3D Scanning of Heritage Artifacts as an Interactive Experience: Creating a Window into the Past

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3D Scanning of Heritage Artifacts as an Interactive Experience - Creating a Window into the Past

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ABSTRACT
This paper looks at innovative methods in the capture of high quality 3D detail from historical artifacts. These forensically accurate details are then applied for use in building engaging interactive entertainment outcomes. The Mephisto, the only remaining German tank from the First World War, was used a case study to examine the methods available to accurately record a large and iconic piece of war history. This paper introduces 3D scanning workflows as a method to create an accurate three dimensional model of Mephisto, and also addresses how the high quality information from the tank can preserve, and also allow for analysis and presentation of Mephisto in ways that have never been seen before. Combining 3D scanning workflows with forensic analysis and historical war records, this paper explores the possibilities of how to best communicate and present this 3D information through interactive and virtual realities. It describes how augmented and virtual realities can create a window into the past, possibly answering some of the questions surrounding the tank, its story, and allowing visitors an interactive user experience bringing realism and truth to a historically accurate digital tank. Thus building a powerful mechanism for communicating history through innovative capture and presentation techniques.

Categories and Subject Descriptors
• Human-centered computing ~ Human computer interaction (HCI) • Human-centered computing ~ Virtual reality • Human-centered computing ~ Visualization

Keywords
3-Dimensional; 3D Scanning; Heritage Preservation; Forensics; War History; Virtual Reality; Augmented Reality; Interactive Experience; Interactive Realities.
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1. INTRODUCTION
What happened to the German tank known as Mephisto has been scrutinized for almost 100 years, but research may help put an end to the speculation and take the public inside the tank, for an interactive digital experience, for the first time.
The Mephisto was immobilized in the area close to Villers-Bretonneux called Monument Wood in France when it became lodged in a shell crater during the First World War. The Germans were unable to recover Mephisto, so it remained stranded until July 1918 when Australian troops of the 26th Battalion AIF, which was composed mainly of Queenslanders, eventually regained the lost ground and pushed the Allied front line past Mephisto's position [1].

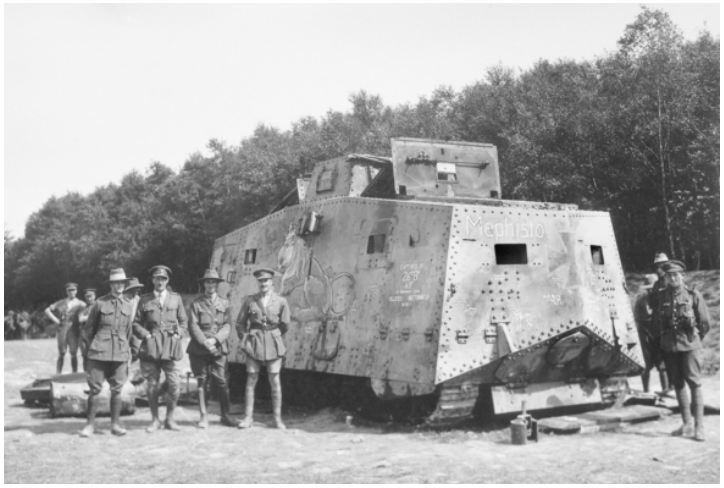

Figure 1. Mephisto after its retrieval during WWI [2]

As a result the battalion's commander ordered the retrieval of Mephisto (Figure 1.) and it was sent to Australia as a war souvenir. It is currently the sole surviving A7V tank in the world and many people have a memory of the Mephisto from seeing it on display at the Queensland Museum, where it was housed, in open air, for many years. However, due to its historical significance, it now sits in an air tight preservation bubble (Figure 2.) and very few people are allowed to get close and personal with Mephisto, and even less have had the opportunity to experience the tank from the inside. The potential for digital capture and display, through interactive augmented or virtual reality systems offers potential to enable this historically important item to become more accessible.

1.2 Recent Conservation Efforts

Over the past thirty years the Queensland Museum has made considerable effort to analyze and preserve Mephisto. A number of laboratory investigations including metallurgical analysis, paint colour testing and composition sampling have been undertaken.

Mark Clayton, Senior Curator of Social History at Queensland Museum suggests "In more recent years the Museum's scientific focus has shifted more towards conservation and archaeology, both of which remain central preoccupations. While the former has always been an overriding interest, the 2011 Brisbane Flood led us to dramatically increase our efforts in this direction" [2]

Figure 2. Mephisto on display at Queensland Museum [2]

2. Digital Revolution in Capture

Chris Little explains 3D scanning as a non-contact method of "digitally importing the physical shape of an object as three-dimensional information. This accurately defines the size, shape and colour of a real world surface as a computer generated model." Whether time of flight or phase based, a vertical strip of laser leaves the scanner, hits the object and returns to the scanner. This information is recorded as three-dimensional points known as point-cloud [3,7]. He also suggests 3D scanning began "in the 1960's, where lights, cameras and projectors were used to create the first 3D scanning technology. Originally used as a measuring tool by surveyors and engineers, this was replaced with white light and lasers in the late 1980's and Cyra Technologies [now known as Leica Geosystems] was founded in 1993 and produced one of the first commercial scanning systems." [3].

2.1 Digital Heritage Preservation

No longer is 3D scanning used only for reverse engineering and quality assurance. The 3D design and innovation space is constantly developing and improving with technology becoming smaller, more affordable and easier to use. This has introduced digital 3D scanning systems to several emerging fields where traditional methods of data recording may soon become obsolete. One of particular interest is the area of Archaeology and Digital Heritage Preservation where the application of 3D scanning and digital photogrammetry are being used to capture irreplaceable items from the past. The capture alone is a valuable piece in the preservation of this knowledge, but the potential to extend beyond capture, to create interactive experience, could bring these historical relics to life for a much larger audience.

2.2 Smithsonian Institute Digitization Program Office

As part of the Smithsonian Institute, the Digitization Program Office carries out digital preservation activities for significant artifacts of differing scales. This office "uses a variety of 3D scanning tools and techniques to capture the geometric and colour information of Smithsonian objects and scientific research sites and is an integral process for their archiving and presentation of 3D information." [4]. The Digitization Program Office provides information from completed 3D models through their X3D web based viewing platform [www.3d.si.edu] to enable a broader audience to access these valuable pieces of history [8]. The key objectives of this capture and online delivery system are to:

- Allow schools to freely download and 3D print iconic Smithsonian objects in the classroom
- Provide new measurement tools for research
- Provide conservators a condition report for Smithsonian objects

The Smithsonian Institute also explains how "the Digitization Program Office is also involved with advanced 3D scanning and modelling techniques for the future, such as the "Next Generation 3D Portraiture: A Digital Life Mask of President Obama" (Figure 3.) where Barak Obama is the first presidential portrait created from 3D scan data. Using two hand held structured light scanners, 8 DSLR's and 50 light sources mounted on a frame, the president sat still for 90 seconds of data capture producing a 3D model and 80 high resolution images." [4]

Figure 3. Next Generation 3D Portraiture: A Digital Life Mask of President Obama 3D printed model [4]

2.4 The CyArk 500 Challenge

CyArk is a not for profit organization involved in the conservation of valuable world history through digital technologies. Their main concern is in the preservation and capture of the world's heritage sites and they state that:

> *"heritage sites are a significant part of our collective memory and we are losing them at an alarming rate. The stories they tell are at risk" [5].*

With the help of scanning experts around the world and collaboration with industry giants such as Google and Leica Geosystems, Cyark's vision is to 3D scan 500 heritage sites within 5 years.

CyArk has already completed 40 projects toward its goal of 500. These sites, called the Exemplar Projects include Pompeii, Babylon, Mt. Rushmore (Figure 4 & 5), the Leaning Tower of Pisa, the Titanic, the Sydney Opera House and, most recently, the Tower of London [5].

2.3 The Historical Scotland Digital Documentation Team

The Scottish Ten is a 3D scanning project to digitally document Scotland's five World Heritage Sites and also five international World Heritage Sites. These sites include:

- New Lanark
- Orkney
- Antoine Wall
- St Kilda
- Edinburgh
- Mount Rushmore
- Rani ki Vav
- Eastern Qing Tombs
- Sydney Opera House
- Nagasaki

In partnership with Cyark, the Scottish Government has provided critically important support through a mix of heritage, survey and visualization experts. To ensure the best possible results these teams have come together (and continue to do so) using a variety of mid-range and long range scanners combined with digital photogrammetry to deliver accurate terrain and building models to a very high level of detail. The 3D data sets for these large environment based projects are extremely large, and the need for smart file management and efficient data post-processing workflows are critical to the final outcome.

To achieve this the project has had 2 key phases. In phase 1 the data capture and acquisition is the focus, where in phase 2 data visualization and dissemination of knowledge, through engaging interactive experience, is the focus. As outlined in the project:

> *"Phase 1 of the Scottish Ten projects has focused on fieldwork for each of the ten sites, and production of basic deliverables including geo-referenced registered pointcloud, 3D images and animations. The main objective of this phase has been data acquisition to create an accurate 3D record of information." [6].*

> *"Phase 2 of the Scottish Ten project will focus on re-purposing of Scottish Ten digital assets to be used for research, dissemination, learning and engagement. This will involve the use of mobile apps, augmented reality and virtual reality viewers." [6]*

Figure 4. Practically scanning Mt Rushmore [7]

Figure 5. 3D Scans of Mount Rushmore [7]

2.4 Interactivity - Bringing Life to History

The potential to apply technology based interaction techniques, including online interactions, games and VR/AR systems, to deliver access to these historical datasets for a broad audience is evident. From the earliest days of computer games and virtual reality, the ability to place the user in an artificial space built or modeled on real world history has been actively pursued. In fact the use of "iconic" historical sites is common in both early and modern computer games [9,10]. The ability for an immersive computer game, or VR environment, to place the user in an unreal, yet believable space is potentially a powerful tool to address the loss of our historic sites, and more importantly their stories, as outlined in the Cyark quote (see section 2.4).

Virtual Archaelogy or Virtual Heritage, is a well established field with many examples of visualizations of history going back to the earliest computer graphics based systems. As computing, and particularly rendering power, has increased, examples of highly realistic immersive historical environments, contained within interactive games has also increased. Interactive games range from those directly based on the history and its interactive visualization [11,12,13,16] through to many others that simply utilize environments that are rich in history (or historical references, such as the gothic or medieval styles of many role-playing games (RPGs). Such games utilize our human understanding of history to help place players in a believable virtual story, the historic elements accuracy helps to make this experience more immersive and engaging for a range of (perhaps not based in true history) forms of play [14,15,16,17].

As developers of rich interactive systems, the value of realistic and engaging environments is critical. Photorealistic, or close to, virtual worlds are becoming more common, yet the time required to digitally design and construct these more and more complex worlds, and the props/items within those worlds, presents a challenge for modern game developers. Automated content creation tools, such as l-systems, shape grammars, fractal and other rule-based techniques allow for the quick, automated creation of rich content [18,19,20,21]. These tools are effective in building realistic and rich content, yet these automated items/spaces lack reference to identifiable real world entities and their history, which we as humans often value. There is a clear need for systems that enable developers to more quickly obtain "real-world" items/environments to enrich virtual spaces, yet current systems for capture and workflow are complex and comparatively slow (note how the Scottish Ten project (involving many highly skilled members) has only targeted 10 sites).

2.5 Interactive Engagement

Virtual archaeology and history have evolved from 2 slightly different perspectives [22]. The first, based in information capture and presentation, involving obtaining, documenting and at the highest quality, recording and preserving the key information and data. In simple terms, this perspective involves getting and recording the artifacts accurately for future use. The second perspective, based in entertainment and distribution of knowledge, involved the development of interactive ways of enabling users to experience the history. The work of the teams from the Smithsonian, Cyark and Scottish Ten are all good examples of the capture oriented approach, where the computer games and VR simulations (such as historical strategy or RPG) are all good examples of the entertainment based approach. One of the challenges for virtual archaeology is bringing these two fields together. Enabling interactive entertainment to be able to utilize the historical data, including both the raw scan information as well as other related knowledge (which plays a key role in telling the stories of what happened). This research project looked at workflow processes to enable highly accurate data to be captured and analyzed, to help tell the story of how specific historic events unfolded, then extending into the use of that information for interactive experience, utilizing virtual systems to make best use of interactive and play based systems to engage users [23,24].

3. WORKFLOW METHODOLOGY

At the heart of developing effective mechanisms to enable these "real world" sites and items to be captured, and delivered to an audience, is the core workflow of accurately capturing both the data and the related information that builds the full story. Then using that full set of information to create engaging and interactive visualizations, like those described previously.

3.1 Planning The Workflow

There are four main steps in the 3D scanning process:

Capture => Processing => Analysis => Presentation

Understanding how to 3D scan these objects is only the first step in producing an accurate, workable deliverable to a client and the point cloud always looks beautiful in its native scanning software. [3]. To "Plan the Scan", in helping determine the best type of scanner and workflow required before 3D scanning the following needs to be considered:

1) What it is that being scanned (and are their restrictions on what can be used)
2) What information are we wanting the extract from the 3D scan data or what is the end deliverable
3) What is the accuracy required
4) How to best communicate the 3D scan to others

3.2 Capture - 3D Scanning The Mephisto

To commemorate the WWI centenary, the Mephisto was temporarily relocated to the Australian War Memorial. As part of Queensland Museum's ongoing effort to preserve the tank, while away from its resting place 3D scans were taken of Mephisto before and after its journey to Canberra. These 3D scans of Mephisto were in order to assess any possible damage to the tank during transit.

Upon examination of this original 3D scan data it was agreed that the data captured, while taken for a specific purpose, and while fulfilling their original brief, was incomplete and did not contain sufficient information as a basis for a complete, and archaeologically useful three-dimensional model of Mephisto. The initial 3D information scanned from the tank did not include the level of detail required for such a significant piece of war history, however the initial scan data did become the topic of conversation. This lead to discussion on how to best utilize these 3D scanning workflows for the tank to become a digital heritage piece for the Queensland Museum. Through these discussions exciting new possibilities were able to be developed for the virtual version of Mephisto.

3.2.1 Mephisto - What was being scanned?

Mephisto is the remains, post WW1 war damage, of an A7V tank (the last of its kind in existence) and measures 7.3 metres long, 3 metres wide, with a height of 3.3 metres. Because of its overall size, shape and material type, the tank was best suited to 3D scanning with a mid-range, phase based laser scanner. The tanks exterior including all sides, the roof and undercarriage are scanned using this method. This would create the base geometry with an accuracy of approximately 2mm (good for many uses eg. in game but perhaps not detailed enough for preservation of detaiailed damage). A hand-held structured light scanner is a very portable system and is used to also 3D scan the inside of Mephisto and any blind spots or missing information not included in the base model scan data (including high detail areas).

3.3 Processing - Scan data & Deliverables

Through conversation with Senior Curators at Queensland Museum there were a range of possible outcomes that they targeted relating to the 3D scanning of Mephisto:

- Accurate information vaulted, recorded and documented
- Interactive augmented reality experience at Queensland Museum
- Interactive virtual reality experience at Queensland Museum
- Web based viewing and schools access for teaching
- Deterioration comparisons for condition reporting
- As built information
- 3D printing
- Forensic analysis of the explosion to the roof
- Bullet trajectory analysis

These target outcomes very closely align with many virtual archaeology projects, with accurate capture and recording playing a key role, but also interactive entertainment (through VR/AR and related systems) and its use in better presenting and understanding the story of what occurred.

The forensic analysis plays an interesting role in the later, particularly from the entertainment perspective. Through the 3D scanning/capture element very high quality data is obtained. Such data, through the analysis of bullet holes and related physical damage, can be used to forensically analyze the trajectory of indvidual bullets and through this information, when placed in a VR simulation, to help replay the scenario (the story) of what occurred to the Mephisto in its final battle.

3.3.1 How much accuracy is required?

The end deliverables and the amount of information they require (for example the VR system may not require super high accuracy, but the forensic analysis does require extremely high accuracy to enable trajectories to be established) plays a critical role in determining the accuracy required for the 3D scan data. Scan data accuracy is critical, in capturing most historically significant

items. Not only because of extremely limited access to the item (in this case the tank (see Figure 2)) but also the 3D scans of Mephisto will be vaulted, recorded and documented for heritage preservation and war history. While the mid-range laser scanner provides the Queensland Museum with a sufficient data set for an interactive display, it does not have the level of accuracy required to capture fine detail for forensics such as bullet markings (Figure 6.) and the explosion to the roof of the tank (Figure 7.). This required scanning with a high-resolution hand held scanner with 0.1 millimetre accuracy.

Figure 6. Bullet and shell fragment scars to side of the tank [2]

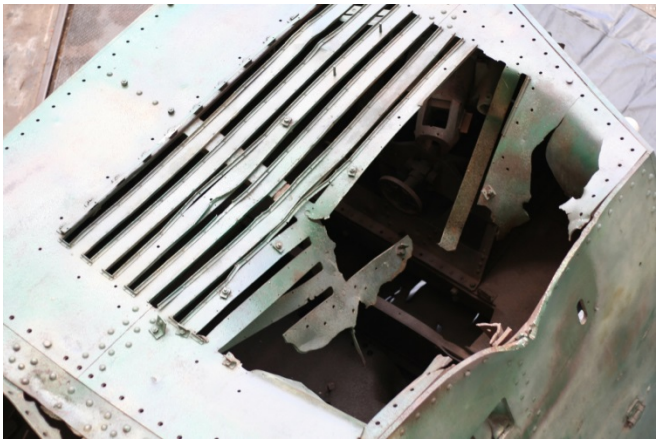

Figure 7. Major impact that tore the tanks roof apart [2]

Once captured, at the correct level of accuracy, the digital information can be used for further forensic measurement to research bullet trajectory and explosion analysis to help bridge the gap surrounding questions of what caused the Mephisto's battle scars during its last days at Villers-Bretonneux.

3.4 Analysis – Turning Data Into Story

Developing story, based in truth and established from captured information involves a complex set of analytical tasks. Research deliverables from the analysis of the 3D scan data of the tank may be divided into two main technology paths; Interactive Experience and Forensics. Both require new innovative processes for analyzing and communicating point-cloud information from the captured 3D scan data. Scans of large-scale items, such as Mephisto, generate large data-sets. Managing the data and enabling its use at an appropriate level-of-detail for the differing tasks is critical. The size, accuracy and complexity of the raw information, when registering and post-processing 3D scan data, needs to be considered. The workflows undertaken in this area by Smithsonian Institutes Digitization Program Office, CyArk and Historical Scotland's Digital Documentation team for digital heritage preservation and management of large data sets provided existing methods for this task and outlining them is beyond the scope of this paper (see [4,5,6] for details.

3.4.1 Story – Map, Scan, Forensics, Diary Accounts

With support by Mark Clayton, Senior Curator of Social History with Queensland Museum, imagery from the battle field has been imported into Google Earth to find "the exact location and position of Mephisto when it came to rest in Villers-Bretonneux." [2]. This important piece of information is the building block allowing us to 3D scan the area of interest and digitally place Mephisto back in its original position. Combining this terrain model, with diary accounts from Australian, British and German commanders of WWI and forensic analysis of bullets and damage we are able to reconstruct, in an immersive virtual sense, an accurate story of Mephisto's last days in battle at Villers-Bretonneux (Figure 8).

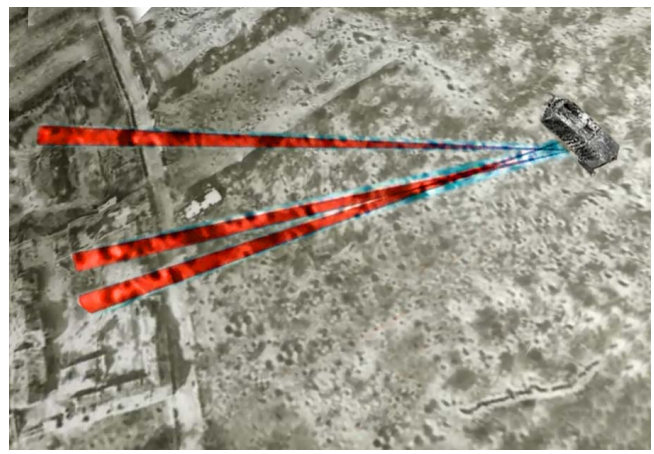

Figure 8. Proof of concept – 3D reconstruction of Mephisto on the battlefield in Villers-Bretonneux.

This finished 3D reconstruction of the tank on the battlefield needs to be easily accessible to those visiting the Queensland Museum. Through the use of the 3D scan data, and its interactive display (augmented and virtual realities using mobile devices and hologram models are all possible). These methods for accurately highlighting points of interest will greatly improve the user experience and provide increased understanding of "the Last Days of Mephisto." [2]. The use of advanced, and immersive 3D interaction techniques will assist in placing the user in the experience [25,26,27,28,29]. Linking this with effective social media tools and interactions aims to enhance the users immersion and experience while also building a larger community for the experience itself and those engaged with it [30,31].

4. CONCLUSION

The aim of this research is to develop 3D scanning and post-processing workflows for Interactive Realities to provide people a truly accurate and realistic user experience with Mephisto and its captivating tale. Whether a war enthusiast seeking answers, someone who remembers Mephisto from their childhood or a visitor to Queensland Museum for the first time, it will allow

people to involve themselves with its history and follow its story while trying to solve the mystery behind what happened leading up to its retrieval in those last days at Villers-Bretonneux.

While it is a privilege to work with Queensland Museum on the Mephisto project, it is the development of these workflows required for museum artifacts and heritage sites, and the techniques involved with analysing and presenting this information that must be considered of special importance.
Methods for manipulation of large point-cloud data sets are still inadequate. Until this is properly addressed, communication and presentation of heritage items requiring measurement and detail accuracy cannot be achieved. The rapidly evolving technologies in Interactive Realities can provide 3D scanning for heritage preservation an opportunity to create a window into the past and present history in ways that users have never experienced before.

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