doesn’t elaborate on what does values might be.

Big values in 3D, especially for maps and comparing objects.
Appendix:

Interview with Kristin Ilves

Ola Karlsson
Dr Kristin Ilves, Helsinki University

What is the purpose of Archaeology/maritime archaeology for you?

As side note from Kristin: It is different from person to person, one odd thing is that Maritime archaeologists are the only ones who always want to add the “maritime” addition, archaeologists who dig on mountains don’t call themselves mount archaeologists.

The purpose is to understand the humans, to do this we use both material and immaterial sources, source material is always a basis but at the same time we use things like myths and stories and names of places, to get hints and clues, which we can then look into.

The source material will often direct the focus as archaeology is largely about studying empirical evidence. But as mentioned earlier we also factor in other things.

What are your views on reconstruction?

- Raw information vs. interpretation?
- Should we reconstruct, without all the data, what if we make the wrong assumptions?
- Purpose of reconstructions?

Depends on the research question, based on the research question, you look at what material is available and suitable.

Sometimes you can answer your research question, just based on looking at reconstructions, while for other questions, you have to look at the raw/primary material.

Regarding speculations when doing reconstructions: What you have to remember, is that archaeology is not history. Often, we don’t know things for sure and we have to speculate/interpret things based on the material we have and the knowledge we have. Just looking at shards from a broken pot is not interesting, it must be put into a bigger context and one way of doing so is be reconstructing things.

We then spoke about historic versus pre-historic archaeology, where pre-historic is the time before written material. In pre-historic, we have no other source of information, so then we have to make guesses and assumptions based on the material we have and our own knowledge.

Specifically talking about wrecks, is it important to visit the wreck yourself, or is documentation from others just as good? What is the difference?

Of course, it is exiting and fun if you are the first one to find something.

And yes there might be a certain added value to being on the site, especially for bigger things but not so much for smaller objects.

Kristin also feels that it depends on where you are coming from, for example when I mention that Jon Adams talks about the experience and feelings of being there on the wreck as a big thing for the archaeological work, she point out that he comes from a background both as a diver but also as an artist (painter?) and that this will colour his view on something like that.
What is your workflow?
Everything starts with the research question.
Landscape survey – Looking around get the general area
Finding and measuring – Zig zag photo documentation / sketching
Write report

Raw material versus interpreted material
When looking at interpreted material, you are looking for holes which need to be filled in.

What is the purpose with the repository you propose?
Looking at citizen science for example in England they have the Portable Antiquities Scheme, which makes it easy for the public to submit anything they find. This has resulted in over 400 scientific papers. Increased access to research material, lead to increased research.
Also for public outreach and for divers but primarily for researchers.

The difference in a public viewer and a scientific viewer?
Both are probably to inspire but in different ways, the scientific/research one would have more details and let people explore their research questions. See details they might not have seen and find more questions.

Regarding the level of detail:
Again depends on the research question.
--But for example, when talking to for example Mikko Huhtamies (Maritime historian at Helsinki University), he doesn’t care about the finest details, more about where something is in relation to something else or of something is present or not.

Problems with Sketchfab
The user interface it hard to use, hard to get the right view.
Limited in the quality [Ola Note – unsure if this is true and if so what is the limitation].
Going more and more commercial.
Can’t download models.

Working with others or individually?
At digs, there’s always a team however in the analysis and research part, often alone.
Would like more collaboration regarding research questions and the bigger picture.
Your thoughts on immersive visualisations?

Better when you can zoom etc.

Dimensions matter on shipwrecks, which might be good for VR.

You can take your time, no stress getting it done. Can look at things from different angles etc.

VR might be good for interest in cultural heritage and for non destructive archaeology.

VR might also be useful in teaching archaeology, again since it is non destructive.
Appendix:

Interview with Niklas Eriksson

Ola Karlsson
Niklas Eriksson is one of the leading maritime archaeologists in Sweden when it comes to sketching and drawing shipwrecks. He also does a lot of work around the space in ships, what can be called the architecture. How was space divided on a ship, how did that effect the crew and the interaction of the crew and how did that reflect the society of the time.

1. How do you document a wreck?

Very much depends on the questions I’m asking and what I’m looking at/ for.
Head mounted video camera when diving, turn on when entering water, let run all of the dive. If there are clear land marks or features on the wreck, follow those, otherwise place measuring tapes or similar to follow.
Takes underwater notes and some drawing.

Then do sketches when at home or the office based on the material collected on site.

2. Can everybody do sketching?

IT’s an older technique, older archaeologists always used to do it. However the digital recording is a type of “sketching” because you choose what to record or measure.

**Big things with sketching is that based on your research question or your purpose, you choose what to include in the sketch.** In a photogrammetry mosaic or model, there is soo much information and details that it is often hard to see the things you are looking for or that you want to communicate. In sketching you choose based on your question and your knowledge.

3. Being on the wreck vs seeing it on recorded media?

There is no benefit of being on the wreck, that time is only information recording. The thinking/understanding and break throughs happen at home when analysing the material and making the sketches.
At the site, you are limited by visual distortions, visibility, possibly not being fully comfortable in the dive equipment etc.
But then he mentions, that there are two types of archaeologists, the ones which love to go out exploring, trekking through the wilderness and the ones, which prefer to sit at the office and do research and think through things there and he firmly puts himself in the office type.

Also talks about how UW arch and wrecks are different from archaeological istes on land, for example the houses at Skansen. Walking around those houses, you can get a feeling for what it might have been like, where as a shipwreck is totally different as it is broken up etc.

I then asked about the “Ghost ship” wreck and, how about a VR experience letting you be in the small cabin where the crew lived with a low ceiling etc. to feel what it was like.
Eriksson, does not seem sold on the idea. There is too little information about how it looked inside the wrecks and a reconstruction where someone is guessing at that, might give totally wrong messages, leading to wrong conclusions.
4. Photogrammetry mosaics or 3D models as base for sketching?
   Eriksson believes this is the future but doesn’t really see any point in using VR for this but also acknowledges that, this might be because he is a bit old fashioned.

5. How about analysis and reconstruction?
   Eriksson strongly prefers, the raw wreck material instead of reconstructions. Reconstruction is interpretation and He does not want someone else’s interpretation, he wants to draw his own conclusions based on his own knowledge.
   Hence when documenting or doing reconstruction, he is for leaving “white holes”, where data or information is missing.
   He makes the analogy of reading a book vs watching a movie, filling in with your mind, vs someone else’s interpretation.

   Eriksson prefers looking at plans and sketches and measurements and then envisaging the room/space.

Other things that came up

Historically, too much focus has been on the methodology and technology, with these new techniques (like photogrammetry and 3D models) making wrecks and the like more accessible, Eriksson says that maritime/UW archaeologists can finally focus on being the humanists, they are supposed to be.

Eriksson mentions a couple of papers/reports which might be of interest.


Enqvist, Delia Ni Chiobhain, 2018 - Digital Maritime Sights: Digital visual documentation and communication in Scandinavian contract maritime archaeology

Eriksdotter, Gunhild; Anglert, Mats, 2018 - Människor byggnader sammanhang : Idéskrift om en utvecklad byggnadsarkeologi

Summary/Take away

Eriksson uses sketching both as documentation and analysis. He selectively chooses what to include in the sketch, based on the research question at hand.

He does not currently see any use for VR in the analysis but acknowledges that, this might be because he is somewhat of a traditionalist.

He sees photogrammetry as potentially useful as a material to base sketches on, he does not see photogrammetry mosaics or 3D models as the end visualisation as they most often include much, too much details. He however hopes that with the use of new technology increasing to document the wrecks and making them accessible to larger audiences, maritime archaeologists can focus more on the humanistic side of things and move away from the methodology discussions.

He does not want reconstruction, he prefers to see the bare wreck, so he can interpret based on his knowledge.
He does not feel that there is any benefit to be onsite by the wreck, the view is distorted and the persons attention is distracted by equipment and environment etc.
Appendix:

Interview with Riikka Tevali

Ola Karlsson
Riikka Tevali, Researcher at Helsinki University and the Finnish Heritage Board

**What is the purpose of archaeology and maritime archaeology for you?**

[I had to elaborate and mention focus on things vs anthropology]

This is probably different for the individual archaeologist, but the view that archaeology is more of an anthropology science comes from the US and here in Europe it has historically been more that archaeology and UW archaeology is more of methods, that their own science.

The trend is going towards looking at the bigger picture and how archaeology can help us understand the past and people.

Also largely dependent on the project, why you are doing it. This is often controlled by the funding.

**What type of projects do you most often work on?**

Riika have worked on both research and commercial. When working with commercial arch, you have to often strictly limit yourself to what the contract says and what the law demands.

From a research point of view, it has gone in Finland, from being the government funding most projects, to now also include EU, universities and funds.

**Do you generally work alone or together with other researchers?**

Always with others, the maritime archaeology is such a small field that we always work in groups. Also often need to ask other for input, you can’t know everything yourself. Often international teams, in Finland, the shipwrecks are very seldom Finish, but instead, Dutch, German or Swedish, hence makes sense to work together.

Always cross disciplinary teams, researchers from different fields, technicians, engineers, divers, etc.

**How large part of archaeology is the outreach to the public?**

At the end, all projects. Again maritime and uw arch is a small field. There is no sense in us creating knowledge just for ourselves, it is meant to be shared.

Also in Finland a lot of UW arch is done with the help of volunteers. Many hobby divers send in their photos and videos, hence the relationship with them is important.

**What’s the hardest in UW archaeology?**

Funding, time, resources, depth...

But beside that, strangely enough, the intactness of the wrecks. A degraded, broken apart wreck is much easier to examine, they often break from the keel and split apart making int easy to view the structure and layers of building. Intact wrecks can be easier to date and see from where or when they were but harder to analyse how they were built, as it is very hard to see inside.
What is your view of reconstructions?

You only do a full reconstruction if you do a full excavation and take apart the wreck to see all the details. You have to get down to the keel, to see how everything’s been built up from there.

You can make some deductions and educated guesses but still best to work from the keel and up.

However another source of information for reconstructions, could be ship models which have been built by real ship builders, like the Ebersdorf Ship model


You need computer programs for reconstructions, 2D drawings are not enough.

However, do not agree with the idea that we should not do reconstructions because we didn’t have enough data. We have to make educated guesses and deductions, this would stimulate discussion between different archaeologist.

We have to experiment and try things, otherwise we cannot move forward. We must of course though clearly mark what is fact/raw data and what is deductions/guesses.

Researchers should look at both raw data and interpretations from other scientists.

We will always have to involve modern thinking in our interpretations as we don’t know how it was done, but this points out problems and things we don’t know and need to research more.

I’ve read about the concept of sensory archaeology, does it matter to be (or have been) on the wreck for you?

Yes, because if you only look at material others have gathered it gets very frustrating if you want to look closer at something and they have not recorded that bit. Have even worked where diver is on wreck with head mounted camera with direct feed up to ship and radio com but even then there is frustration, having to try and tell them what to look at and how to move.

Also you can only see a fraction and it is hard to imagine/visualise the whole when only seeing little bits. Could be alleviated with 3D models but still think there is “something special”, having visited the wreck.

Training of UW archaeology?

Training can be quite hard, you must learn what things might look like under water and having been degraded, so you can then spot potential interesting finds.

In a spot in England, then have funded an excavation by turning it into a training site.

Using 3D or similar, so you don’t have to go back down to the site, would be very useful.

Your thoughts on 3D and immersive?

[As Riikka and I had already spoken briefly about these things and the workshop we met at was about these things, I included this question.]
Simulations of how the ships might have behaved and what it was like on the ships would be very interesting, comparing different ship types on performance.

The choices shipbuilders made, being able to have a “explode” view of something and see how it looks inside

Summary/Takeaway

Although. She doesn’t say so straight out, looking back, Riika seems to put a lot of focus on how ships are built and which choices were made.

Laws around the depth of diving is often prohibiting uw archaeologists, diving on some wrecks themselves. Have to contract in deep divers or get material from volunteers.

The law in Finland says, everything which is excavated (and thereby destroyed) must be carefully documented, so that it can later be used.

Cost is always an issue, not just in commercial but also in research, this among other things leads to archaeologists maybe don’t invest in learning new tech, as “the old ways work”. However, this can also become a push to do things more efficiently (for example with digital aids)

It is very hard to see inside wrecks, they don’t like going inside from a risk of damaging the wrecks, also risks for the diver and equipment, if cameras are poked inside, they might get tangled. But often there are not big enough holes to get equipment in and get decent photos. This makes it hard to analyse how they were built.

Not possible for one person to know everything, must collaborate.

Main things where immersive vis might be useful:

- **Training**
  Takes years to learn to visualise for one self, hence tools for this would be helpful in training
- **Showing**
- **Build big picture**
- **Understanding**
  For example, almost nobody is allowed inside Vasa, would be wonderful to experience that. Using VR to get a feeling for something, archaeologists are humans and humans get better understanding through immersion
Appendix:

Interview with

Senior forensic technician,

National Forensics Centre

Ola Karlsson
Benefits

- Investigators today put a lot of energy into arranging and sorting pictures from a crime scene. With 3D and VR they can get a direct full copy of the crime scene.
- Investigator get a much better and realistic feeling for a room or a space, for example is it plausible that event X happened in this space, is there enough room?
- Easier to imagine and follow/reconstruct events in a 3D space of the scene, than doing it with puzzling together photos. Also showing angles and line of sight etc.
- The models are not only used for investigation but also for showing in court. Again easier for everyone to get a realistic feeling for the scene.
- Stepping into someone else's shoes/perspective
- De-dramatize - one of the unintended uses has been in a gruesome case where the photos from the real crime scene, where to graphical to show in an open court. Images and videos rendered from a 3D model could be used instead, showing events and placements of things etc.

How to show

In the work today most of the work is done by rendering images or video from the models, not actually showing the models themselves. An investigator might for example ask for an image from where a witness was standing, rendered with the camera at the height of the witness eye level, so that they can see what the witness would have been able to see.

Recording of data

The recording is done either with laser scanning or photogrammetry, laser scanning. I got the impression that laser is preferred but if nothing else, photogrammetry can also be used. NFC are working on guides for how to best collect photogrammetry data (take photos, which can be used for photogrammetry)

General benefits with recording a scene

Storing of data

There is a goal that in the not too distant future (1-2 years?), every more substantial crime (grövre brott), should have the crime scene recorded as a point cloud as part of the documentation.

Benefits with this is that you can go back and look at the scene at any point in time.

Most of the time, not the full scene is rendered and stored but instead stored in its point cloud format.

In general, they store data from different sensors in the original sensor format, trusting that the manufacturer will continue to provide support for that format. Unfortunately the sensor manufacturers often use proprietary formats, locking the users in.

Tools

The NFC has looked at a number of tools but for now, they use the software for viewing and manipulation provided by the manufacturer of the laser scanning equipment. Things like measuring distance is simple and as this is a big thing in forensics, there are also plugins to buy for various more complex things like calculating and visualising bullet trajectories or analysing patterns in "blood splatter". You can also link in 2D images provided and match them into the environment.
Issues

Needs training
Interviewee mentions how one of the biggest problems, is that he feels that investigators have to have special training, to be aware of possible issues in the models like artefacts, which might not have been there in reality but is an artefact from the digital processing.

Quality
There is a risk of creating something which might give the wrong impression. When rendering videos or images, the technicians must make sure they are objective and not put their own interpretations or biases into what the produce.
Appendix:

Interview with Veronica Palm

Ola Karlsson
Quality and format of primary/raw data
Discussed difference between primary/raw source material and manipulated material. If things like 3D models are to become the primary source material, it has to have good enough resolution to then be used. It is her feeling that this is not the case today. Need to have a standardised procedure for recording the raw material and format to store it, neither is there today. Need to be precise enough to use for measurements. People are creating photogrammetry models and uploading to Sketchfab as a fun, cool thing but most people don’t know how to create them in high quality and they don’t know what to use them for afterwards.

Research vs "Commercial" archaeology
Difference between archaeology for research and "commercial archaeology" where archaeologists are called in to record an area or a site when there is exploitation happening, like building or roadworks. In those kind of projects, resources are often very constrained as the company in charge of the building are the ones paying. Then it is the job of the archaeologist to record things according to a standardised procedure. For example photogrammetry is not part of the standard procedure and Veronica, thinks it would be hard to convince the companies to pay for it.
There is almost never any financial resources for further research in the cases of commercial assignments, hence things just get documented according to the standards but never analysed of displayed.

Reconstruction
As part of science research, find might be reconstructed and 3D models can be useful for this. In experimental archaeology, archaeologists even go as far as physically reconstructing things, using old methods to test what was possible. Veronica things that in their cases they might find 3D models and VR interesting.

Archaeology - 3 steps
1. Collecting data and Documentation - this generates what's called Primärdokumentation (primary documentation), this is the raw "objective" data.
2. Data manipulation and Analysis - the raw data is interpreted and maybe reconstructions are done based on the raw data together with other information. Analysis is done.
3. Displaying - creating a display in a museum
In the case or immersive visualisations, it is easy to fall straight into the display step.

3D models underwater
In regards to underwater, Veronica definitely see a great benefit in using 3D models as it is most often very hard to get an overview of a wreck site in reality, due to for example poor visibility, plus also, you can twist and turn and zoom.
2D Video only shows parts at the time and photos are also impaired by the visibility and are 2D. Veronica mentions that maybe 3D models are not as useful on land as there you can get the overview much easier for example with drome photos or video.
**Immersive experience UW**

She is unsure what the benefits would be of having an immersive experience vs just a more standard computer setup. But she is also open to the fact that maybe it’s just because it feels very foreign.

**Tools**

Veronica mentions that in the GIS (Geographical Information Systems), they use, it is very useful to be able to mark things (Annotate? Tag?) and thereby creating almost layers. For example, all these things are from the years of XXX and all of these things are from years YYY or these things are metal and these things are wood end so on. This allows to show and hide various types of things and use that in analysis.

We discussed what would more be useful, possibly both in GIS and VR, for example zooming in on something and then exporting an image of that.

When Ingemar Lundgren also joined the discussion, they both agreed that a tool which could "reverse-engineer" a 3D model built with photogrammetry, so that you could select an object and the tool would show the original still images which were used by the software to create that particular 3D object or part of an object. This would be very useful for quality assurance and check the original "raw data", to make sure there are no distortions or artefacts or if the 3D model is not precise enough or lacking in some detail.

**Future?**

Veronica thinks that immersive visualisations and VR might be the future but it is hard to imagine as it feels very far away from where they are now.

Researcher reflective Note - Some people are starting to use VR to get their own personal giant screen to watch movies, instead of buying a large TV, is there a benefit there?
Appendix, Accessing the deep info

The invitation to the workshop Accessing the deep with information about the program and who participated. This is included as a appendix here as it is not available online.

ACCESSING THE DEEP WORKSHOP
26 - 27 February 2019, University of Helsinki, Archaeology, ArlaPro, Unioninkatu 38 F (ground floor)

Tuesday, 26th of February

09:30  Arrival and coffee
10:00  Agenda and tour the table
10:15  Kristin Ives, UH: Accessing the Deep – vision
10:45  Minna Kolvikko, Finnish Heritage Agency: I have a Digital Dream, visualizing the future of shipwrecks
11:15  Mikko Huhtamies, UH: Wrecks in the archives and on the seabed
11:45  Marcus Lepola, The Maritime Museum of Finland: Beneath the red waves and into the digital: challenges and opportunities of modern museum exhibitions
12:15  Brandon Mason, Maritime Archaeology Trust: Forgotten Wrecks of the First World War – virtually in context

13:00  Lunch at Bryggeri Helsinki (Sofiankatu 2)

14:30  Cessa Rauch, University Museum of Bergen: Sea slugs of Southern Norway; an example of citizens contributing to science
15:15  Suzie Thomas, UH: Crowdsourcing the portable past: developing a finds recording platform for metal detectorists and other finders in Finland
16:00  Discussion slot
17:00  Ending

17:00  Drinks @ Kaisla (Vilhonkatu 4/Vuorikatu 16) (or free time)
19:00  Dinner at Restaurant Kosmos (Kalevankatu 3)
Wednesday, 27th of February

09:30  Coffee
10:00  Nicolò Dell’Unno, Lund University: Brainstorming the Virtual: Exploring Complex Archaeological Environments Using 3D Visualization Technology
10:45  Chris Rowland, University of Dundee: Maritime Heritage: Visualizing the Invisible
11:30  Jon Henderson, University of Nottingham: 3D presentation of underwater cultural heritage: challenges, opportunities and future prospects
12:15  Discussion slot

13:00  Lunch @ Kappeli (Eteläesplanadi 1)

14:30  Daniel Löwenborg, Disir Productions AB: Virtual Reality and Augmented History - some examples of presenting archaeological research with digital technologies
15:15  Timo Korkalainen, CTRL reality: Immersive collaboration in VR
16:00  Demonstrations and discussion slot
17:00  the End

PARTICIPANTS

Brandon Mason, Maritime Archaeology Trust
Cessa Rauch, University Museum of Bergen
Chris Rowland, University of Dundee
Daniel Löwenborg, Disir Productions AB
Jan-Erik Engren, University of Helsinki
Jon Henderson, University of Nottingham
Kalle Virtanen, University of Helsinki
Kari Hyttinen, University of Dundee
Kristin Ilves, University of Helsinki
Laura Johansson, (University of Southampton)
Marcus Lepola, The Maritime Museum of Finland

Markku Luoto, Finnish Maritime Archaeological Society
Mikko Huhtamies, University of Helsinki
Minna Koivistok, Finnish Heritage Agency
Nicolò Dell’Unno, Lund University
Ola Karlsson, Linköping University
Pasi Lamm, Suunto Oy
Riikka Tovari, Finnish Heritage Agency
Sanna Siltanen, Hylly.net
Suzie Thomas, University of Helsinki
Timo Korkalainen, CTRL reality
Wesa Perttula, University of Helsinki

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If you have any questions regarding the workshop, please do not hesitate to contact either one of us:

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