Exhibiting the Virtual House of Medusa: Lessons Learned from a Playful Collaborative Virtual Archaeology Installation in Various Museum Exhibitions

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"Virtual and Augmented Reality" (VR & AR) technologies are becoming increasingly important in educational and cultural contexts, providing users an interactive experience with cultural and historical content. Particularly for material and structures that are no longer in existence or are too fragile to be available to the general public, such approaches permit a level of access that would not be possible otherwise.

However, despite the growing success and promise of VR and AR technologies in this field, current applications primarily focus on an immersive single-user experience and typically do not employ collaborative elements that can promote discussion, reflection and other social aspects. In addition, very little has been done to integrate larger audiences into such activities, which would enable multiple participants and audience members who occupy the same physical space to interact and create a shared cultural experience.

The "Virtual House of Medusa" (VHM) is an interactive co-located playful VR installation for a museum context that was developed in collaboration with the Federal Monuments Authority Austria to illustrate several fragments of Roman wall paintings. The installation employs a cooperative approach that allows participants to slip into the role of an archaeologist and restorer and interact with digitized artefacts. Four virtual workstations provide different perspectives and playful interaction possibilities to actively engage multiple users in their exploration of the remains of an historic Roman villa. The VHM has been undergoing evaluation in multiple museum contexts and preliminary analysis from these activities indicates potential benefits and ongoing challenges for interactive museum installations. This paper presents a number of lessons learned that were collected while exhibiting and presenting the installations on multiple occasions. The reflections concerning these lessons should help both designers and researchers in their efforts to more effectively develop playful virtual archeology installations in the museum context.

Key words:
VR Museum Installation, Virtual Archaeology, Shared VR, Co-located Play.

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INTRODUCTION

"Virtual and Augmented Reality" (VR & AR) technologies have become even more important in recent years and are employed in various fields of application, ranging from industrial applications to edutainment. Despite the limitations of current VR and AR devices, these technologies are used increasingly within the context of museums. VR museum installations for cultural heritage and virtual archaeology [Reilly 1991; Bawaya 2010] have been developed since the 1990s, including scientific visualizations and journeys through historical and fictional worlds. In comparison to typical museum exhibits, such as computer animations or interactive screen-based applications, VR-based installations offer many advantages to communicate scientific information to a broader audience, as they can

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provide museum visitors with an immersive, playful and engaging experience. However, due to a number of practical reasons (e.g. increased need for guidance, isolating single-user experience, time-consuming introduction) many of these installations have offered fairly limited interaction capabilities, which counteracts some of the benefits created by the immersive nature of VR.

Although the advantages of VR-based solutions for cultural heritage and virtual archaeology are still enticing, even with some limitations, various design challenges need to be overcome. One of the greatest challenges is the fact that, even today, most visitors have little or no experience with VR and are facing an initial hurdle. In most cases, an introductory phase is needed to lower the entry barrier. A majority of VR museum installations utilize "head-mounted displays" (HMDs). Since these devices are designed as a single-user experience, there is a restricted connection to other visitors or museum guides. In some cases, museum guides introduce the VR installation by talking to the VR player and a second screen is provided that allows other visitors to watch the virtual experience.

This paper introduces a playful virtual archeology installation entitled "The Virtual House of the Medusa" that addresses these challenges. Lessons that were learned during the exhibition of the installation in multiple museums are presented and discussed. This information should assist designers and researchers in their design process in regard to the challenges in creating playful virtual archeology installations for multiple players.

RELATED WORK

Virtual archaeology evolved as a subdiscipline of digital heritage in the mid-1990s [Reilly 1991] and, in a nutshell, deals with digital visualization and simulations in archaeology. Current technologies, such as 3D laser scanning or image-based modeling, facilitate the development of detailed 3D reconstructions of archeological findings for various applications, including documentation; conservation; restoration; reconstruction; scientific visualization; analysis and queries, dissemination of information; teaching; and, finally, infotainment and edutainment [Gruen 2013]. These digital reconstructions also serve as the basis for computer animations, virtual simulations and VR installations for museums [Bawaya 2010; Gruen 2013]. Virtual archaeology in the museum context utilizes the same technology employed in the entertainment industry and has become an established discipline [Bawaya 2010]. Although there are many 3D models and simulations of archeological findings, only few of them are actually accessible to the general public and even fewer are accessible in museums [Bawaya 2010].

A great deal of scientific content on archaeology can be retrieved online, in particular in so called virtual museums, and these have been well documented by a number of researchers [Lepougas 2004; Sylaiou et al. 2005; 2009]. Virtual museums also emerged in the 1990s and can take various forms, ranging from digital preservation to presentation and can provide an entertaining and educational experience for visitors [Lepougas 2004; Sylaiou et al. 2005; 2009]. Virtual museums can also serve as an additional exhibit to a physical museum, exist as a stand-alone exhibition or as a virtual copy of a physical museum on the Web [Sylaiou et al. 2009]. In contrast to virtual museums, VR museums are immersive and, in most of the cases, interactive virtual worlds. So-called "enhanced VR museums" can provide a more engaging experience for the visitors and offer an educational value at the same time [Hürst et al. 2016a; 2016b]. Such installations that feature content from the field of archaeology enable impressive experiences, for instance journeys to far-off or inaccessible places [Ars Electronica Center 2018].

VR applications can be designed as a single-user experience (e.g. with an HMD) or can be used by a large number of players (co-located experience), such as in the case of CAVE [Cruz-Neira et al. 1992] systems. The CAVE (cave automatic virtual environment) is a multi-person, room-sized, VR installation that allows artists, developers and educators to guide visitors through virtual environments. In doing so, such installations can be considered to be co-located VR as they allow the users to co-inhabit the same physical and virtual space. This can offer numerous advantages, particularly for museums, as it facilitates the creation of a shared experience between users, and in many cases, a purpose for them to communicate and socially interact with each other. Such interaction can foster deeper engagement and more active processing of an exhibition's content. One of the first co-located VR museum installations developed for the context of cultural heritage is The Multi Mega Book [Fischnaller and Singh 1995]. This multi-person, room-sized VR environment offers a virtual journey through a fictional renaissance city, featuring various artworks from that period. At the beginning of the journey, a virtual non-player character welcomes the visitors and guides them from one historical building to the next.

If a user is visualized as a virtual character and interacts with other players in the same physical space, this co-located hybrid between real and virtual is defined as "Mixed Reality" (MR) [Milgram and Kishino 1994]. Since new

HMDs such as the Oculus Rift[1] and the HTC Vive[2] are now readily available, they are being increasingly utilized in museums. Recent examples for instance are the Tate Modern [Tate 2017] or the VR Lab at the Ars Electronica Center (AEC) Linz [Ars Electronica Center 2017]. These exhibits are also typical implemented as single-user experiences and, in most of the cases, non-interactive installations or 360° videos. To better communicate the experience, a secondary overview display typically shows the perspective of the VR player or an overview of the installation. Recent examples of VR museum installations on cultural heritage [Ferrari and Medici 2017; Sierra et al. 2017] provide a limited interaction for the VR player and no interaction between the VR player and other people in the same physical space. This problem is known as the "Perspective Gap" [Ishii et al. 2017]. Although research on collaborative VR settings started in the 1990s [Lalioti et al. 1998; Knöpfle 2002], current research on shared, co-located MR settings with HMDs [Ishii et al. 2017; Masson et al. 2017] and on remote MR collaboration [Piumsomboon et al. 2017] is still at a very early stage.

In addition to social interaction, playful elements can encourage users to experience virtual archaeology [Ferrari and Medici 2017; Cassidy and Robinson 2017; Anderson et al. 2009]. There are only a few case studies on co-located playful settings using current VR devices [Anderson et al. 2009; Ars Electronica Center 2018; Sierra et al. 2017; Rae and Edwards 2016]. Asymmetric gameplay and customized game mechanics can foster the gaming experience for the VR player and also enhance the interaction between spectators or co-players [Sajjadi et al. 2014; Liszio and Masuch 2016].

The analysis of these limitations but also the advantages of VR installations provided the basis for the design of the "Virtual House of Medusa" (VHM), a VR museum installation which utilizes a novel MR approach to help guide museum visitors through a VR experience. Details regarding the design of this installation will be addressed in the following section.

THE VIRTUAL HOUSE OF THE MEDUSA

As previously addressed, interactive VR installations offer a great deal of potential to convey additional perspectives on cultural and historical content. VR offers the potential to more meaningfully interact with the content to acquire a deeper understanding, for instance by being able to virtually touch, assemble and/or disassemble and explore archeological artefacts. In addition, the VR user can switch between different roles; for instance, he/she can slip into the role of an archeologist or can walk through historical landscapes. But VR museum installations using HMDs tend to neglect possibilities for interaction for spectators, limiting their experience to simply following the virtual journey on an additional screen. In most cases, interactive VR installations also have to be introduced and explained in detail by the museum staff. Additional interaction and guidance possibilities are therefore of particular interest to museum guides to improve the introduction phase and the VR experience for the VR user and the spectators.

The VHM aims to facilitate a shared virtual experience including one VR user, additional museum visitors and the museum guide [Hagler et al. 2018a]. By means of an MR-based guidance tool (a tablet that is connected to the VR space), the museum guide can introduce the VR installation to the HMD user and the spectators [Hagler et al. 2018b]. He/she can explain relevant events and mechanisms and navigate participants through the virtual experience.

The VHM is a playful co-located VR installation for a museum context about a Roman villa and its wall paintings [Santner 2017]. These fresco fragments were found in 2000 at the Danube Limes, specifically at Loch, near Enns in Upper Austria.

"Five large blocks and over sixty crates filled with fragments represent the largest and most important find of provincial Roman wall paintings in Austria ever discovered".

[KHM 2017]

These wall paintings once decorated two rooms of the roman Villa. Prior to this find, only a few discoveries of painted ceiling and/or wall frescoes were known that adorned several rooms of one building. These wall paintings

[1] https://www.oculus.com/rift/
[2] https://www.vive.com/

from the third century consist of up to four layers of plaster with decorative elements and magnificent figurative elements in exceptionally good condition [KHM 2017].

The installation was developed by the research group "Playful Interactive Environments" (PIE) in collaboration with the "Federal Monuments Authority Austria" (BDA)[3] in 2017. The VHM is designed as a complementary installation that serves as an addition to the original artefacts exhibited at the museum. The aim was to show aspects of the archeological find that are not possible to experience in the real world. The same fragments are presented in different ways to give an overall impression of the excavation. The players can experience the feeling that the past is being brought back to life – piece by piece – from a pile of shards. The VHM is a playful installation that allows visitors to work at four virtual workstations.

1. At the first workstation, the player receives background information about the archaeological find and learns how and why the frescos overlap. The villa was completely repainted on four separate occasions, suggesting that the house was owned by multiple, wealthy Roman generals.
2. At the second workstation, the player slips into the role of an archaeologist and has the opportunity to reconstruct the three fresco layers of the first station as well as three other frescoes. The task is primarily based on examining unique features of the fresco fragments, which gives the player a sense of the complexity of the work of an archaeologist and allows him/her to identify the smallest details in the paintings.
3. At the third workstation, the player can look inside the reconstructed building. The player can move through the house by moving a virtual camera along the floor plan. This gives the player an overview of where the fragments are found in the floor plan. By turning his/her wrist, the player can transition between the different decor phases.
4. At the fourth workstation, the player can explore a miniature model of the reconstructed building and obtain yet another perspective of the reconstruction.

Although the entire installation can be used in a single-user scenario with one HMD, additional visitors can passively or actively participate as well, using the same setup as the MR guidance tool. In addition to simply viewing the content from the four workstations with an independent camera in the VR environment, visitors can directly collaborate with the VR user via touch input on a tablet combined with verbal communication. Touch interaction can be used to either control animations for each participant's virtual avatar (see Chapter "Technical Setup") or create a particle animation in the scene so that visitors can effectively point to and highlight virtual objects. This form of interaction is particularly useful for the second workstation, allowing the co-located users to assemble the fresco fragments as a collaborative puzzle activity.

Technical Setup

With the MR guidance tool, the museum guide can look into the VR environment, provide support for the VR player and introduce the experience to the spectators in detail. This is achieved using an HTC Vive tracker mounted on the backside of a tablet device. Furthermore, the installation consists of a VR headset (HTC Vive) with one single-handed game controller (HTC Vive controller), which was, for reasons of simplicity, controlled by a single button (trigger).

Fig. 1 shows the physical devices of the two actors (guide and VR player) and the rendered screen view of each device. The MR guidance tool user (guide) is visualized as a very simple, abstract avatar and allows users to select objects by touching the tablet screen. Using a swiping gesture from the top edge of the tablet, a menu appears. The menu contains multiple functions, such as resetting the installation; switching between different visualizations of the museum guide; switching between the four workstations; switching between different cameras (camera player, camera audience, etc.); animation controls of the avatar to improve social communication (wave, nod or shake head, wink); and showing hints or additional property functions (tutorial, language, etc.).

[3] https://bda.gv.at/de/

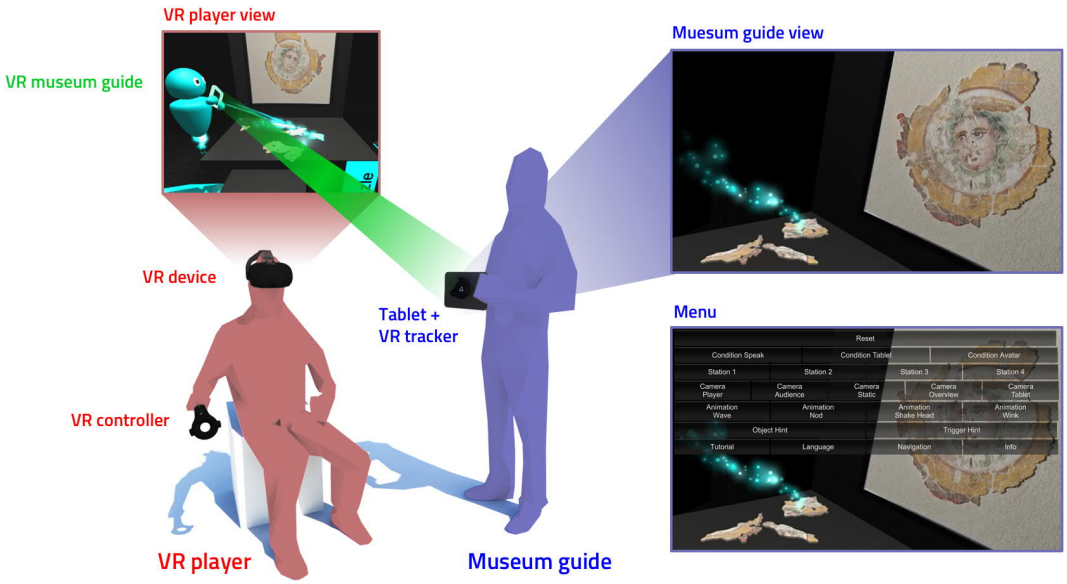

Fig. 1. Technical Setup: VR player (red), seated VR experience with an HMD (Vive); Museum guide (blue) can look into the virtual world and can touch virtual objects via a tablet, equipped with a VR tracker; via a menu the museum guide can navigate the VR player and spectators through the VHM. The museum guide is visualized in VR as an abstract avatar (green).

Exhibitions

The VHM was exhibited at a total of eight different exhibitions in three distinct settings to identify design potential and implications. These settings (see Fig. 2) differ in regard to how the audience and the guides are integrated into the VR experience. The VHM was demonstrated and observed with a supervisor as a guide on a total of 23 days in multiple locations and was then additionally exhibited unguided over a period of six months at the "Ars Electronica Center" (AEC).

The first prototype of the MR version of the VHM was presented at the beginning of 2018 at the "Kunsthistorisches Museum Wien" (KHM)[4] as part of the special exhibition of the original artefacts of the House of Medusa. A more elaborate version was then exhibited at the OÖ Landesausstellung 2018 and at the GameZone at the Stuttgart International Festival of Animated Film 2018.

In a further step, an adapted version for Ars Electronica´s Deep Space [Ars Electronica Center 2015] was developed. The Deep Space at the AEC is one of the few environments that can facilitate a VR experience for a large audience, featuring high-resolution stereo 3D projections for both the wall and floor. A museum guide introduces the installation and up to 150 spectators can virtually travel back to the Roman Age on a large screen of 16x9 meters. Particularly in this case, the involvement of the audience is very important. At the same time, an unguided version was exhibited at the VR Lab [Ars Electronica Center 2017], a special exhibition focusing on projects that utilize VR and AR. Hands-on experience and active involvement are major principles of the museum experience at the AEC. As such, the willingness for visitors to try out new technology for themselves is therefore very high.

[4] https://www.khm.at/

Fig. 2. The VHM was exhibited at three different museum settings. At the VRLab in the Ars Electronica Center, a museum guide introduces the installation to the VR players exclusively by talking to them. Spectators observe the interaction process via an overview display. At the Kunsthistorisches Museum, a guide introduces the installation using the MR guidance tool. Spectators can follow via an overview display. At Deep Space in the Ars Electronica Center, a museum guide navigates the VR player through the VHM. A large audience can watch the journey through time via a large overview projection (16x9 meters).

LESSONS LEARNED

Approximately 400 participants were observed in total over the 23 days of exhibition, including 121 participants who also completed questionnaires about general experience and social presence. The individuals were not specifically chosen for the study, but instead were already in attendance at one of the exhibitions and were willing to participate in the study. The participant demographics ended up being quite diverse, with 55 % female and 45 % male, and ages ranging from 6 to 86. Although such participant information was collected and evaluated in each of the settings, the initial data collected does not lend itself to solidly defensible conclusions about this approach to multiuser VR installations. This is partly due to the complexity of the setting and the general difficulty with evaluating a setup in the wild [Hornecker and Nicol 2011; Rogers 2011]. One major reason for this difficulty in this particular case is that the level of experience with VR varies significantly between individual museum visitors. Approximately 75 % had little or no experience with VR; only 2 % of the sample had their own VR device at home. Another factor that played a role is that testing collaborative elements with multiple users (such as with the puzzle assembly virtual workstation) is problematic in a live setting due to continual interruptions from other visitors. However, despite these shortcomings, a significant amount of data was collected during the exhibitions, both from observation and general user feedback. The results from these activities can be summarized as a series of lessons that should be taken into consideration for future works.

VR Setup (no MR guidance tool)

In the VR-only setup without the MR guidance tool, there was very little communication between spectators and the VR users. Spectators simply watched the overview screen and either waited their turn to try out the VR application or simply consumed the content from the overview screen and moved on to other exhibitions. The overall playtime was also noticeable short for VR users, possibly due to the isolation from other people from their visitor group or

because they wanted to give others the chance to try out the VR installation. The oral introduction (even without the use of the MR guidance tool) worked relatively well; however, this needed to be repeated for every new user as spectators could not always adequately follow the displayed interaction on the overview screen. Overall, the VR experience was well received by visitors, but was a fairly time-intensive and tiring job for the person supervising the installation.

MR Setup (with MR guidance tool)

Using the MR guidance tool (tablet), it was generally much easier to introduce new users to the installation, in part because the MR avatar could highlight VR objects with a virtual beam of light. There also tended to be more frequent conversation between the supervisor and the VR user, possibly due to the virtual avatar and perceived presence of the supervisor in the same virtual space. Playtime was generally longer, as the avatar could more clearly assist in tasks such as puzzle piece selection. However, although the benefits were immediately apparent, the feasibility of the system for longer sessions was put into question. The tracking and graphical systems necessitated a significant amount of processing power from the tablet device, which would quickly drain its batteries, requiring recharging and/or swapping out devices. Even though these issues could be handled, the setup proved to be unsuitable for extended (all day) sessions with a sporadic but frequent influx of users.

MR Setup Deep Space

Using the MR tool as a guidance device for a larger audience proved to be the most appropriate setting for this approach. Being able to switch camera views on the fly for the audience while the main VR user was focusing on his/her own interaction allowed the application to be demonstrated very quickly. Multiple MR devices were also passed out to audience members after a general introduction, and although the scalability of such an approach is still somewhat limited (i.e. only so many people with devices can fit within the VR tracking space), the potential for simultaneous experiences with shared content was quite promising. Nevertheless, additional input modalities to integrate more users into the shared experience would be advantageous (i.e. allowing users to view individual content from the installation on their own mobile devices). Another important aspect that was particularly important in this context, namely the implementation of an additional camera perspective that followed the VR user's perspective, but with smoothed movements similar to the use of a camera gimbal. This prevents the development of queasiness or cybersickness on the part of the audience, since the overview screen in this setting is very large (larger than life) and they are not in control of the movements themselves.

General Considerations

Despite the expectation that VR technology would primarily be interesting for digital natives or a younger audience in general, positive feedback was received equally well from young and old, with the oldest participating VR player being 84 years old. Nevertheless, some design decisions that were made to simplify interaction were not effective. The use of gaze as a method to jump from one virtual workstation to the next (i.e. looking at another workstation until a visual bar is filled) rather than using the more conventional method of teleporting via the controller proved confusing for many, as they would inadvertently leave a workstation and not understand exactly why. The supervisor was able to rectify this quickly with the MR guidance tool, but for inexperienced VR users, it proved more effective to use the MR tool to switch workstations for each user. The choice to make the VHM a sitting experience, however, was justified, as very few users complained of virtual reality sickness issues, even though some were apprehensive of this being a potential issue for them. The camera-tripod interface utilized in the third workstation to move around the virtual floorplan, although not always immediately perceived as intuitive, proved to be an effective means to combine navigation and locomotion in a virtual setting. And although the time-lapse metaphor of turning the wrist to view each of the décor phases required some explanation, it proved to be one of the more unique experiences for VR users in the application.

CONCLUSION

As demonstrated by the VHM approach, co-located, interactive VR installations can effectively augment museum exhibitions by including additional perspectives to the available physical content. This potential for VR to enhance educational and entertainment content with interactive components and increase immersion can open up new target groups for museums. During tests and exhibitions of the VHM with actual museum visitors, a number of insights

were gained in the area of co-located VR museum installations. An analysis of previous VR installation and the experiences gained during the exhibitions highlight how actual museum visitors interact with a VR installation and what problems typically occur. The observed problems concern the perceived spatial separation also known as the “Perspective Gap”, social isolation, hindered communication and assistance from outsiders as well as the connection of multiple user roles (guide, VR player and spectators). As a solution to these problems, a novel approach of guiding museum visitors through a VR experience was developed. It features a unique MR guidance tool using a tracked tablet device and mechanisms to communicate between the two visually separated worlds (virtual and real world). The proposed solution enables museum staff to guide both the VR player in the virtual world as well as the spectators in the real world. With the help of the MR guidance tool, the communication could be noticeably improved and first solutions for some of the problems could be established. However, further study is necessary to validate these approaches, and the viability of these technologies is only directly relevant for certain settings. Nevertheless, the use of MR guidance tools to better facilitate communicative tasks and to improve social experience among visitors is worth pursuing in future VR-based museum installations.

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