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important in educational and cultural contexts, providing users an interactive experience with cultural and historical content.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/

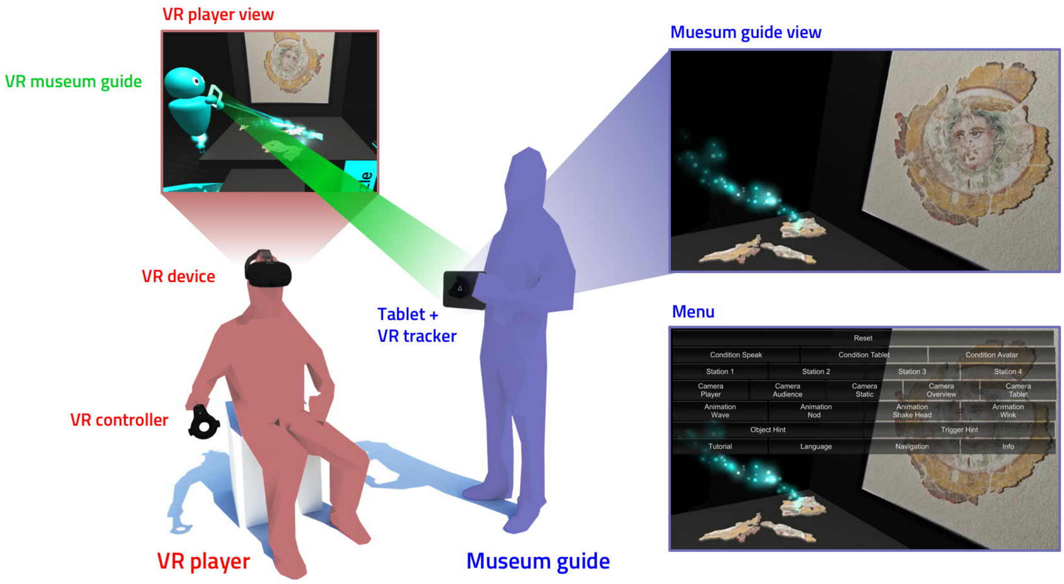

Fig. 1. Technical Setup: VR player (red), seated VR experience with an HMD (Vive); Museum guide (blue) can look into the virtual world and can touch virtual objects via a tablet, equipped with a VR tracker; via a menu the museum guide can navigate the VR player and spectators through the VHM. The museum 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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Mann-In-Colours. The First Italian Database on Polychromy of Ancient Sculptures

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The application of scientific surveys on classical statuary has developed rapidly in recent years thanks to the growing interest of archaeologists and scholars in the "rediscovery" of polychromy in ancient works. The project proposed here concerns the creation of the first Italian database on ancient polychromy funded by an Italian museum; it also aims to build an innovative method, on how to communicate following results, that can attract a large number of people, thanks to the use of new technologies and digital software never used in Italy for the enhancement of this field of studies. Mann-In-Colours is a three-year scientific project carried out by the "National Archaeological Museum of Naples" (MANN) in collaboration with the National Taiwan Normal University di Taipei. The project works on chromatic traces, sometimes imperceptible to the human eye but still existing on sculptures. It has the purpose to recover the original aspect of these sculptures and so to revolutionize their aesthetic perception on part of visitors in the course of centuries. From the scientific point of view the project includes chemical and physical analyses on selected Farnese Collection sculptures, allowing to recompose their pertinent chromatic sets. all collected data will be systematized in a database specifically designed by scholars made for this purpose, usable by scholars. One of its sections will be available for general public fruition.

Key words:
Photogrammetry, 3D Modelling, Database, Polychromy.

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INTRODUCTION

> *"Since the publication of the celebrated work by Quatremère de Quincy [1815]* **-** *Le Jupiter Olympien – that is to say, scarce forty years ago, the question of the polychromy of ancient monuments has not ceased to occupy the antiquarian and artistic world, without having, as yet, been determined in a satisfactory manner."*
>
> [Semper 1851]

Although there is still a lot of work to be done, the application of scientific investigations on classical statuary has developed rapidly in recent years, thanks to the growing interest of archaeologists and scientists on the "rediscovery" of ancient polychromy [Østergaard 2010]. The project that we are going to outline here, in its general lines, concerns the creation of the first Italian database on ancient polychromy, sponsored and funded by an Italian National museum. This will be based on an inclusive strategy aimed at attracting many people; it will combine the use of never utilized digital skills in order to enhance this field of study. The keystone of the project is a huge analyses campaign on the Farnese Collection. All the results will be offered to public not only for scientific research but also to engage in carrying out "capability building" practices and techniques of approaching complex topic as this one. An innovative approach will allow individual to take up the challenge to interact with multifaceted issues, to keep a good recall of the museum experience. It will give means to understand, according to own abilities, what is offered and finally, to become agents of experience. To sum up, Mann-In-Colours wants to change museum visitor perception letting them become prosumers (pro-ducer and con-sumer) able to mix individual values with their acquired learning. If on the one hand scientific research has made great strides on the development of diagnostic investigations (invasive and non-invasive) for the research of ancient colours [Østergaard 2009], on the other hand it should work on educational tools and disclosures

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aimed at attracting, without spectacularizing. Therefore, thanks to the setting up of never experimented simultaneously digital tools, Mann-In-Colours represents an unprecedented case.

SCIENTIFIC APPROACH

Despite recent studies on ancient colours are making great strides, we're still far from considering polychromy in Greek and Roman statuary a common topic. Many artefacts jealously guard precious secrets so: helping people to realize the original colours and shades would enable them to understand their correct meaning and the significance of the different colours employed. it would besides help to comprehend the reasons for different supplies; preparation; application and their symbolic values within a broader cultural context [Brecoulaki 2014]. For one sculpture that has preserved original colours (even partial and imperceptible to naked eye) there are hundreds that totally lost theirs, and so missing, as inauspicious consequence, their original meaning. The issue is consequently to help people to understand that Ancient Classical Past once was dominated by polychrome sculptures. Otherwise, how could we expect them to appreciate the difference between material object and sublime sculpture? And considering the ancients' everyday life: was the use of colour reserved only for few works of art or was it more widespread than we have thought so far? Had it a symbolic use? [Alfeld et al. 2016] If we fall into the fascination of these questions, it becomes clear that colours were applied for many more purposes we have considered so far, drives not only concerning client's economic status but also values for social and human narrative. Therefore, we need to come back to the originals if we really want to understand the message they conveyed to contemporary watchers: it becomes an urgent necessity, coming back (or at least try) to the original representative of classical works, whose right context follows.

In the scientific field it is a fact that copious Greek and Roman sculptures, as well as many decorative architectural elements, were coloured [Grand-Clément 2009] but the daily perceiving (and for museums is a great unsolved challenge) general idea, difficult to debunk, is a past populated by pure white marbles [Jockey 2013; Grand-Clément 2016]. For about twenty years research on polychromy has been enriched by the contribution of numerous scholars, whose interdisciplinary results convey towards the purpose of restoring philological correctness to ancient narration. Thanks to the use of sophisticated instruments and chemistry, archaeological investigation has achieved tangible results [Sandu et al. 2012; Verri et al. 2010]. Archaeology, history, collecting, philology and art history combined have devised significant guaranteed interpretation tools [Jockey 2014], expressing their full potential in terms of knowledge [Siano et al. 2010]. Obtained data, however, are struggling to fight the common interpretative lexicon and are impeded by hypercomplex terminology and theoretical superstructure and misinterpretation [Bradley 2009; Brecoulaki 2014]. Today we must oppose the myth of Winkelmann's candour, in order to be open-minded and reinterpret old-school knowledge [Gasanova et al. 2018]. Therefore, to complete this virtuous circle we'd actively involve people with multifaceted interests, schools and families. This means to eliminate physical and theoretical barriers: doing a multiverse exploration [Ainsworth 2005] and become convinced that museums always transfer proper knowledge.

With the view of effecting a research based on a list of strong points around which to set a working program, given the vastness of the Museum's archaeological collections, it was decided to select some of museum's masterpieces, partly belonging to the Farnese Collection [Gasparri 2009], thus guaranteeing unity and completeness. We chose also specific masterpieces to join selected iconographic types specimens, to make the data set immediately comparable. From philological and iconographic point of view the Farnese is ideal for a research project on this topic, since we can refer, for example, to many replicas of the same model and to its variations (cf. Venus Marina) [Becatti 1971; Carrella 2008]; on the other hand, however, it conceals large contradictions and complexity, which are typical of private art and archaeological collections, created in ancient epochs: transfers from one location to another, stylistic restorations, prolonged displays in unsuitable environments…just to cite the most macroscopic criticalities. Given the fact that further displacement would damage them, investigations started in situ with visual examination using video microscope and taking macro and microphotography (Fig.1); just in case of a real and undisputable evidence of trace, we carry out physical investigation and technical imaging with different types of radiation such as "ultraviolet" (UV) fluorescence, "fluorescence" (UV-FL) and "visible-induced luminescence" (VIL) [Verri 2009], ending with chemical investigations like XRF/XRD [Lutterotti et al. 2016] and Raman spectroscopy [Vandenabeele and Edwards 2005], indispensable inspections to recognize pigments [Siddall 2018; Beckhoff et al. 2006]. Invasive non-destructive technique is also carried out taking microscopic samples for microscopic cross-sectional analysis [Calza et al. 2015]; more specific analyses are processed at the Centro Interdipartimentale Grandi Strumenti of the University of Modena and Reggio Emilia[1].

[1] https://www.cigs.unimore.it/index.php

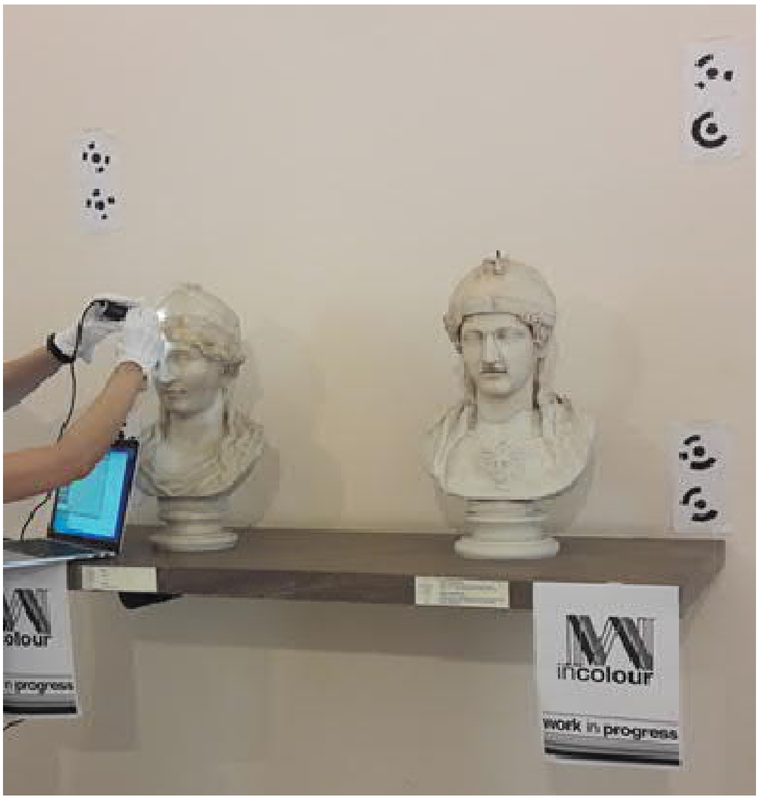

Fig. 1. Optical petrographic microscopy analysis. Athena INV 6304 – Museo Archeologico Nazionale di Napoli – Photo C. Barandoni (© Museo Archeologico Nazionale di Napoli)

All the data acquired will converge into a finalized purpose database; for the first time an Italian National Museum supports and funds a single-topic digital catalogue, available in two ways: the former is a restricted area for scientific purposes and accessible only to scholars (after registration); the latter is available to general public and contains a selection of open data, modulated with a simplified language, appropriate for general public. The cross-examinable via "query" scholar's database, will report: description, history, provenance; references, survey's results, archival and documentary data. Each investigated masterpiece will be entered as follows:

1) Inventory number, material, measures

2) Inventories, origin, collectible history, current location

3) Conservation status

4) Polychromy analysis results

5) Drawings and prints

6) Bibliography

Uploaded sculptures are being subjected to a photographic and photogrammetric campaign thanks to which we will have 3D models, available for further scientific and study purposes; if traces of colours are particularly manifest, through augmented reality, we will try to replace them to indicate their original polychromies, those of course, verified by chemical analysis [Doménech-Carbó and Osete-Cortina 2016]. Into the database we will initially upload artefacts belonging to the National Archaeological Museum but, hopefully, this project will also host other museums contributions, becoming a factual tool of knowledge. This will offer the chance to host other cultural Institutions to to supplement the project with their own researches, encouraging worldwide specific cooperation. Research streamline is based on association and comparison model between different explored elements. Starting from simple query, it is possible to retrieve entire sets of analyses and focus on the presence of a given "colour" in reference to a precise iconography. The obtained statistics, whose elaboration is both qualitative and quantitative, are indicative also to highlight occurrences, allow chemical-physical classification of pigments; describe and statistically analyse each marker, till the iconographic comparison of each marker. From general queries (provenience, material and context) to specialist ones (pigments), we can obtain results expressed in percentages and statistical data to check the frequency of a "colour" within the collection but also examine the context of a specific association between colour and kind of artefact. It is a structured cross-reference research, pledging material for further studies.

COMMUNICATION STRATEGY

Parallel to the diagnostic investigations, Mann-In-Colours is open to satisfy general public needs to be constantly engaged in museums behind the scenes activities [Brinkmann 2010; Graham 2012]. For this purpose, we set up to an expert room (i.e. an open laboratory, Fig. 2) where small groups of visitors are invited in, to observe investigations closely. The same opportunity is offered to virtual visitors that can watch work-in-progress, simply connecting to the website of the project (under construction) where videocasts and podcasts are uploaded. A museum wanting to carry out its cultural role must work without preconceptions and fears to face today's needs to build a virtuous circle of knowledge. This project's aim is not only the premise of a scientific research, which is its *conditio sine qua non*; the National Museum wants to channel resources to correct the understanding of its collections, and specifically reestablish the original significance and plural meanings of statues in ancient times. The relationship with public is as essential as the scientific approach. To combine them the museum constantly facilitates access to the sites of the surveys, granting free access to the Expert Room; it explains – with basic language – results and analyses techniques; designs educational workshops and thematic activities for different categories of visitors (adults and children) and last but not least, wants people and specifically kids to have fun coming and visiting experts at work. On the website of the project, along with the 3D models we will upload short movies so users may profit with minimum effort and maximum delight; it represents a pedagogic accomplishment trying to break down cultural divide and support inclusion. A specific section is entirely devoted to host audio and video podcasts that can be used during visits. Some of them are specifically designed for disabled people. To underline the importance of combining different media, we cite FOR this purpose the project by MAP-GAMSAU about the Treasury of the Massaliots in Delphi[2] [Jockey 2012]. Beside the material produced by scholars and museum personnel, this section will host visitors' contributions, consenting them to play the role of storytellers: with their videos visitors will act as special heritage advocates, fulfilling the role of active citizens, enthusiastically involved in the cultural heritage sector. This is a critical conceptual step forward to stimulate user to a commitment that concerns him/her in person, making him/her feel somewhat responsible of an enrichment process, less anonymous, more empathic. As underlined above, visitors won't be any longer just eyed up as consumers but as truthful producers of experience, feeling happy to be a part of a community.

Fig. 2. Expert Room, Numismatic Section, first floor Museo Archeologico Nazionale di Napoli. Left: Marine Venus INV. 111387. Right: Lovatelli Venus INV. 109608. Photo C. Barandoni (©Museo Archeologico Nazionale di Napoli)

[2] "Le trésor des Marseillais – 500 avant J.-C., l'éclat de Marseille à Delphes", la Vieille Charité, Marseille, 2013.

Via these actions, a virtuous connection will be started between scholars and general public more and more mindful and conscious. The creation of a virtuous multilayered path is particularly functional for a Museum whose aims, amid others, is to develop a sense of familiarity with places called “museums” among people that usually don’t come and visit [Rose-Greenland 2016]. It is a refined and progressed form of smart marketing to establish a connection, based on mutual trust (museum-visitors); the obtained results should bring to an increase of acquaintance, efficiency and effectiveness. In fact, continuity over time produces not only data but involvement, satisfaction and positive feedback (as if we were in front of buyers who do not just want to consume a product but want to taste it) [Soren 2009]. In this ideal frame the Archaeological Museum of Naples becomes a place of living an experience, not only a structure to visit, a place thanks to which visitors can implement their quality of life.

CONCLUSIONS

Mann-In-Colours is a project of high scientific value, whose purpose is the knowledge of the polychromy of several ancient Greek and Roman artefacts, displayed in the national Archaeological Museum of Naples. If we had thought only about scientific research, the project would have had no social value, which for us is the priority together with investigations. Science and community, with structured and organic means and methods, united by a path of knowledge and inclusion: that will bring enrichment for both protagonists. The works of art in the National Museum will have a new occasion to tell ancient relationship with their belonging context.

Modulating a project that belongs to everyone means being able to narrate in multiple forms, satisfy need for knowledge but also to become a part of something bigger. A project that really aspires to define itself as *inclusive* should be concretely available to people, be their casual users or scientific scholars. Involvement, public but scheduled and participatory, will encourage visitors feeling be co-protagonist. Taking part in different steps of the project will motivate them to visit the museum again. Emotions and evocations will be warmly invited to be shared through the museum and project’s social networks, telling a story of stories, accessible to everyone. These are the prerequisites for an all-encompassing project that wants to be defined as such. This is the only policy, giving visitors dignity and considering them not only a number and an undefined source of profits. It means supporting personal human development and enriching the museum experience with a permanent dialogic relationship Archaeology and museums become part of a person’s daily life from which instead they are usually excluded.

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Masada, the Desert Fortress. Discovering the Archaeological Site by Gaming

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In the last decades the interest in the use of serious games as learning tools has grown and the awareness of how the game is effective in the transfer of information from the object to the user is consolidated. The paper discusses the possibilities that this type of tool offers in terms of learning and dissemination of Cultural Heritage. Through the consolidated methodologies of survey and representation, the key points are highlighted for the realization of an interactive 3D model that can be used through 'playable' modalities. The interaction between the information contents and the visualization tools required a reflection on the quality of the graphic system and the virtual design. Everything must be designed to be an expression of an effective graphic language, starting from the narrative plot up to the rules of the game and the scenario. Special attention is given to the creation of the graphic interface, the buttons, the layout, and the color palette. A possible game platform designed about the Masada fortress in Israel is still developing and, as well as representing an instrument for sharing Cultural Heritage, supports the conservation of artifacts; at the same time it allows to know and protect the intangible assets that make up the identity of the places represented.

Key words:
Serious Game, Gaming, 3D reconstructions, Archaeology, Masada.

CHNT Reference:
Monica Bercigli 2018. Masada, the Desert Fortress. Discovering the Archaeological Site by Gaming.

INTRODUCTION

This paper is focused the theme of the access to Cultural Heritage through the most recent digital technologies developed in recent decades. The entertainment industry in general, and more specifically that concerning videogames, is now considered the most promising in order to bridge the gap, generated by the contemporary, between those who 'create' or preserve the Heritage and those who enjoy it. For this reason, a particular study is dedicated to the theme of serious games, a potential tool for the re-appropriation of museum spaces and all those places that no longer arouse the spontaneous interest of people.

Today there is a clear need to preserve the Heritage from the test of time in order to ensure the preservation of the 'memory'. The museum structures, together with all the disciplines that regulate its functioning, have available 'new tools' to reach these purposes [Tramontana 2007]. The potential of the most innovative technological systems and their use within museums, both real and virtual, can be exploited [Solima 2011].

The disciplines of survey and representation in the current digital age have in turn become digital and the tools they use are developed hand in hand with technological innovation. Representation models are increasingly used in 3D models, even if they are constantly supported by traditional graphic systems [Remondino 2011].

3D models as well as providing design support are important for permanently recording the shape of existing architectural works and artifacts, in order to achieve the future generations. The 3D model therefore becomes an important 'tool' of the discipline of representation, useful for the construction of virtual scenarios for the use of the Heritage [Guidi et al. 2005].

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This work concerns the complex case study of the archaeological site of Masada in Israel, under UNESCO protection, and the construction of the digital archive obtained through the use of integrated digital survey methodologies and 3D modeling.

The research presented aims at the definition of a methodological process that, starting from a digital database, rich in information obtained by archival research, photographic and digital survey campaigns, allows to 'translate' this data and these 'materials' in contents accessible and usable by the general public. For this reason within this research a serious game called 'Masada Museum' was designed and partially developed as a potential tool in order to increase the potentiality of the current museum structure.

BACKGROUND

The first 'classic contemporary' publication about “play” is the essay entitled *Homo Ludens* by the historian Johan Huizinga which defines “play” as a ‘propeller of art’ and of all human activities from which culture is developed in all its different forms [Huizinga 1949]. Next to the *homo faber*, who creates and transforms things according to his needs, there is the *homo ludens*. After Huizinga, other scholars have defined the concept of ‘play’ and have described its dynamics, such as Roger Callois in his essay *The Game and the Men* of 1958 [Callois 2014].

According to Chris Crawford, a computer game designer who incorporates some theories expressed earlier, the concept of ‘play’ is linked to the ‘art’ one: the artist in the strict sense of the term usually creates a work or an experience that the public meet directly, while for the game the artist creates the conditions and the rules but it is the public himself who creates his own personal experience. Games unlike other forms of entertainment such as cinema, theater and reading books can be defined as 'participatory', where the player can create the story through the consequences of his actions. A story usually unfolds in a linear way through immutable cause-effect relationships and is meant to be 'experienced' only once, whereas a game with its own multi-pronged narrative structure [Crawford 1984] becomes a multi-purpose experience because it is possible to choose different 'branches'. The advantage of an interactive and participatory representation of video games allows the exploration of all parts and aspects of a story.

The role played by the game designer today is that of a real 'artist' able to identify and deduce the moves of a possible player, his expectations regarding the storytelling and the graphics, so as to create credible 'twists' that provide the player with an unexpected and unusual experience. In this regard Crawford affirms that

> *“…computer games are much like candy, comic books, and cartoons. All four activities provide intense or exaggerated experiences. Whether they use sugar, exclamation points, or animated explosions, the goal is the same: to provide extreme experiences…”*

[Crawford 1984].

Interaction plays a crucial role for the success in creating these sensations because it allows the player to feel an active part of the storytelling and the computer screen, in the case of video games, becomes a sort of space for experimentation and innovation.

Video games can be considered the heirs of the popular arts, “one as appropriate for the digital age as those earlier media were for the machine age” [Jenkins 2005], are lively art that has the ability to provoke strong and immediate reactions [Seldes 1957].

During the 20th century, many scholars have discussed the concept of ‘game’ and all aspects related to it, have described the characteristics of different video games and have been classified according to specific criteria but have never been formulated formal definitions.

A definition of the Italian dictionary (Treccani[1]) defines the 'game' as any freely chosen activity to which children or adults are dedicated, individually or in groups, without any other immediate purpose than recreation and leisure; physical, manual and intellectual capacities are developed and practiced at the same time. This definition suggests that the player influences the result with his own abilities and at the same time consolidates or develops new ones. This awareness of the player to play an active and dynamic role in the development of the storytelling and the possibility of acquiring new skills and being able to exploit them in the game itself, emerges strongly also in video

[1] http://www.treccani.it/vocabolario/gioco/

games. These therefore represent a medium of great relevance in the digital era and can be exploited even in non-entertainment fields, overcoming the 'cultural' obstacle that the videogame is an enemy of education and learning, and also an element distraction from traditional activities.

The historical studies on serious games, such as those on games, has not followed a consistent linear path of legitimization, but instead moves in stops and starts [Wilkinson 2016] and the research was based mainly on studies of social sciences, psychology and information technology. Digital technologies today offer more representative possibilities than traditional systems and digital games represent a field of experimentation and innovation for the contemporary world [Jenkins 2005].

The games have always occupied a special place in the minds of intellectuals and scholars and serious games, despite some sporadic uses for learning and training, have only become established since the 21st century. Serious games with their interdisciplinary nature and being inter-contextual provide a wide field of research for the development of tools and systems for the dissemination of Cultural Heritage (Fig.1). However, having an interdisciplinary character and being often the subject of temporary interest by 'amateurs', the definition of the notion of serious game and their integration with the theories of learning and representation has found difficulties.

The term ‘serious game’ was coined by Clark Abt, developer of military computer games, who describes them analyzing that

> *“…we are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement.”*

[Abt 1970]

When Abt wrote his theories, many war-games had already been published and according to him [Abt 1970] serious games are an extension of the previous simulation-based learning approach, a practice strongly supported by Richard D. Duke [1974].

Despite the technological development of the last decades and the awareness of the last few years of how video games can be considered a powerful tool for conservation but also for communication and the dissemination of Cultural Heritage, there are still very few experiences and experimentations in this direction, both from the scientific community and the 'insiders'. The serious game is a tool that can be useful to museum institutions in order to create thematic paths full of participatory and interactive content, which arouse curiosity towards the museums themselves and their contents, and more generally the awareness towards the Heritage. The combination of technological tools, such as those used for “Augmented Reality” (AR) and “Virtual Reality” (VR) is able to create experiences for the exploration of the Heritage of great emotional impact, suitable at the same time to perform functions for cognitive development.

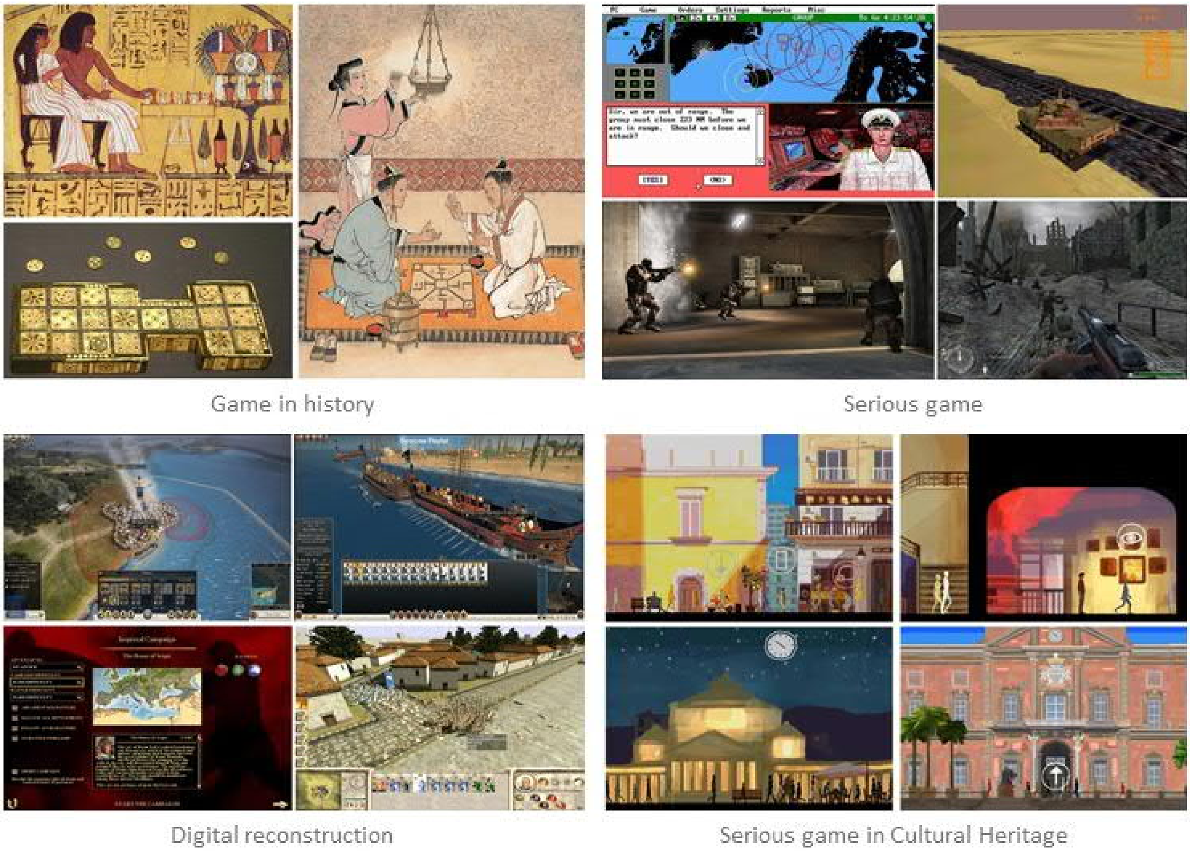

Fig. 1. Representations of ancient games (top left), examples of serious games in the military and cultural fields, and examples of digital reconstruction of historical scenarios

MASADA: THE CASE STUDY

The research project is about the digital documentation of the archeological site of Masada[2] in Israel, which was conducted in accordance with the heritage sites management rules of UNESCO, with the agreement of Israel "Nature and Parks Authority" (NPA). The research[3] took place during four years of international missions in which professors and researchers from the Italian Universities of Florence and Pavia participated, in collaboration with the Shenkar college of Ramat Gan (Tel Aviv), and the results were made available to the NPA in the form of a digital document to support the development of the site's 'management plan'.

The work represents the first complete digital documentation of the current state of the site and demonstrates the possibility of using advanced digital technologies in conditions of extreme environmental difficulty, as the orographic and morphological nature of the site presents terrain unevenness of over three hundred meters and inaccessible mountains sides. Thus, the use of Laser Scanners with 300 m range and "Structure from Motion" (SfM) terrestrial and middle-range photogrammetry methods has permitted the realization of the photogrammetric survey of the inaccessible slopes. Each participating university developed research guidelines; specifically the Florence department has aimed at creating interactive multimedia functional to the tourism promotion of the archaeological park.

[2] For further information please refer to [Netzer 1991; Yadin 1968].
[3] In 2013, 2014 and 2015 survey campaigns were directed by a team of professors from Italy, Stefano Bertocci (University of Florence) and Sandro Parrinello (University of Pavia), and from Israel, Rebeka Vital (Shenkar College of Tel Aviv). In 2016 the campaign was directed by Stefano Bertocci and was coordinated by Monica Bercigli. (University of Florence). For further information please refer to [Bertocci et al. 2013; 2014].

The technological progress in the field of archaeological survey – where the use of digital techniques is now strengthened (from organization and acquisition of data to post-production) – involves a series of consequences, the most significant of which appears to be the increase in the amount of data and of acquired information. This consequence leads to the ability to develop new documentation and dissemination strategies in order to obtain the best results from the digital potential (Fig.2).

For system consistency but also for convenience in terms of space and time costs all these results must be organize in a tidy system, which needs to comply with the digital tools in order to organize open systems for conserving and disclosing information and, above all, to contribute to the preservation of an archaeological site that is truly a part of the human heritage.

Since 2007 the Masada Visitor Center, located at the foot of the cliff on the east side, holds a museum that exhibits the findings found during the excavations executed by Yigael Yadin between 1963 and 1965. The museum (Fig. 3), in addition to the traditional display cases and information panels, reproduces scenes through representations and real-scale reconstructions of places and people, accompanied by evocative sounds and illuminating from time to time what illustrates the narrating voice.

This theatrical approach aimed at recreating the atmospheres of the different 'occupations' of the Masada site, makes the museum visit 'immersive' so as to entertain the visitor through both visual and auditory sensations. In the museum are reproduced nine scenes concerning the period of Herod, the period of the Zealots and the Romans one. The archaeological finds exhibited are portions of original frescoes and columns of the Palazzo Nord and parts of the floor of the Palazzo West etc.

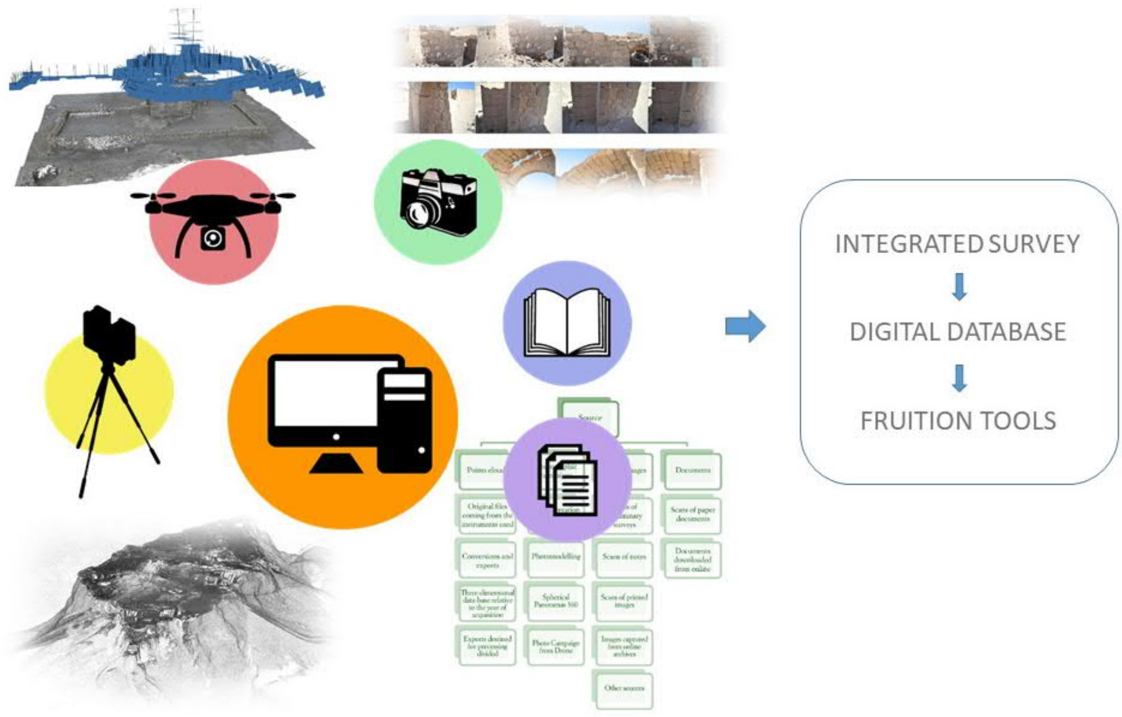

Fig. 2. The scheme summarizes the different types of tools used in digital surveying and the types of output that are generally produced. The challenge is to define a workflow and a useful tool for sharing this digital database

Fig. 3. The Visitor Centre at the foot of the mountain and two rooms of the Masada Museum

A useful tool for the museum both for on-site and remote viewing can certainly be the videogame for all the reasons previously described, starting from the greater involvement of visitors up to the possibilities of cognitive development of children. The museum experience is made more pleasant and the use of the heritage in general is made more accessible through the use of games, able to 'attract' visitors and introduce them in unfamiliar subjects.

MASADA MUSEUM VIDEOGAME

The video game designed and still under development is a single-player type and is only playable by one person. It is possible to share the results in a general ranking with other users, but there is no interaction during the game. The character during the game is related only to some characters in the video game, with which they interact through predefined dialogues that help the player to understand the game plot (Fig.4).

The game is based on a prize-reward progress system where through mini-games and the resolution of the puzzle successive levels are unlocked and are awarded with prizes and points. The 'challenge' factor thus becomes fundamental to make the game attractive and to keep running the interest in exploration and knowledge. The game consists in impersonating the figure of the 'curator' of the museum of Masada who has to set up the permanent exhibition about the history of the site. The game takes place mainly in two places, i.e. the virtual environment of the museum and the plateau of the site, where the character has to go to find the objects. The exhibition rooms of the museum correspond to the four main stages of the history of Masada: Herod’s stage, Zealots stage, Romans stage and Byzantine stage.

Fig. 4. The first interaction scene between the Director of the Masada Museum and the curator character

The visualization of the museum rooms takes place by 2D top-down views and by 3D views with the possibility of exploring the virtual museum with an avatar. In this case the course of the game is linear because it is not possible to place freely the objects found in the rooms, but it is necessary to follow the correct historical progress of the different stages.

It is possible to define the part of the game set at the plateau as open-ended (or sandbox) so that the course of the game is not linear and the player is free to perform his preferred actions without following a mandatory plot. The narrative structure of the game is nonbinding for the development of the plot and a player in this way can 'build' his knowledge without constraints.

The player has a map that shows the constructive situation of the phase related to the research objects and can interact with it by choosing to explore different representative buildings. After choosing a building general information is provided and the player can start the exploration with the avatar in 3D models.

The research of the objects is supported by another small map that shows the playing area and the position of the avatar, and a radar that provides an indication of the objects position, thus encouraging the exploration of the places (Fig. 5).When the player is in the immediate vicinity of these objects and interacts with them, the interface of the respective mini-games is activated.

Fig. 5. Videogame scene with an interactive object within the 3D model

There are three types of mini-games: puzzle, memory, and quiz, which can be found within the game several times, performed for different objects and at a different difficulty levels. The structure of the mini-games is well defined and applies the 'always win' approach where the player wins and collects the object located. On completion of the collection of objects and after their placement in the various rooms, a video illustrates the main events and describes the historical and architectural features, thus adding an additional component for the knowledge of information. The aim of the game is to collect all the objects and complete the museums exhibition, thus assuming the role of 'curator' of the Masada Museum.

DIGITAL DATABASE AND GAME CONTENTS

An important step in the creation of the videogame is the visual design phase, the choice of video game graphics, the definition of the interface, etc., but also the content. In this regard there are several specialists who work within the 'chain' of the creation of video games, such as 3D builder, 2D artist, 3D character builder, 3D character animator etc., and that deals with the creation of all the virtual content.

In order to realize a serious game, however, it is necessary to take into account the communication aspects of the information and how to gain effective and captivating content from the digital database. It is essential to study the historical sources and to have a clear understanding of the structure of the storyboard and of the plot for a correct exposition of the peculiar contents.

The greatest difficulties are the 'simplification' of the amount of data collected during the survey and post-production phases together with the complexity of the archaeological site's history and the interpretation issues concerning some buildings that have not yet been completely solved. The procedures used to 'transform' information and data from the digital survey and documentation into game content are here summarized (Fig.6).

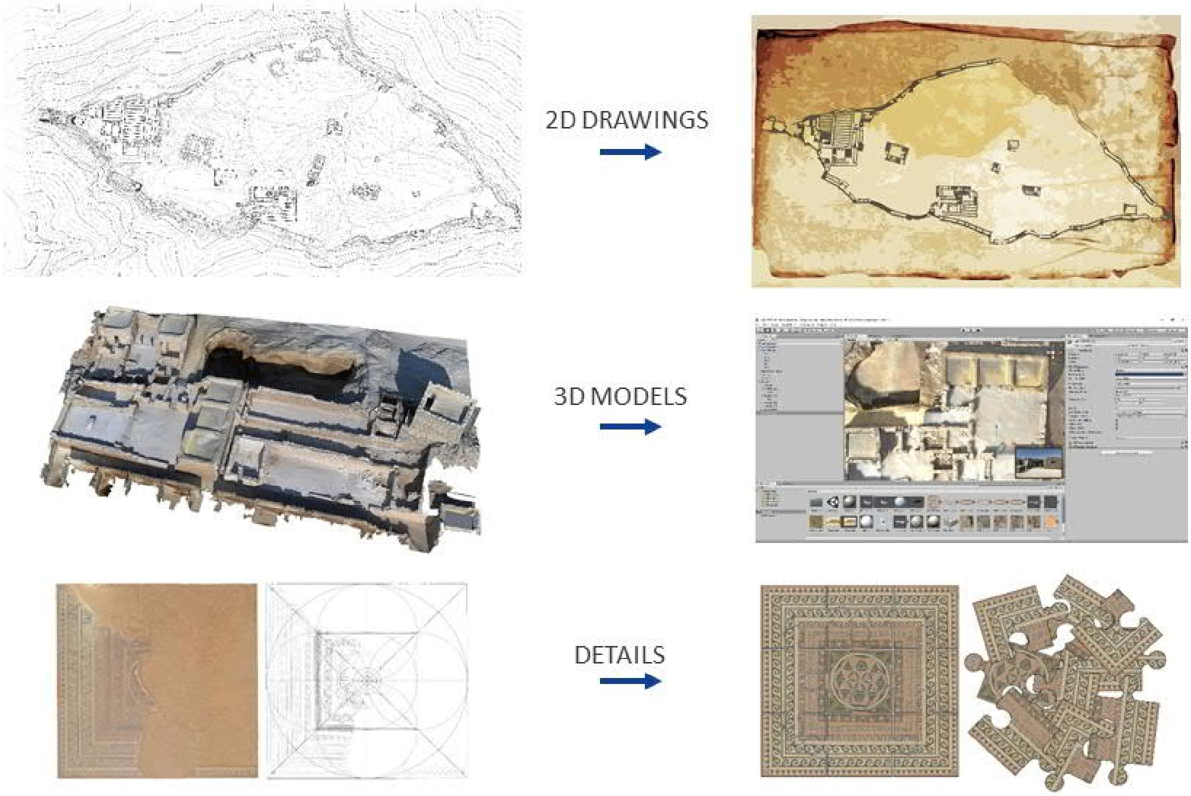

Fig. 6. From digital database to game content. Examples of how to use 2D drawings as map, 3D model as scenarios and detailed element for mini-game

The 2D planimetry obtained from the digital survey has been used as a basis to realize the maps of the game, and it can be useful for the realization of a location-based game. Modern cartography allows the placement of objects to be searched in precise and exact positions and the localization of the user and the objects through satellite positioning via GPS. The 2D drawings of the buildings were used as a basis for the 3D model reconstructions (Fig. 7), for the study of the elevations in their original size, and for the study of architectural typologies.

For the environment of the game, in order to reconstruct the area around Masada plateau, *contourlinemaps* were used, and then the various other models were placed. A multiscale and multi-resolution model has been created, that is a model made up of different parts with a different level of detail of the polygonal meshes.

3D models of the game's main environments have been realized, using the integration of data coming from laser scanners and SfM techniques so as to obtain a complete model in every part and equipped with photorealistic textures. Further detailed models have been realized and concern all the parts the player is interacting with at a close range and therefore require greater accuracy and at the same time an optimal graphic quality.

Fig. 7. Example of virtual reconstruction of the Large Bath House

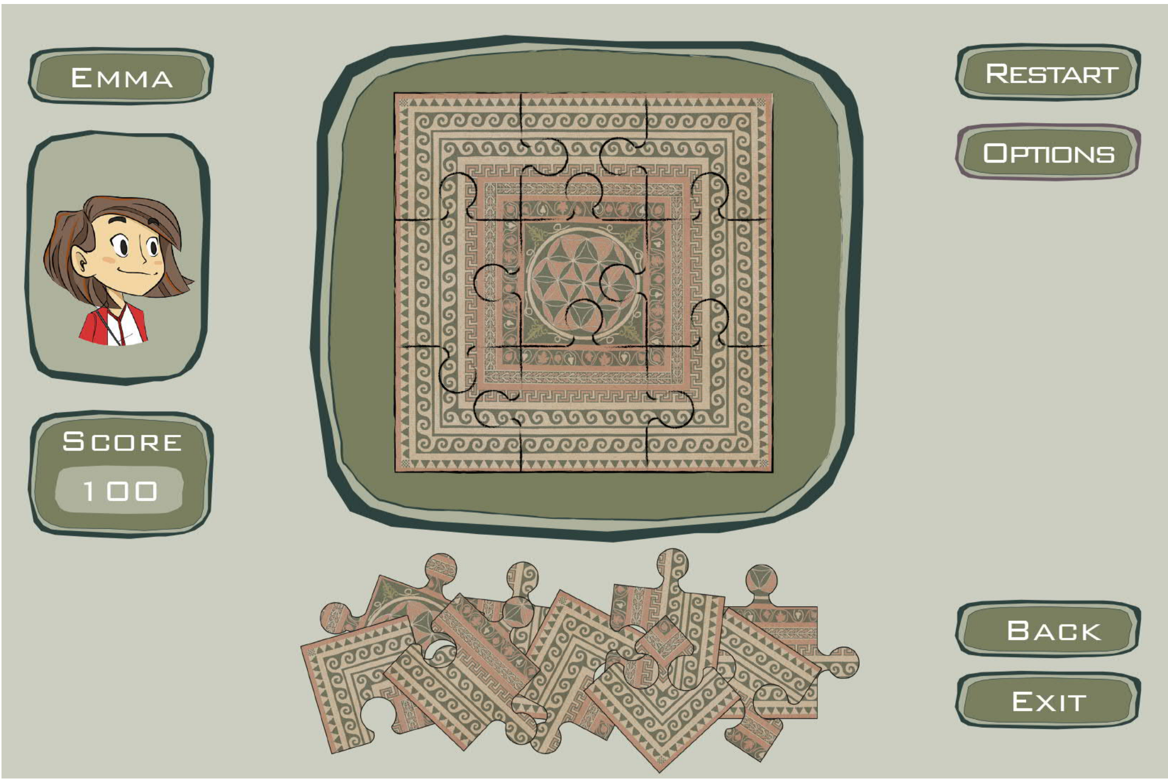

Fig. 8 Example of a puzzle mini-game

At the end the contents of the mini-games were realized taking into account the objects presented in the Masada Museum and representing each of the construction stages of the site in different eras. An important example of using the digital database for mini-game content is about a mosaic in a room in Western Palace; in this case the mosaic in its entirety was rebuilt and used as a puzzle game (Fig. 8).

CONCLUSION

Ludic activity has played an important role in the history of humanity and accompanies every human being during the period of growth. Starting from birth and childhood, when playing is manifested as a spontaneous activity and allows cognitive development thanks to processes of imitation and emulation, until adulthood, when the playing turns into a leisure activity voluntarily carried out and often becomes manifest in sports activities.

Today video games represent a medium of great importance, able to fill the gap and the widespread disinterest that contemporaryly has opened between cultural heritage and users; the 'Millennial Generation' and all the 'Digital Natives' prefer what is equipped with an interactive screen, ignoring the importance of direct contact with the places, with the works and social relationships in general. It is therefore necessary to exploit this growth in favor of the re-appropriation of museum spaces by users, using videogames as the ‘driving force’ of innovation and 'cultural promotion'.

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The Complex of *villa rustica* Near Blagoevgrad, Bulgaria – Archaeology, Possible Reconstructions and Some Ideas Using New Technologies

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The largest archaeological site in Bulgaria was excavated near Blagoevgrad over the last two years (2017-2018) [Dimitrov et al. 2018, 374-377; Dimitrov et al. 2019, 380-382]. This is a huge Roman villa (an area of over 30 decares), with production centres for ceramics, metals and other materials, the family tomb and part of the nearby village. The chronology is the 1st–4th century AD. A Roman military diploma from the year 74 AD was also found there. The villa is located on the route of the new motorway from Bulgaria to Greece. That is why it is imperative to use all new technologies for digital documentation and repairs in these rescue excavations. In order to rescue these archaeological structures, which will soon be lost in the field, our large team carried out a complete photogrammetry of architectural complexes from the site, aerial photography, orthophotography and graphic reconstructions and produced a complete virtual tour of the separate premises of the villa and the tombs. The main idea of the scientists, excavating the villa, is to create a new museum (in situ), along the motorway, on that part of the site that will be preserved. This museum, which will expose the tombs and large parts of the villa, will offer virtual tours of the complex, exposed finds, graphic reconstructions, and most of all 3D visualisation of the villa complex.

Key words:
Roman villas, Rescue excavations, New technologies.

CHNT Reference:
Zdravko Dimitrov. 2018. The Complex of *villa rustica* Near Blagoevgrad, Bulgaria – Archaeology, Possible Reconstructions and Some Ideas Using New Technologies.

INTRODUCTION

In this Roman *villa rustica*, discovered on the route of the new motorway from Sofia to Thessaloniki, Greece, all archaeological structures are localized very close to the town of Blagoevgrad [Dimitrov et al. 2018, 374-377]. The newly found site is 400 m. long. Therefore heavy rescue excavations have been carried out in these large complexes (Fig. 1).

Fig. 1. General view (panorama) of the whole site No. 2 along the route of the Struma Motorway, near Blagoevgrad, Southwestern Bulgaria. Excavations 2017-2018

All the archaeological complexes, layers and materials were unearthed during active archaeological excavation works, lasting for nine months in the period from April 2017 to July 2018. The excavations were carried out by the following team of archaeologists: Associate Professor Zdravko Dimitrov, PhD, team leader, Assistant Professor Milena Raycheva, PhD and Nikolay Rusev, PhD, deputy team leaders, and Associate Professor Lyudmil Vagalinski, PhD, all of them from the Department of Classical Archaeology of the National Archaeological Institute with Museum at the Bulgarian Academy of Sciences. Over 250 workers, 47 archaeologists and more than 20 interdisciplinary experts were involved in the excavation works.

In this particular case a large part of the complex could be preserved. The Roman villa, the bath to the villa, the family tomb and the church, constructed for the late antique village, are scheduled to be restored and displayed. However, the real field archaeological situation that was unearthed on a space of 60 decares cannot be completely preserved – on the one hand because the route of the future motorway runs across this area, and on the other hand – because the ground surface has been severely broken by deep ploughing. The land in the "Shirinite" (the "Widths") area was agricultural throughout the socialist period in Bulgaria.

Therefore, in view of preserving the original archaeological data, and also in view of producing a complete reconstruction of this huge archaeological complex consisting of a villa, tomb ensemble and a village, we need to make use of the new technologies – digital documentation, visualization and 3D reconstructions.

In the end the Ministry of Culture in Bulgaria decided that one third of the site should be allocated to the route of the motorway to Greece, another third of the site, bordering on the motorway, will be dedicated to a future museum, and the family tomb and the church will be transferred and reconstructed on the last third of the original site, next to the museum (Fig. 2).

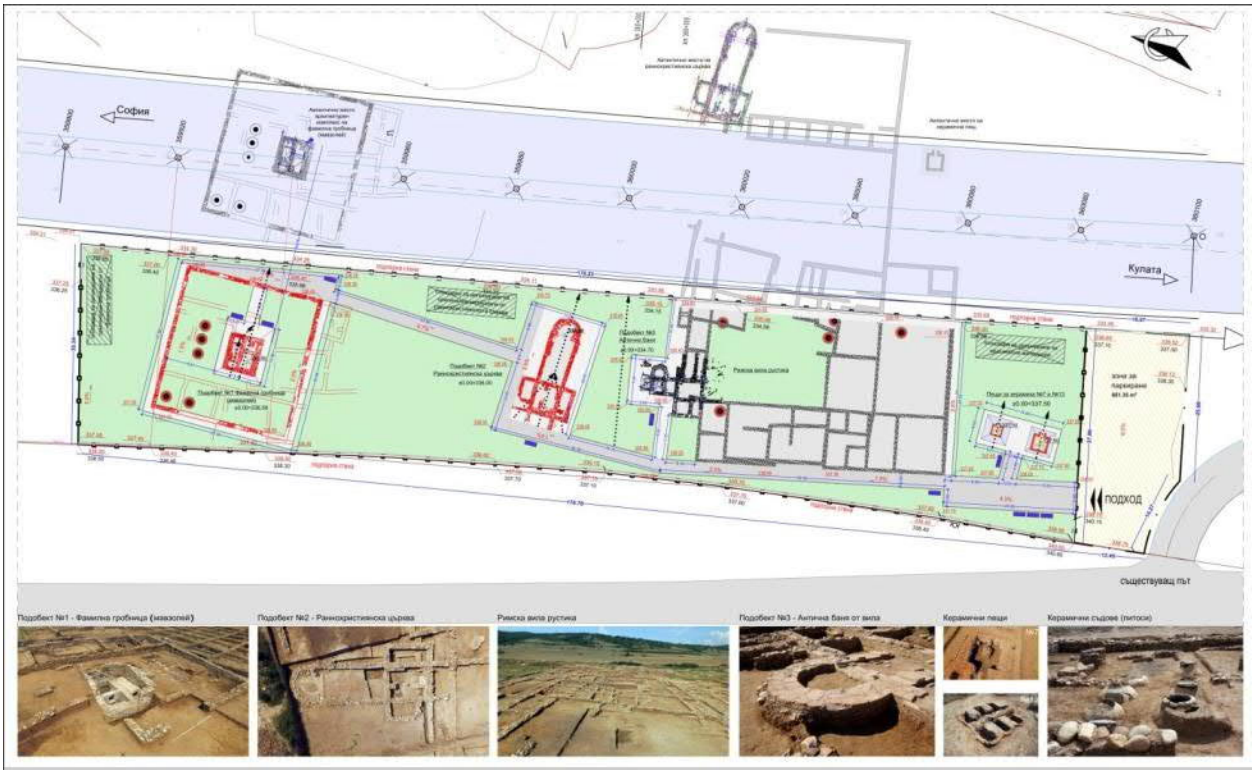

Fig. 2. The new idea for preserving the site – the main building of the villa with bath, church and tomb form a huge museum centre in situ, next to the motorway

NEW METODS AND TECHNOLOGIES USED IN THE EXCAVATIONS

In order to rescue these archaeological structures, some of which will be shortly lost in the field, our interdisciplinary team produced a complete photogrammetry of the archaeological complexes on the site, aerial photos, orthophotos and graphic reconstruction, a complete virtual tour of the individual premises in the villa and the family tomb.

The main purpose of the scholars is to set up a new museum in situ, along the route of the motorway, on the part of the site that will be preserved. This museum, around which the tombs and large parts of the villa will be displayed, will offer virtual tours of the complex, will have various finds and graphic reconstructions on display, and above all – a 3D reconstruction of the villa complex.

Site no. 2 of Struma Motorway LOT 3.1. covers the distance between the villages of Pokrovnik and Zelen Dol on the right bank of the Struma River, right opposite Blagoevgrad.

The area of the rescue archaeological excavations in 2017-2018 covered 60 decares – 600 m long and 100 m wide. The remains of the Roman villa, the tomb and the village were spread on 38.4 decares (about 400 m long). The entire site was divided into three sectors: a "north" sector, a "central" sector and a "south" sector.

THE ARCHAEOLOGICAL REMAINS - VICUS, GRAVE COMPLEX AND ROMAN VILLA RUSTICA

In the "north" sector remains of a large village from the Roman imperial period were uncovered, dated to the 2nd-4th century AD. There we registered 26 non-solid buildings made of pebbles bonded with mud (Fig. 3).

Fig. 3. Aero-photography of the northern sector – Roman vicus next to the villa complex

Only the foundations of all of them have survived. In terms of functions these are residential buildings, small yards and streets between them, as well as a number of workshops and small storage premises. This outlines a typical provincial village from the Roman imperial period, meeting the production and daily needs of the adjacent large Roman villa.

The most interesting and best preserved architectural complexes were unearthed in the "central" sector. The archaeological structures in this place developed over a long period of time – from the 2nd-3rd c. AD to the middle of the 5th century AD and again in the Ottoman times in Bulgaria.

In general here were placed a huge grave complex – Building № I, the most interesting and the best preserved archaeological structure in the whole site. It is very close and well connected with the Roman *villa rustica* to the south. Here we registered four cultural layers (Fig. 4).

The first layer contained only remains of one or two buildings. It dates to the 2nd–3rd cc. AD. The second layer, which dates definitely to the 3rd c. AD, contains huge courtyard and the building inside. This is a large family tomb representing a burial memorial (mausoleum) in the centre surrounded with a wall (Fig. 5).

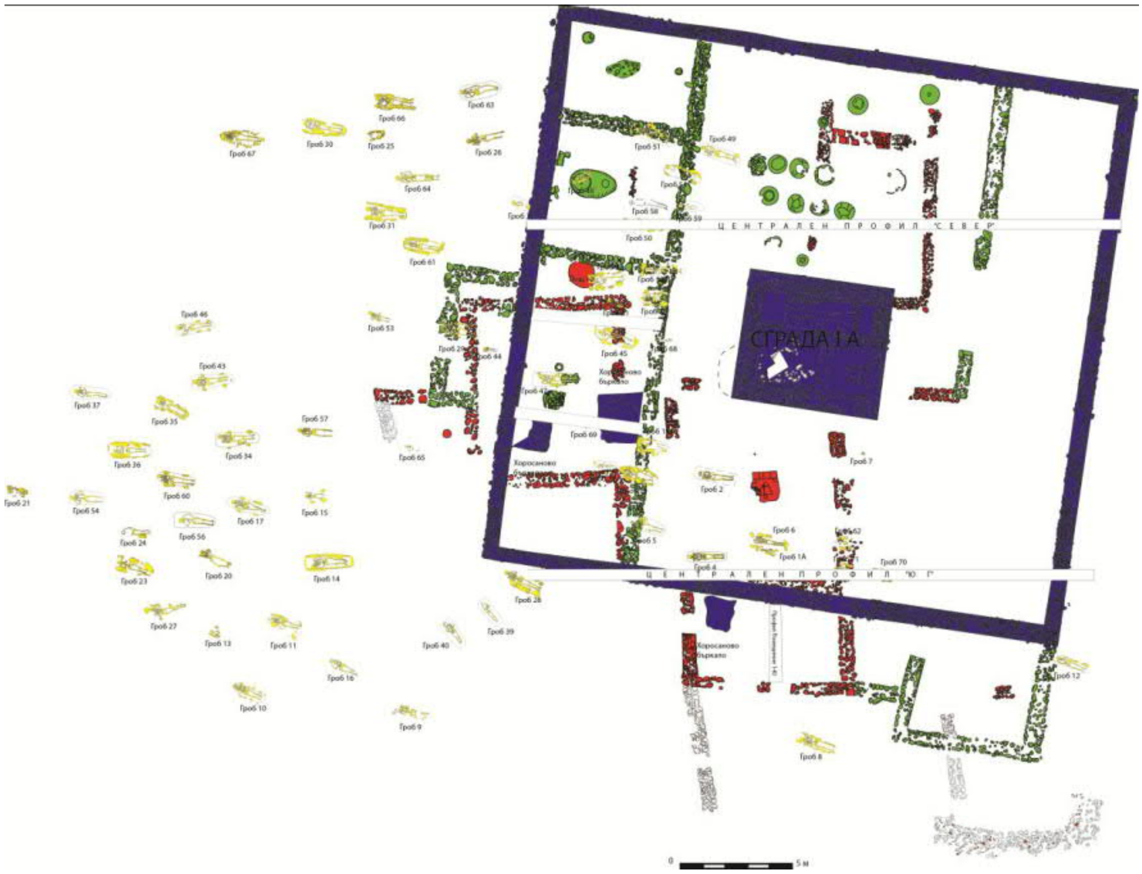

Fig. 4. General plan of the four cultural layers in the central sector – I layer (red): 1st construction period, structures before grave complex; II layer (blue): a grave complex, a Roman family tomb (mausoleum); III layer (green): storages from the late Antiquity; IV layer (yellow) – a necropolis from Ottoman period, the 17th-18th century

Fig. 5. The grave complex – a family tomb built like a mausoleum complex surrounded by the wall (peribolos)

These burial ensembles date to the second half of the 3rd century AD and were in use till the early 4th century. AD at the latest[1]. In the next, third layer, of this zone the mausoleum was abandoned after the population converted to Christianity and all the complex was transformed to a storage facility (Fig. 6).

Fig. 6. Reconstruction of the complex in Late Antiquity – storage premises with many pithoi in situ

New premises from the 4th-the first half of the 5th century AD and over 30 pithoi dug into the ground were localized here. These last complexes were raised to ashes during a huge fire in the middle of the 5th century AD, most probably during the raids of the Huns in the 40s[2].

The last, fourth layer, consists of a huge necropolis with 70 graves from the Ottoman period (17th–18th century AD), placed accidentally here and dug into the ancient ruins.

Exactly the mausoleum from the second layer is the most important archaeological complex in the whole site. This Roman family tomb consists of a big surrounding wall, which shapes the whole sacral space enclosing it in a wide yard of about 1 decare.

The cult building itself was localized in the centre of the yard – a mausoleum consisting of two parts: a structure above the ground made of mortared stones and bricks (*opus mixtum*) and a structure under the ground (*hypogeum*) which is the tomb (Fig. 7).

The structure above the ground was erected high above the surface level (resembling an antique temple – outer dimensions: 6.5 m in the east-west direction and 5.75 m in the north- south direction). This cult and tomb structure was richly decorated. The team unearthed two thresholds (within the building itself) and an Attic-Ionic base (found not far away in the field (Fig. 8)) attesting the configuration and decoration of the building. Moreover, two big limestone blocks (found also not far away in the field) seem to have belonged to this “temple” section of the mausoleum complex as well.

[1] At this early stage of the study, this is just a general chronology. It will be specified after the analysis of the finds and bones of the tomb.
[2] The latest coin under these destructions is from the first half of the 5th century AD (No. 1677/2018; diameter 14 mm; sector M 87; level 334.70 m, probably Theodosius II (408-450).

Fig. 7. Inside the mausoleum – burial chambers, stairs and construction of the hypogeum part

The following were uncovered in the underground part (*hypogeum*): stairways (3 big steps made of bricks), an antechamber and two burial chambers – one of which was robbed in Antiquity, and the other one has survived intact (Fig. 9).

Fig. 8. An Ionic base from the Attic type found on the terrain next to the mausoleum

Destructions from the roofing were found in the first burial chamber (measuring – 2.20 m x 1.97 m), which was a barrel tomb; however, a golden ring was also unearthed, perhaps from the burial inventory. The robbers failed to collect it. The bones in this burial chamber were found in disorder in the antechamber. The bones are believed to have belonged to several individuals, yet the bones are subject to an anthropological analysis. The second burial chamber has survived intact from the time of the funeral (measuring: 3.30 m x 1.40 m outside; 2.30 m x 0.90 m inside). It was carefully excavated for 7 days.

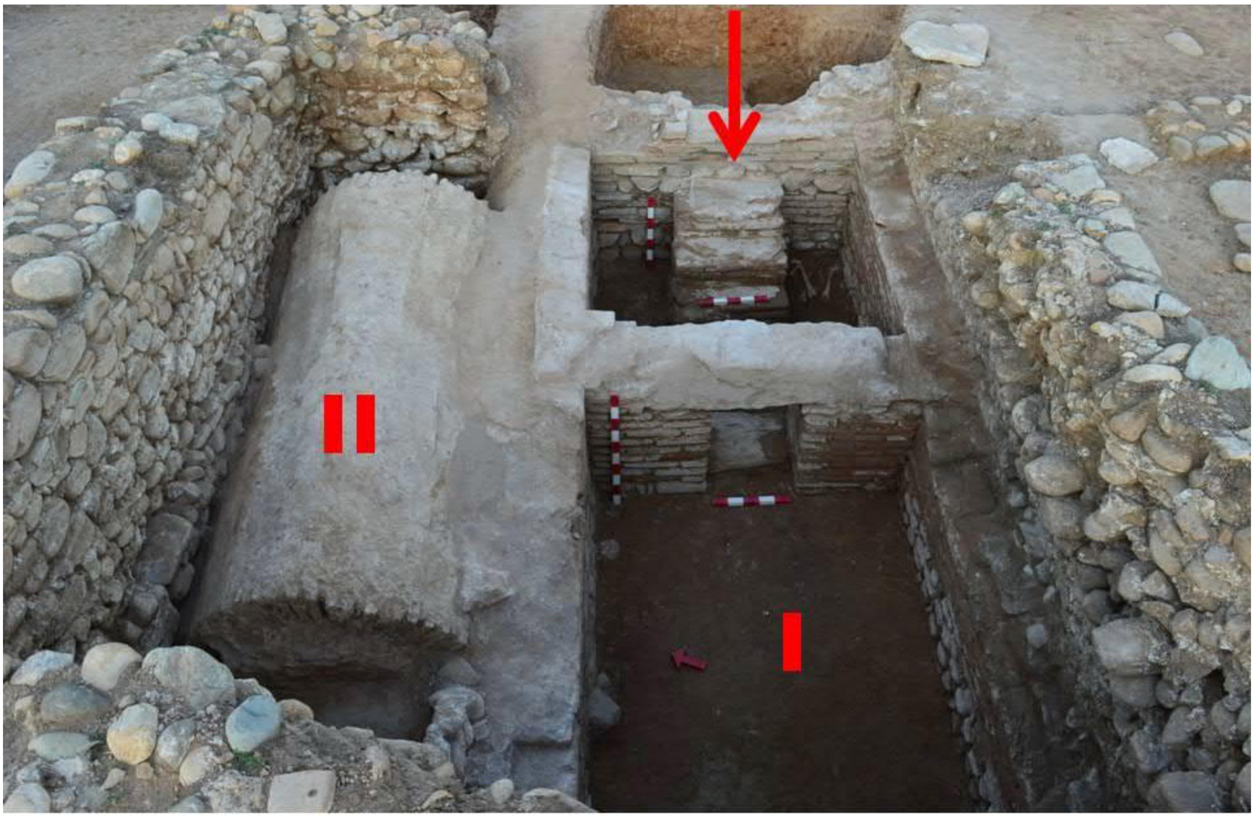

Fig. 9. The tomb complex, hypogeum inside – two chambers, antechamber and stairs

The architectural structure consists of a barrel vaulted burial chamber with a brick floor. It was built entirely of Roman bricks bonded with mortar. The foundations are made of rough stones, with no bonding at all, which are dug in the clay layer under the burial chamber.

In the burial chamber proper, bodily remains of a man were found along with a number of objects in situ, the way they must have been laid during the funeral ritual (inhumation, performed on the clay floor, the body was aligned in the west-east direction). The burial inventory consists of two glass vessels (Fig. 10), a clay lamp (Fig. 11) and bronze objects, which are writing tools (Fig. 12). Several textile fragments were unearthed in this important archaeological situation, yet they are difficult to interpret before being reconstructed. Chances are that these are not only fragments of the clothes of the deceased, but also of the material the body was wrapped in (a shroud or any other enveloping garment in which a dead person is wrapped for burial).

All the material found in the tomb dates back to the end of the 3rd century AD- the beginning of the 4th century AD – writing tools, glass vessels and clay lamp [Eckardt 2018, p. 38-39, fig. 2.8; Isings 1957, 157-158, Form 127; Fünfschilling 2015, p. 101, Abb. 128,2; Kuzmanov 1981, p.10-20].

Fig. 10. A glass amphora in situ by the excavations in the tomb chamber No. 2 – 25.04.2018

The bath was added to the villa complex (Fig. 14). This structure was built in the *opus mixtum* technique bonded with mortar. On the terrain we found seven premises from this bath and two construction periods, dated back to the 4th century AD.

The biggest architectural remains in site no. 2 were found in the "south" sector. On an area of over 8 decares we found remains from a Roman *villa rustica* having more than 40 premises (Fig. 13), two interior peristyles and two exterior peristyles for the cargo carts.

Fig. 11. A clay lamp in situ by the excavations in the tomb chamber Nr. 2 – 25.04.2018

Fig. 12. Bronze objects – writing tools (stilus, box, ink cartridge and little chain) in situ in the tomb chamber Nr. 2 – 25.04.2018

Fig. 13. The Roman villa rustica – general chronology from the 3rd-5th century AD

During the latest stage of living in the area (5th-6th century AD) there was an early Christian church in the easternmost section of the site. This is a single-apse, single-nave church (Fig. 15). The two very intriguing architectural complexes (the bath and the church) date to different periods. For instance the bath was appended to the villa in the 4th century AD and was reconstructed and rebuild after the middle of the century. It belongs to the second, third and fourth construction periods of the villa (4th-first half of the 5th century AD). At least four construction periods were identified in the whole villa – from the second half of the 3rd century to the 5th century AD (Fig. 16). Certain zones of the villa were destroyed by fire just like building no 1 (the family tomb).

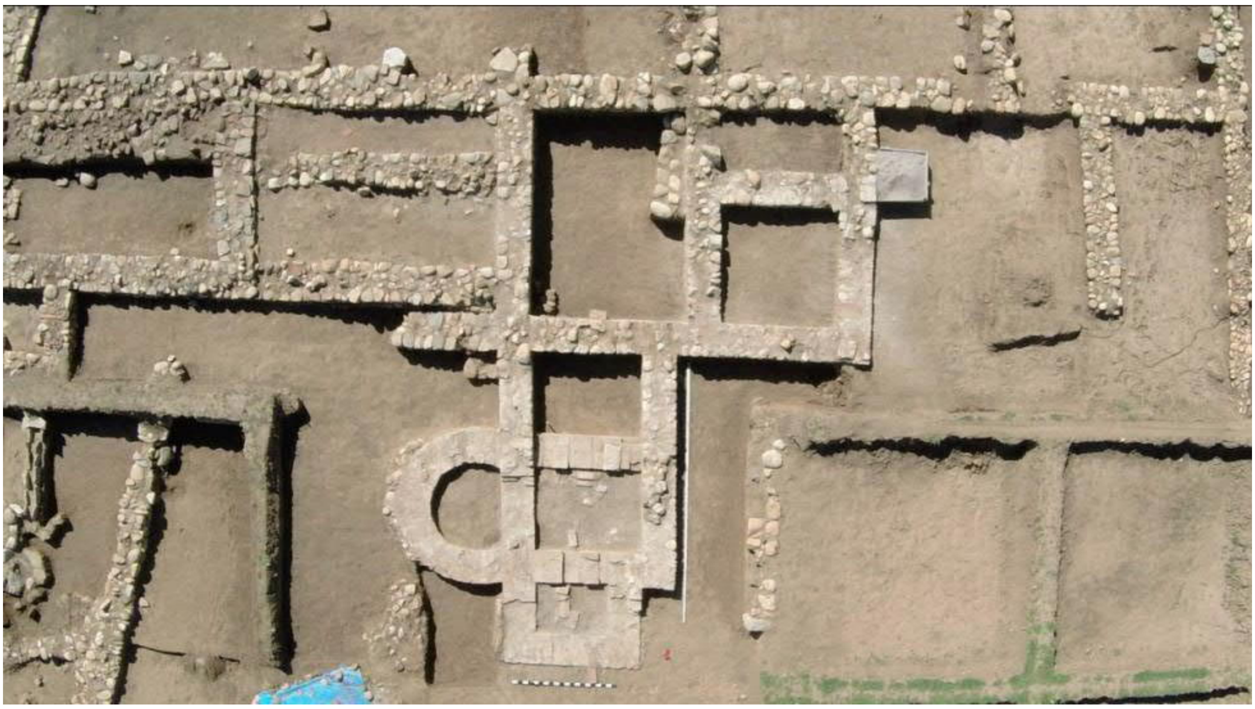

Fig. 14. The bath – built in the northern part of the Roman villa complex in 4th century AD

Fig. 15. The early Christian church (5th-6th century AD) – built over the ruins of the Roman villa

On the other hand, the early Christian church was built after the villa was abandoned. It is the cult building of the late village (post-villa settlement), which was built in the ruins of the old Roman villa in the 5th-6th century AD.

It was precisely after these invasions in the second half of the 5th century, quite likely by the Huns, that the lifestyle in this place changed – people returned to settle in the ruins of the big villa, but lived in a much more primitive way. The so-called post-villa micro-vicus appeared. During this new development stage the ruins of the big building were reused to erect a small church for the population that had already converted to Christianity (Fig. 14).

This place was inhabited by peasants in the vicinity from the second half of the 5th century AD to as late as the reign of Justinian (527-565), the period to which the latest finds and coins from the site date.

In these uncertain times people lived in the former villa and the vicus, appearing on top of it, only in peaceful periods. However, as the settlement was not fortified, a fortress was built not far away – 2.5 km to the northwest, near the village of Zelen Dol. The peasants from the Struma River valley hid behind the walls of this fortress during the numerous invasions by the Huns, Avars and Slavs, which were commonplace in these lands in the 5th-6th century AD.

ANALOGIES AND SUMMARY OF THE ARCHAEOLOGICAL RESULTS

Finally, in conclusion, it is possible to mention that the Roman *villa rustica* near Blagoevgrad is a typical villa complex for the provincial system of the Roman Empire. The main models started from Italic aristocratic homes and residences and developed in the provinces [McKay 1998, 100-114, fig. 38-42; Ward-Perkins 1994; Percival 1987, 527-546; Mielsch 1987]. Although there is no luxury in it, it is one of the largest in Bulgaria, compared with villas in Montana, Armira and Madara [Dinchev 1997, 32, 34-35, 38, 55-60, 74-79]. This new complex is a major contribution to the study of villa ensembles in the western part of Bulgaria.

Quite a few similarities in the architectural plan can be noticed in the villas of Mursalevo and Montana [Dimitrov 2017, 73-88; Alexandrov 1980, 12, fig. 1; Alexandrov 1981, 50; Alexandrov 1984, 12, fig. 1], as well as in the large residences of Kostinbrod and Nis [Dinchev 2003, 8-61, fig. 5-7; Petrovich 1993, 30, fig. 9].

Fig. 16. Five cultural layers in the zone of Roman villa – I layer (red): buildings before the late Roman villa was constructed; II layer (blue): the Roman villa, 1st period, the first half of the 4th century AD; III layer (purple): the Roman villa, the second period, after the middle of the 4th century AD; IV layer (brown): the Roman villa, the third period, the end of the 4th-5th century AD; V layer (green): the vicus, post-villa living in the area, the second half of the 5th-6th century AD

A total of 2700 finds were unearthed in this big architectural complex along the Struma Motorway: coins, ceramics, jewellery, household objects, weapons and even a large fragment of a Roman military diploma dating to 74 AD.

As a result of the excavations in building no 1 (the Roman family tomb), building no 3 (the Roman *villa rustica*), building no 5 (the Early Christian church), the adjacent more than 25 buildings (belonging to the Roman *vicus* to the north) and 18 pottery kilns (Fig. 17) we have obtained excellent data, which provides wonderful opportunities for potential virtual reconstruction. The cultural layers have been fully examined, the horizontal and vertical planning of the building has been perfectly identified. We also have many architectural details, various wall tracts and a drain-channel system that allow us to make a variety of reconstructions.

ADDED REALITY AND RECONSTRUCTIONS OF THE GRAVE COMPLEX

The modern busy life and the rapid development of high technologies provide new opportunities to display the archaeological finds. At the same time the archaeological site must be tourist-friendly, so that tourists can understand what is displayed and can appreciate the significance of the finds. The new technologies allow for more flexibility, better visibility and more details without damaging the finds.

Fig. 17. Pottery kiln no 18 – the region of building XXIII (A-B 56-57), a general view at the end of the excavations

The 3D visualizations, the “Added Reality” (AR), virtual tours and documentaries help tourists understand better the job the archaeologists have done. It is similar to the case of the mausoleum complex, where it is possible to make very good reconstructions of the main grave-building (Figs. 18, 19) and of the whole courtyard also (Fig. 20). These reconstructions are close to reality and by using some new technologies and virtual effects it could be much more intriguing for the visitors. The objective of the team is to have high technologies in place so that while looking at the ruins the visitors can effortlessly gain an overall understanding of the whole context. It is often the case that tourists have limited time to spend in a museum, therefore the information should be dynamic and the ideas should be easy to see. For instance, an added reality by a 3D holographic effect can demonstrate on the basis of the remains of a kiln what the whole kiln looked like and what it was used for, thus arousing a stronger interest in the site.

This will be coupled with reconstructions, acted and graphic alike, and shown at the site itself, rather than broadcast on a special program. In such an environment the film would be easy to understand and useful, and the tourists will not be bored. The team is developing a complete vision about the particular site at the Struma Motorway: a virtual tour can take the tourists back to the time when the archaeologists unearthed the finds before the motorway was constructed; 3D visualizations will develop the whole building, inside and outside, starting from pictures of the ruins; and actors can add information about the functions of the building. This is a very fast and appealing visualization with multiple effects: Interest arousing, clear and understandable message about the period, an enjoyable learning process. Our purpose is to make tourists willing to come back to the site, because tourists see the site as significant, accessible and fun.

Fig. 18. An ideal graphic reconstruction of the complex of the Roman mausoleum

Fig. 19. The main façade of the mausoleum complex – view from the east

Fig. 20. Reconstruction of the courtyard of the complex

In Bulgaria there are many remains from ancient towns, fortresses and temples. A lot of ruins have survived from the Thracian kingdoms, the Roman Empire, the First and the Second Bulgarian Kingdoms. The archaeological excavations reveal the layout of the buildings, whose remains are at best not higher than 1-2 metres or only the foundations were localized.

On the other hand the ordinary visitor finds these structures, even conserved, difficult to understand.

In order to provoke the interest of the mass visitors it is necessary to restore the presumable shape and height of the building. This would convey a better idea of the building and the history would be easier to perceive by interpreting it in a certain context.

The reconstruction of any building on the basis of scarce archaeological finds is a complex and risky job. The point is that apart from the relatively accurate layout and the eventual finds inside or around the building, there are no other data about it.

It is more easily, more effective and less expensive to solve the problem with the preservation and “displaying” of the site by employing interactive and accessible contemporary information technologies through multimedia. The virtual buildings are easy to change at later stages, when new data may be obtained from the current studies or archaeological excavations regarding the architecture of the monument. Moreover, the different stages of the existence of the monument can be sown dynamically. For this purpose first of all high-quality content needs to be created as a 3D model, and afterwards it needs to be visualized in the most appropriate way for the visitors, so that they can have a really great experience and learn something new about the history of the visited monument.

I believe that it is most appropriate to use the AR technology to visualize a cultural monument, considering the following:

The AR-software overlays virtual objects on video footage captured with a camera and gives users the impression that virtual objects actually exist in real-world environments and allows comparison of virtual and real-world objects.

Visualization with AR creates a sense of real dimensions of the virtual reconstruction, something that is difficult and expensive to achieve with pure VR technology.

Parts or walls of the actual cultural site may be used in order to visualise the added information.

A scenario for cultural heritage reconstruction and visualization by using the AR technology based on mobile technology, and by using mobile devices (tablets, smartphones) to display the added content. The advantage of this option is that it does not require expensive specialised equipment for terminal devices. Users can have it independently on their mobile devices if they install the special software. With this option, 3D visualizations can be combined with an interactive guide to the archaeological site.

This requires a very good 3D model of the building from all possible angles throughout the site.

The “ Virtual Reality” (VR) technology has already reached a level of maturity that allows it to be introduced into the liberal arts like education and cultural heritage. Recently, due to the significant research, the AR technology has been making a good progress. It expands the VR systems by mixing real and virtual elements into a continuous composite scene. By combining virtual reality with real-time video processing and computer visualisation technology, the AR systems deliver a natural view of real scenes and objects enriched with virtual objects and scenes. So today we have the potential to make the cultural and historical monuments of Bulgaria more accessible, more interactive and more interesting to the ordinary visitors.

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The International Project VirtualArch: Visualization and Presentation of Hidden Archaeological Heritage Across Central Europe

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Different approaches and challenges, sharing experiences but reaching the same goal – a better understanding and raised awareness of hidden archaeological heritage and its protection by presenting it via new information and communication technologies like VR/AR. That is the main background of the EU-project "VirtualArch – Visualize to Valorize", running from July 2017 to June 2020. Ten partners from eight central European countries try to elaborate a transnational strategy to valorize hidden archaeological monuments by visualizing them. Therefore, eight selected pilot sites were digitized/visualized and presented to stakeholders via guided field tours and information points on spot. The pilot sites are presenting different archaeological types, forms and periods like prehistoric and medieval mines, roman and medieval harbors as well as cultural landscapes with prehistoric pile dwellings or urban archaeology with huge and complex stratigraphy. This includes also different areas and environments, impacts and audiences. Although the project is still in its first half, the session seems to be a perfect area to present project and its actors as well as share first experiences with all present professionals and experts.

Key words:
Heritage communication and protection, VR/AR, transnational cooperation approach.

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INTRODUCTION

The rich and diverse archaeological heritage of central Europe is in parts excellently developed and utilized. But in contrast to finds in museums, a broad share of this heritage sites, even of international importance, is very often hardly visible and tangible for the public. Moreover, archaeological heritage is affected by different human activities and spatial usage conflicts.

VirtualArch focuses on the practical application of innovative and trendsetting visualization tools in the field of virtual and augmented reality [Reffat and Notfal 2013]. One of the aims is to unveil regional archaeological heritage – located underground or submerged, partly with global importance (UNESCO) – to local and regional stakeholders that are responsible for economic development. By tailoring and implementing of target group oriented and specially designed visualizations and presentations using "Virtual or Augmented Reality" (VR/AR), their level of awareness and acknowledgement will be increased [Frontoni et. al. 2015]. Furthermore, virtual reconstructions could be used as innovative visualization tool during spatial usage conflict management and hence contributes to a better heritage protection.

VR/AR provides not only a better accessibility to hidden or inaccessible archaeological heritage, but offers also new possibilities for tourism, regional development, cultural participation and the usage of archaeological data in the field of creative industries and media sector. Even virtual open-air-museums could be built [Unger et. al. 2016].

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PARTNERS AND PILOT SITES

Different to many other VR/AR visualization projects in archaeology, VirtualArch approaches through transnational cooperation with different heritage. Facing similar challenges and sharing same objectives, ten partners from eight countries get together in a EU-funded project (Interreg Central Europe), running from 2017 to 2020. The partner consortium is composed of regional and national archaeological institutes and heritage offices, two universities/research institutions and also two local communities as heritage owner. On eight selected pilot sites all over Central Europe, their experiences were shared, distinct innovative visualization and communication approaches were discussed and introduced, special applications due to the demands of each heritage and their audience developed [Lobinger and Hemker 2018].

Fig. 1. Pilot sites and partners of Interreg Central Europe project "VirtualArch – Visualize to Valorize" (© Archaeological Heritage Office of Saxony)

This heterogeneous approach is also reflected in the diversity of the pilot heritages, like in Fig. 1. The sites are characterized by various archaeological cultures, areas, environments, impacts and challenges. All of these sites contains unique finds, often from organic material like Fig. 2 which allows a huge insight of past life and procedures and thus of international importance for research and general public. But none of them are accessible or even visible, and because of their complex structures they are also hardly tangible especially for non-professionals.

According to their nature the pilot heritages can be separated in three groups: urban area, mines and underwater sites. Each of these groups has its specifics, as in a way of the gathering primary data, but also in a way in which they are further presented to a public. Also, each pilot site has its specifications concerning the main aim of what is there to be achieved as a goal.

Fig. 2. Wooden parts of a winch in a medieval mine under the current town of Dippoldiswalde (© Archaeological Heritage Office of Saxony; photo by Martin Jehnichen)

Within the group of mining heritages there are at first the prehistoric salt mines of Hallstatt (Austria), since l997 part of the UNESCO cultural landscape "Hallstatt-Dachstein/Salzkammergut"[1]. Known in the scientific community for the famous cemetery excavated in the 19th century, Hallstatt is one of the most important sites in European archaeology, thanks to outstanding results of excavations and experimental researches undertaken by the Natural History Museum Vienna since the 1960s in the still active salt mines [Reschreiter et al. 2018]. Nowadays, the Salt Valley is already a popular tourist destination with a good infrastructure, so the aim in this project is to develop more precise and attractive ways of presenting the finds or to show them in a new light for the public. On the other hand, the heritage is threatened seriously by natural movements of the rock itself [Reschreiter et al. 2017].

[1] https://dachstein.salzkammergut.at/en/world-heritage-hallstatt-dachstein-salzkammergut.html

Fig. 3. Survey and digitization of prehistoric mines in Hallstatt (© Natural History Museum, Vienna)

The second important mining heritage is located in Saxony (Germany), where unique and almost complete mines of the Middle Ages were found under the Town of Dippoldiswalde. As part of the “Erzgebirge/Krušnohoří mining region” (Ore Mountains), the Dippoldiswalde medieval silver mines recently achieved UNESCO World Heritage status[2]. Since 2008, the Archaeological Heritage Office of Saxony records and recovers this outstanding heritage [Hemker 2011; Hemker and Schubert 2018], which is – due to security reasons – not accessible and visible for non-professionals or tourists.

Another big mining landscape was in the mountainous area around Civezzano (Italy) near Trento. Especially from the 12th to the 15th century silver ore was exploited there intensively so archaeologists discovered a mining area with sinkholes and gallery entrances over 12 km^2 [Casagrande 2013]. Due to security reasons they are not accessible and threatened itself by agriculture and forestry.

A big and important mining and metallurgic settlement from the 13/14th century next to visible mining relicts was discovered near Utín in the Bohemian-Moravian highlands [Derner et al. 2016]. The settlement, mostly known thanks to geophysical surveys, includes interesting features like miners' houses, ore mill, a stamping mill or furnaces as well as a hospice and a filial chapel. The area is nowadays rarely inhabited but agriculture and especially forest activities could endanger this interesting site. Identifying in its full extend, virtual reconstructions and target group oriented lectures and tools enables a better understanding and consequently protection, for example by creating special exclusion zones.

Urban archaeology is represented by the pilot site Nitra (Slovakia) which was a princely residence since the 9th century) and is of national importance as oldest center of early Christianity [Fusek and Bednár 2008]. The urban area of Nitra was settled since the Neolithic period. The settlement layers and layers of rebuilding made the archaeological localities invisible to the visitors´ eyes. Here, mainly the excavations done since 30 years by the Slovac Acedemy of Sciences as well as small finds will be visualized to present the importance of the site from the smallest detail like a tiny cup to the big picture [Ruttkay 2011].

[2] https://www.montanregion-erzgebirge.de/en.html

In contrast to the latter example, the Slovenian pilot region[3] is a large wetland area near Ljubljana containing several prehistoric pile dwellings, since 2011 UNESCO World Heritage.

.The pile dwellings are a tremendous source of information not only for archaeology, but also for dendrochronology, botanic, climatology, geology and other fields of interest. The preservation of this archaeological heritage of a global importance is however heavily endangered. Ljubljansko barje constitutes a very attractive area from agricultural land-use point of view and is therefore highly endangered by the interventions of the local farmers e.g. building new, deep drainage channels and deep ploughing. Interactive landscape history visualizations and AR applications showing the nowadays invisible settlement structures should sensitise the stakeholders for a better protection.

Finally, the special field of underwater archaeology is represented by two important harbors: First, we have the ancient roman harbor Barbir in Sukosan, located at the Adriatic Sea coast of Croatia. There are several submerged stone structures as remnants of piers or breakwaters as well as pottery and small finds from the 3rd to 4th century. Although the International Centre for Underwater Archaeology is seated in near Zadar, only few research and surveys were conducted and the site is almost unknown to the public. Second, a large site from the 10th to 14th centuries in the Baltic Sea is known offshore of the Polish town of Puck [Pomina et al. 2016]. Over an area of 12 acres several remains of the harbor construction, 4 shipwrecks, potsherds and bones from the 10th to the 14th century were found. Puck was probably the largest early medieval port in the southern Baltic Coast, bigger than well-known places like Haithabu, Schleswig or Lübeck.

FROM 3D SURVEYING TO VIRTUAL MODELS

Although the differences between the heritage sites, the activities in the pilot regions are based on a same multi-stepped strategy:

First, all partners were gathering and digitize data of the archaeological pilot heritages like in Fig. 3, including field surveys and aerial reconnaissance. Finds and archaeological features were 3D recorded via different techniques ranging from structure-light scanners to photogrammetry and 3D scanning of finds[4] as well as hydroacoustic survey methods for the underwater sites.

The obtained and processed data provides the base for modelling of the virtual reconstructions as the second step. Depending on the visualization options and the “storytelling” behind it, the high resolution meshes have to been reduced, missing items added or situations and textures exchanged, like Fig. 4.

In the third step the result – the almost realistic virtual model of a heritage – will be visualized via various VR/AR options. During the year 2018, project partners met together as well as with other interested parties (external experts, stakeholders etc.) to create a coherent vision for digitalization and visualization of the pilot sites. This contains interactive panorama views of e. g. prehistoric or medieval settlements which are now invisible under the current construction of modern town or under the surface of farmland like in Fig. 5. Interactive 3D models of small finds or even whole landscapes allow a better understanding of the subject. With AR methods, users could walk virtually through past settlements and mines directly on resp. over the heritage site. Finally, new VR data glasses enables immersive experience of inaccessible sites using “ancient items” which are normally hidden in archives or exhibited in showcases of archaeological museums.

[3] https://www.palafittes.org

[4] For the mining archaeology see for example [Göttlich and Reuter 2013]

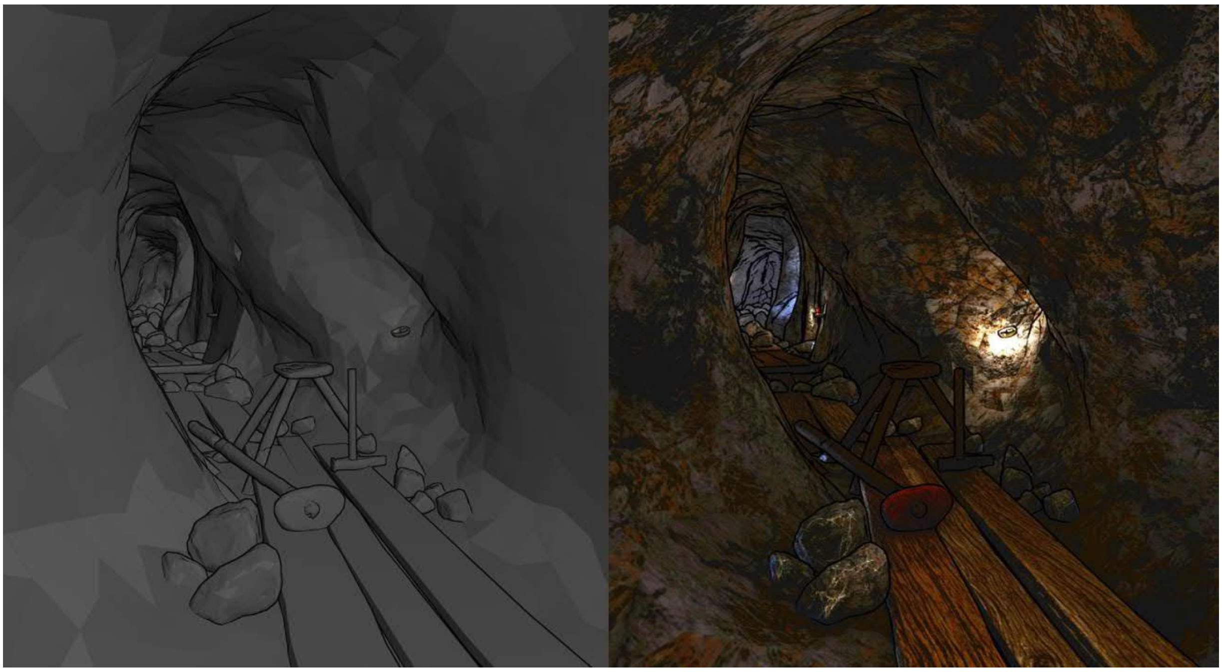

Fig. 4. Virtual reconstruction of a medieval mine based on archaeological surveys and digital documentation methods (©Archaeological Heritage Office of Saxony; image by Jiři Unger)

VIRTUALARCH MOBILE APPLICATION FRAMEWORK

To understand the heritage, its background and to discover several “points of interests” in hardly visible heritage landscape, these special applications were provided through a developed transnational mobile app with information texts, pictures, videos and interactive maps about the heritage.

Programming an app is expensive; keeping the content up-to-date furthermore requires regular updates which add up to the running costs. Furthermore, the diversity of the pilot monuments and local realization concepts make “one App” almost impossible. In our work for the EU Project VirtualArch, we have thus sought a way in which each partners can cross certain technical barriers and produce a location-based App without need for programming or external consultancy.

Therefore, we have produced a portal which allows for each pilot site the upload of a zip file containing a range of media (images, text, 3D files, panoramas, movies) in one or more folders; each one is transformed into a point of interest on a map for which the associated media can be shown as a slideshow. The key strength of the approach lies in the fact that the portal can produce both web presentations as well as apps using the same content. Technically this is achieved via the use of rules for transforming the content into html/css + javascript, and Apache Cordova/Adobe PhoneGap for turning the resulting web page into an app. Concerning individual wishes links to supplementing applications with VR/AR content are possible. With this portal and immersive visualizations tools partners now have the possibility to disseminate their often complex research, archaeological relevance of their heritage and detailed protection objectives frequently to a wider public using only smartphones.

Fig. 5. Making visible the invisible via VR/AR mobile applications (© Archaeological Heritage Office of Saxony)

IMPLEMENTATION, COMMUNICATION AND ENHANCING CAPACITIES

Archaeological stakeholders of the partner territories will be involved in the planning and implementation of the pilots and the evaluation of their success. Workshops and guided field trips are offered to them to learn more about the existing heritage and raising their awareness, especially in case of heritage threats and protection conflicts. Beside, workshops and conferences about related topics – archaeology & tourism, public archaeology, archaeology & agriculture or usage of archaeological data in media sector – bolster the knowledge of all partners and capitalize good practises (for upcoming events, see https://www.interreg-central.eu/VirtualArch).

For a better physical appearance and access, especially other audiences like tourists or local communities, the partners realize further smaller investments such as information boards with basic heritage information or WiFi hotspots providing internet access for free app downloading on their own devices. QR codes links to digital data, markers open 3D model in the various AR applications. Beside conventional communication methods, users could experience archaeology on a complete new way. Due to this valorization of heritage, both regional identity and cultural participation could be enhanced boosting also local tourism and regional development.

But not only non-professional locals and tourists should learn about their “heritage”, also future generations like students, young researchers and specialists from the fields of archaeology and related subjects have the opportunity to be involved and increase their knowledge in virtual archaeology and their methods in an upcoming (and free of charge) summer school in June 2019, organized by Partners in Torun (Poland).

Based on the experiences in these pilot regions a transnational strategy for future projects as well as guidelines for similar heritage sites will be worked out. In addition, the development of a free accessible visualization home kit is planned providing existing 3D models including detailed information about find spot, age determination, chronological and regional occurrence as well as the important question about accuracy of virtual reconstruction. Users, especially small actors like local museums, could utilize these models as base for their own small-budget visualisation projects (building-block principle) following the strategies of VirtualArch.

Archaeological heritage and the sharing of knowledge about them is a public matter carried out by different regional and national archaeological institutions. VirtualArch enhance this duty by introducing and promoting VR/AR approaches as possible new path in communication and protection of our cultural heritage.

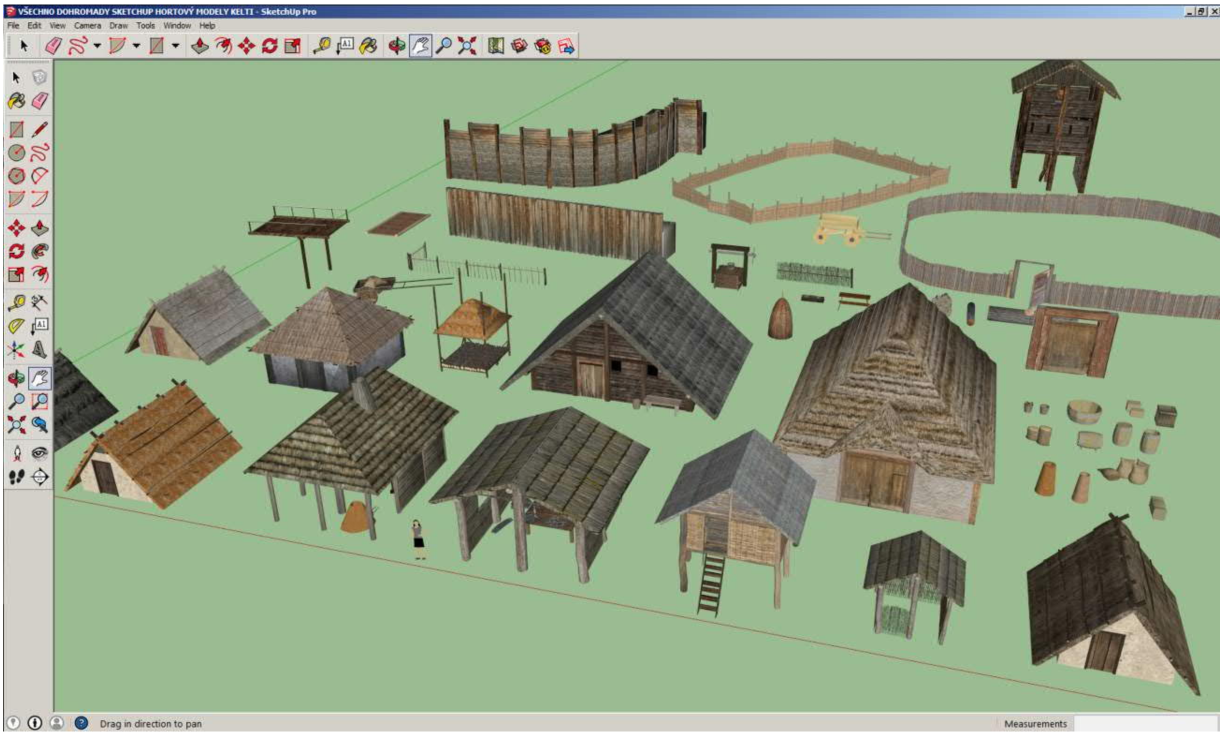

Fig. 6. Different components for a virtual reconstruction of an early medieval settlement, based on modular principles (© Institute of Archaeology of the CAS, Prague)

CONCLUSION

One of the important contributions of the VirtualArch project is the implementation of cultural mediation, as one of the central tasks of archaeological heritage. By using modern IT technologies hidden or inaccessible archaeological sites and areas such as mines, harbors and settlements become virtually accessible to various interest groups. Even complex facts and reconstructions were presented understandably by the applied VR and AR technologies directly on site. Beside this, coming from eight European countries and different institutions dealing with archaeological heritage matters, all project partners create a broad base of experience and promote the international exchange of scientific, strategic, legal and methodical information. As a result of the cultural mediation, the public awareness for these "nonvisible" archaeological places will increase; the heritage offices will be able to reconstruct sites i.e. for stakeholder meetings (conflict management). At the end of the project the applied VR and AR technologies explained by the guidelines will be open not only for heritage or archaeological institutions but as well for tourism offices or local museums to promote and protect their archaeological heritage in their region.

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Casanova Museum & Experience: How to Integrate History with Virtual Reality in Order to Relive the Past

ADELE MAGNELLI, ETT S.p.A., Italia

Casanova Museum & Experience, commissioned by Casanova S.R.L. and the Casanova Foundation, was conceived, organised and produced by ETT S.p.A. It is a museum, created to renew the great emotions of eighteenth-century Venice through the life and the thoughts of that great writer, poet, adventurer and seducer, Giacomo Casanova.
Located in a typical gothic Venetian building, the fourteenth-century Palazzo Pesaro Papafava, this is the first museum in the world dedicated to the most famous Venetian of all.
The multimedia exhibition gives visitors experiential and emotional involvement. They become protagonists and part of Casanova's history. In the "Virtual Reality" (VR) room, with its 18 VR stations, visitors can get first-hand experience of Casanova's exciting adventures thanks to a 360° video, filmed from a subjective point-of-view, which traces the salient events of that period. Following the directions of the Superintendence of Venice, all the efforts of this museographic and architectural project were aimed at reducing size, weight and spatial impact of every exhibition element, in order to make the whole structure as flexible and modular as possible.
Opened on 2 April 2018, the Casanova Museum Experience has had good feedback from visitors of various nationalities and ages, encouraging us to continue with the use of cutting-edge technologies to enhance our cultural and historical heritage.
This paper illustrates the multimedia solutions designed and developed by ETT S.p.A, analysing them in terms of design, execution and use.

Keywords:
Museum, Virtual Reality, Storytelling, Innovation, History.

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INTRODUCTION

The project "Casanova Museum & Experience" is a museum created about Giacomo Girolamo Casanova (*Venice, 2 April 1725 – †Duchcov, 4 June 1798), the eighteenth-century adventurer, *bon vivant* and a great connoisseur of the feminine soul and the one who gave his name to the metaphor of being a seducer and libertine. This museum, commissioned by Casanova S.R.L. and the Casanova Foundation, was conceived and realized by ETT S.p.A. and wants to offer a new perception of Casanova the man, an eclectic and complex character, not completely understood even today.

The museum is located in a typical Venetian gothic building, Palazzo Pesaro Papafava, not far from the Grand Canal. The physical setup has been designed to blend with the architecture of the rooms of the building in order to create a timeless environment, where the visitor is guided by our storytelling and his own curiosity.

The exhibition layout has been created by mixing semi-transparent overlaid sheets, panels with graphics and high-resolution projections, curved and straight video walls. Video contents are synchronized with an automatic narrative audio guide, to ensure a free field of view during the visit. Multimedia contents have elements that encourage the movement and the direction of the visitors' flow, avoiding the risk of crowding. In addition to that, every multimedia unit gives historical information in the form of videos and audio tracks.

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In the most immersive moment of the visit, there is a Virtual Reality experience recorded in 3D in motion technology (see Fig.1): 18 Samsung Gear VR S7 offer visitors the opportunity "to be" Casanova, with a 360° subjective point-of-view video projection. Both the settings and the virtual re-enactments, alternating with interactive settings and interactive exhibits, are also moments of shared view and enjoyment. Each multimedia unit gives "didactic-informational" content in a different way and at different levels of depth. Videos, images and a collection of data and historical information on Casanova's life are included. The voice of Riccardo Rossi (Johnny Depp's Italian dubbed voice) accompanies visitors on the tour and audio guides in ten languages help visitors from all over the world discover the true life of Casanova.

So wearing the Samsung Gear VR S7 visors, spectators can jump into the past and experience a journey in the life of Casanova the eighteenth century Venice. Every scene has been filmed at the original locations with real actors wearing period costumes, to improve the feeling of being part of the scenario and to enhance the magic of the whole experience.

Following the directions of the Superintendence of Venice, all the efforts of the museographic and architectural project were aimed at reducing size, weight and spatial impact of every exhibition element, in order to make the whole structure as flexible and modular as possible.

The multimedia and interactive ETT set-up is enriched with Canon Italia Digital Imaging technologies and ABS Group textile architecture, which let users see and live a new perspective of narrated history.

Opened on 2 April 2018, the Casanova Museum Experience has had good feedback from visitors of various nationalities and ages, encouraging us to continue with the use of cutting-edge technologies to enhance our cultural and historical heritage.

Fig. 1. The VR experience at Casanova Museum

CONCEPT, CONTENTS, AND THEORETICAL BACKGROUND

The traditional model of museum experience based on passive observation is definitely shifting towards active, interpretive engagement. Exhibits are no longer aimed solely at experts but must acknowledge the subjectivity of various types of visitor and perspective. This emerging trend is particularly evident in the popularity of interdisciplinary and inter-institutional collaborations. Museums are rethinking and reworking spaces in order to promote a deeper understanding of their collections and missions, greater interactivity, a fuller range of activities, and increased revenue stability [Cataldo 2011].

Over the last twenty years, audiences in museums, galleries, and performing arts institutions have decreased. Cultural institutions argue that their programs provide unique cultural and civic value, but increasingly people have turned to other sources of entertainment, learning, and dialogue. They share their artwork, music, and stories with each other on the Web. They participate in politics and volunteer in record numbers; they even read more. But they don't visit museum exhibits the way they once used to. Today, in the social media and hi-tech age, how can cultural institutions surprise the public and demonstrate their new cultural value and relevance in contemporary life? Visitors today are not passive consumers; they expect access to a broad spectrum of information sources and cultural perspectives, and to share and remix what they consume.

The goal of the Casanova Museum Project is to meet visitor expectations, delivering fine cultural content with diverse, personalized and changing modality offering a practical way to enhance, but not replace, traditional cultural institutions.

The innovative set-up combines technology and creativity to surprise visitors, stimulating curiosity and creating an educational experience. It also creates new physical and digital connections between the museum and the urban space where it is located. It generates new ways of interacting between visitors and the museum's layout, blending digital active narrative and passive elements to offer and create a strong emotional impact during the exploration of the narrative units. Virtual Museum Tours are steadily becoming more familiar. "Virtual Reality" (VR) has the power to transport users to places they might never be able to visit in real life, so welcoming digital visitors into the world's museums is a natural move. Some museums opt for virtual tours in the form of interactive online maps. Others choose to share image galleries or banks of 3D scans of their artefacts. Only VR, however, offers the most immersive experience, with a growing range of platforms offering more and more variety.

The new offering of the Casanova Museum & Experience museum visit consists of a project proposing an immersive environment in which the observer-participant is totally immersed and able to interact with the space around him; a mixed experience environment, therefore, in which real world and virtual world objects are presented together, in the same visit experience.

We have expanded the conventionally held interpretation of an "experience exhibition" or a "virtual museum" by proposing a new "immersive museum", with distinct solutions in "mixed experience" and different classes of hybrid display settings. To attract the Millennial generation to this new concept of museum we have used technologies and storytelling techniques familiar to them, creating a narrative path that is easy to follow and different levels of didactic detailing [Ioannides et al. 2017].

Studies indicate that adding techniques of sensory input – video, audio and touch – in both real and virtual immersive settings, can increase the sense of association with the objects, information and content offered by the museum. This increases the user's sense of presence and memory and creates a positive reaction to the visitor experience [Walker et al. 1999]. This consideration is the foundation on which this project is built, with much reflection on how content and narration should be elaborated. The result is emotional yet balanced storytelling, enabling visitors to re-experience the splendor of old Venice and Casanova's life.

With a system of settings constructed from semi-transparent backlit walls fixed to wooden frames, with shaped wall niches and ceilings, the exhibition is divided into six coordinated areas. The visit, elaborated in an "Immersive Theatre style", offers and creates an emotional impact that increases the journey through the narrative units. The multimedia set-up has been apportioned in order to show the most significant moments of Casanova's life, selected from writings about him as well as his own written documents.

The museography concept of the "Casanova Museum & Experience" envisages a multimedia exhibition where the visitor becomes the main character in Casanova's story, with a first-hand view of his world in his time.

The museum is developed in six rooms that retrace the life and youth of Giacomo Casanova, his travels, his literary works and the films he inspired. In particular, the museum is structured as follows:

Birth and youth

Giacomo Casanova was born in Venice on April 2, 1725. From early childhood Giacomo's life was a succession of adventures and misadventures. He lived in both luxury and destitution; with thieves, cheats and prostitutes, but also with aristocrats and men of court and culture.

This theme is set in the spectacular corridor. High-effect graphics on backlit fabric, with views of places, letters and portraits, end in an oval setting where an immersive video is shown on a curved wall, with ambient voice over.

Travels and society

Casanova is one of the most famous travellers to cross the borders and traverse the history of all mid-eighteenth-century Europe. Giacomo was an attentive witness and central character in an epoch-making moment of Western culture and civilization. The room is dedicated to the journeys and life of Casanova, told through a wall projection and a set of semi-transparent and inclined graphic panels. The explanatory panels with controlled location lighting recall the history of the narrative video and the most important cities visited by Casanova.

Venice, prison, and escape

Casanova led a dissolute lifestyle: he drank, cheated and had rather personal ideas about religion and politics. For this reason, he was arrested on July 25, 1755 and locked up in Piombi (Leads), the prison in Palazzo Ducale. In this room the visitors can try VR experience with eighteen VR seats, Samsung Gear VR S7, and a 360-degree subjective view video of Casanova's "life" in the Venice of 1753, with true citations and real actors in period costume.

Writer and man of letters

Casanova was the author of many books and pamphlets. The exhibition layout of the room meticulously reconstructs the literary and suggestive atmosphere of the author, with a wall projection and alternating immersive video settings and interactive exhibits on one big consultable "book". In this way, visitors can also learn about the literary talents of Casanova.

The myth and the cinema

Casanova is a very beloved character from the cinema thanks to the thousand nuances of his adventures life: memories, loves, misunderstandings, and mistaken identities, promises of marriage, political persecution, light comical jests and drama. The exhibition layout proposes two different cross projections on a backdrop of semi-transparent panels showing film clips and set images, and giving the visitor some good contextual knowledge of the cinematic production based on the Casanova myth (see Fig. 2).

The bedroom, eighteenth-century fashion

Fashion is an expression of the spirit of the time, but its social meaning differs greatly and depends very much on the style of society in which it is seen. Casanova lived in the eighteen century, a time full of changes, evolutions and even upheavals in lifestyle. On walls of fabric panels, the graphic design project, including images and historical text, surround the luxurious original eighteenth-century bed that welcomes us to this area. Projections on the "secret mirror" and on the bed, interact with visitors, creating two dynamic levels of depth

The whole structure and museum proposal thus created add-ons to experiential and emotional visitor involvement. Using this innovative mix of technology and new models for accessibility and visitor flow management, the visitor experience turns into a great opportunity for vivid involvement.

Fig. 2. Illustrative panels show the main films about Giacomo Casanova

THE PROJECT

The project "Casanova Museum & Experience, promoted by Casanova S.R.L. and the Casanova Foundation, was produced by ETT S.p.A, appointed as the project and technological partner in January 2018. This project is the most complete multimedia museum experience in Italy. The exhibition layout mixes semi-transparent panels, panels with graphics and projections, and video walls both curved and straight. Original high-resolution images, essential graphic design and chromatic harmony, introduces and accompanies the visitor in eighteenth-century Venice. And with nine Canon projectors (Xeed Wux450ST, 4500 ansi lumen, 16:10, with optics 0.56:1), one Canon projector (Xeed6010 - RS-IL03WF, 6000 ansi lumens, 16:10, with optics 0.8-0.85:1) and eighteen Samsung Gear VR S7, the Casanova Museum Experience offers an incredible and complete immersive experience.

Museums stimulate curiosity and create educational experiences by providing access to collections and fostering a range of interpretations. Audience engagement is an important aspect of the museum's value as a repository for knowledge. Today, many visitors want museums that present content in newly considered, thought-provoking ways. It is the key to relevance and audience engagement [Ioannides et al. 2016].

ETT, with this important project, has executed the whole panorama of an Italian museum visit, offering innovative architectural solutions but respecting the historical and cultural constraints of the location. A residence of enormous artistic and historical value, Palazzo Papafava, in which every solution had to smoothly integrate the original surroundings, blended traditional methods of use with innovative digital solutions, creating a very immersive setting. The design of a museum is always an opportunity to enhance a transformative visitor experience. Architecture frames the visitor's path and exhibitions, and as such needs to participate organically in the experience.

Various museum spaces were designed to fit in with the interior rooms of the building and create a path through the exhibition topics (see Fig. 2) Illustrative panels with attractive theme graphics and videos feature in a specific audio ambient, making interaction with information and content easy, proposing pictures, information and historical original texts on Casanova's life for a highly immersive visitor experience.

Fig. 3. One of the rooms of the Museum where next to paintings depicting Giacomo Casanova are the clothes that belonged to him

Furthermore, narrative videos are synchronized with an automatic narrative audio-guide, for a completely free view experience.

This experience and these solutions, mixed with the virtual reality, gives visitors a new kind of visit experience: a visit leading to in-depth knowledge of the history and the life of Giacomo Casanova, a man who, moving between courts and salons, touched a moment of epoch-making change in history.

The complete experience lasts approximately forty-five minutes, with visitors in each of the six areas for about seven minutes. This means no more than five minutes of content in each area, plus two minutes to move from one area to the next.

The multimedia content has elements that encourage movement and the visit-flow direction, thus avoiding the risk of crowding and the consequent reduction of quality and enjoyment of the exhibits.

In order to create an emotional and immersive context, the areas follow a logical narrative thread and, although physically separated, they are continuously bonded by storytelling. Casanova himself tells the story, as though he were talking to a friend about a dream. He is both the protagonist and storyteller.

The on-site visit is in Italian, but foreign visitors can use audio guides in 10 different languages: English, French, Spanish, German, Czech, Russian, Chinese, Arab, Portuguese and Japanese.

Each exhibition area is self-contained: it starts and finishes with a separate chapter of the story of Casanova's life or with a specific theme. Once the visit to each room finishes, visitors are invited to proceed to the next one. Each room has large immersive projections, accompanied by *ad hoc* sound design and narrative voice-over.

Particular attention is given to the management of usable physical space and visit flows, and the visit path is designed to manage visitor movement. The visit experience is freestyle and can be customized by visitors. Up to

20/25 people may visit each area at the same time, while the timing is controlled by the duration of the audio-visual content and the coordination of visit flows from area to area.

Apart from the actual content, each area has an introduction and a conclusion. This keeps the emotional element and the narrative continuity active while moving from one area to another.

The Multimedia content also encourages movement, thus avoiding the risk of crowding and the consequent reduction in quality and enjoyment of the exhibits.

Area 3 is the most particular area in the museum. Each visitor is given a Samsung Gear VR viewer that, combined with a Samsung S7 smartphone, allows users to enjoy Virtual Reality content and experience the real life of Giacomo Casanova. Wearing Samsung Gear VR visors, spectators are greeted with a 360°filmed view of eighteenth-century Venice. They can live the experience of being in Venice in 1753, in the role of Casanova, having coffee and conversing with Zuane Matteo Bragadin, entering a ballroom during a masquerade, living the experience of being arrested and imprisoned. Everything was filmed with real actors in period costume, in the original locations, in order to add the overall sense of being part of the scenario and improve the magic of the whole experience.

Finally, the Casanova Museum & Experience project also offers a dedicated App with a geo-localising function.
The routes and 19 suggested POIs lead the visitor on an exclusive discovery of the city of Venice through the places where Casanova really lived through his adventures.

Here the visitors can see the life of a man without time. Using technology, the museum can meet the new needs of Italian and foreign visitors, making content available in a new way, touching emotions.

Here are some of the objectives of this new perspective of cultural diffusion:

- Combine technology and creativity to surprise the visitor, stimulating curiosity and creating educational experiences by providing access to information, while fostering a range of new ways to view history;
- Stimulate new connections, physical and/or digital, between the museum and the urban space in which it is located, using a dedicated App with a geo-localized function. The routes and the 19 suggested POIs lead the visitor on an exclusive discovery of the city of Venice;
- Imagine forms of visit personalization relative to the varying needs of each visitor, offering different content and modalities in accordance with the personal preferences of visitors;
- Create new ways of interaction between visitors and the museum with an innovative layout, blending digital narrative with interactive and passive elements to offer and create an emotional impact when exploring the narrative units;
- Take care of the pre and post-visit phases with an innovative app and dedicated website;
- Start a dialogue between exhibits and visitors, putting the visitors as much as possible into an emotional and immersive context;
- Involve new generations through technologies and methods familiar to them with fast and simple management of narrative units, wall-videos or special audio-guide functions (didactics – information) to offer content in a different way and at various levels
- Contaminate narrative languages in an "Immersive Theatre style".

The entire project is modular and completely achievable, making it suitable for changes in the world of museums and technology. Since the entire multimedia exhibit must always be able to harmonise and adapt to target analysis, new potential audiences are profiled, and content is created in line with user expectations.

CONCLUSION

Today visitors are no longer passive consumers: they expect access to a wide spectrum of information sources and cultural perspectives. While living an immersive experience, people feel more active and more interested in discovering new things and sharing them with family and friends. This new kind of visitors not only wants to be intellectually stimulated but at the same time wants to be emotionally engaged [Carrozzino and Bergamasco 2010].

We can use immersive technologies as a way to promote more understanding in the museums, by literally showing how it feels to be in someone else ′ s shoes. By bringing people right inside an historical event, the content provokes strong emotional reactions. This virtual add-on is perceived close to reality, verisimilar, and therefore easier to memorize in form of stories. Museums must strengthen their innovative presence so as to attract and engage audiences. Making museums more inviting and accessible is essential to cultivating audiences, and the younger generation is challenging the ‘what’ and ‘how’ of museum offerings. Modes of learning are evolving and museums need to incorporate these modes in order to better meet the needs of young audiences. Young visitors are more likely than older visitors to seek instant gratification and are less likely to wait. Youthful tastes when absorbing information are affecting museum programmes and exhibit design. Moreover, many visitors are interested in engaging families as a whole. There is general agreement that children should be stimulated by museums, not intimidated, and want to return with their families. Ideally, this would support a lifelong appreciation of museums. There is a strong trend toward accessibility – both by attracting visitors and making their experience more intuitive. A visitor’s first impression is critical to the museum experience and visitors largely agree that offering a greater mix of experiences draws more visitors [Johnsson 2006].

Our ICT Company has gained experience by looking at museums from a different perspective, creating immersive visitor experiences, and using innovative technologies to increase visitor engagement and interaction. ETT has achieved this by developing an engaging model using tools such as high-resolution monitors, interactive touch-screen interfaces, 3D reconstructions, proximity sensors, gaming simulations, augmented reality and interactive projections with on-screen actors.

The Casanova Museum & Experience project proposes a new idea of museum and edutainment (educational-entertainment). Since its opening, the exhibition has received extremely positive feedbacks from visitors of different nationality and age range.

This project generates a new perception of edutainment, mixing educational elements to entertainment factors. This experience certainly marks an important step in re-evaluating the role that new multimedia technologies have within the enhancement processes of both historical and cultural heritage.

Good visitor feedback, both Italian and foreign, encourages ETT to continue to implement cutting-edge technologies in order to create better engagement in the cultural heritage sector, both at the Italian and international level. This attractive experience certainly marks a very important step in re-evaluating the role that new multimedia technologies have within the enhancement processes, improving both historical and cultural content.

On the basis of what has been achieved so far, all the virtual and augmented reality fit-outs developed in the cultural field can certainly offer rewarding aesthetic and learning experiences, otherwise difficult to obtain, but this is not enough.

The starting point for the conception and development of such projects is the awareness that the past and the present can both be conveyed simultaneously, through new media, whilst contributing to research into the cultural patrimony which our country (and others) can benefit from. It is about enhancing the audience experience, thus guaranteeing both protection and conservation of art as well as providing an engaging interpretation.

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What's in a Name: Gamifying the Intangible History of Larochette, Luxembourg

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The Larochette app is part of a larger interdisciplinary project to create a digital reconstruction of the town and castle of Larochette, Luxembourg. The paper discusses the creation of an app that serves to pique interest in linguistics and historical geography, traditionally dry subjects with little intrinsic appeal to children and the general public. This project harnesses this effect, presenting the results of the preceding landscape study in an interactive educational environment that rewards the user for engaging with the content. As the app allows natural movement and intuitive interaction, exploration and learning are prompted by curiosity. The goal of connecting place names to heritage is not explicitly stated, nor is it presented as an educational game. In short, this is the second phase of a collaborative case study in the digital experience of history, which is grounded in user experience design and informed by the historical and architectural expertise of the collaborators.

Key words:
Digital cultural heritage, gamification, toponyms.

CHNT Reference:
Christopher M. Morse and Marleen de Kramer. 2018. What's in a Name: Gamifying the Intangible History of Larochette, Luxembourg.

INTRODUCTION

Much as people learn to read a book, they must learn to read a landscape – its individual elements, its hidden connections, and its historical context. This project aims to make historic cultural landscapes – notably their structure, land use, relation of town and countryside, and key buildings – accessible to the public while also showing the variety of data that can help inform our knowledge. Its approach integrates the expertise of researchers in heritage science, linguistics, and information visualization to create and validate a scientifically accurate model of a historical and cultural landscape. It embeds the castle in its sociocultural context and highlights the tangible and intangible heritage that can be traced in the town's structures even today.

The digital reconstruction of Larochette castle and its historic environment supports a broader movement that integrates emerging technologies with heritage science and considers methods of evaluation and documentation that take into account the specific priorities of cultural institutions [de Kramer et al. 2018]. In this phase, the focus is on gamification, a powerful tool for outreach and dissemination. The final goal is the design of an educational game that reveals the connection between a town's past and the names of its squares, streets, and even car parks – a visualization of its intangible heritage.

Further development of the Larochette game builds upon experience fellow researchers have gained in a number of published case studies that explore the adoption of novel mixed reality and other 3D applications of heritage, such as a virtual reality exhibition featuring Cypriot engravings and Byzantine iconography [Loizides et al 2014], a gamified reconstruction of the Palazzo Fruscione-San Pietro a Corte archaeological site in Salerno [Andreoli et al. 2017], and an interactive installation to explore color in medieval illuminations [Correia et al. 2014]. These case studies, in addition to a recent survey [Papagiannakis et al. 2018], emphasize the strength of interdisciplinary collaboration and reinforce the need for iterative user testing and comprehensive assessment methodologies in the creation of serious games.

RELATED WORK

Gaming in cultural heritage has become an increasingly popular method to connect the public with historical places, objects, and ideas. These types of games are generally referred to as *serious games*, that is to say, games designed in tandem with pedagogical models that provide an educational experience alongside general entertainment [Zyda 2005]. A number of studies have shown the benefits of serious games and their effect on learning outcomes and retention [Wouters et al. 2013] and better attitudes toward learning [Vogel et al. 2006].

A recent study on interactive systems in cultural heritage [Koutsabasis 2017] revealed that almost one-third of reviewed systems (15 out of 53) consisted of varying types of educational or historical games. Moreover, 22.6 % of reviewed systems (12 out of 53) made use of 3D game engines, either as standalone PC-based applications or as immersive VR installations.

The present research draws on learning models designed for cultural heritage, notably the “Sandbox Serious Games” (SBSG) model [Bellotti et al. 2012], which immerses users within virtual environments and produces a series of localized tasks to encourage learning. This approach, derived in part from work on task-based learning [Willis 1996], has been re-conceptualized for use in cultural heritage contexts. It extends the project’s reach beyond the academic realm to general audiences and brings the cultural landscape, with its tangible and intangible heritage, to life.

Mortara et al. [2014] differentiate between *cultural awareness* games, which attempt to educate users on intangible heritage, such as customs or beliefs, *historical reconstruction* games, which focus on faithful reconstructions of historical periods or places, and *heritage awareness* games which introduce virtual tourists to the tangible heritage (architecture, natural features, etc.) of a location. The Larochette app attempts to combine some of these approaches by creating opportunities for virtual tourism within a historical time period, while simultaneously presenting both the intangible and tangible heritage of a place based on empirical research.

PROJECT DESCRIPTION

GAME

In the app, the user appears inside a small room high on the side of the castle, its windows shuttered. Directly in front of the user, a small table holds two blocks with symbols for “castle” and “rock,” which can be picked up with the “Virtual Reality” (VR) controllers and combined. On the far wall, a second table holds a map, with the single name “Buerg Fiels” in its center. When the combined symbols are placed on this name, the shutters fly open to reveal enticing glimpses of a winding river flowing through the green, empty valley below. This simple interaction teaches the user the purpose of the game without an explicit, potentially intrusive tutorial, but rather through experimentation and exploration.

When this initial problem is solved, further blocks with symbols will appear on the shelves in the niche and the map populates with more place names, chosen for their multiple clear elements. Combining these and moving them to the appropriate places on the map causes 3D graphical representations of the places attached to the names to appear in the landscape.

To the primary target user group of children and adolescents, the interface will be intuitive, and progress will be easy to measure; learning how place names connect to history is implicit, but not presented as the major goal.

ENVIRONMENT

The game is located inside an enclosed wooden porch or oriel projecting from the eastern facade of the Great Hall in the Criechinger Haus, the private apartments of one of the noble families that co-owned the castle, rather than on top of one of the towers.This decision was made for multiple practical reasons: this oriel offers a broad view over the valley and all place names of interest. It has been physically reconstructed and can be visited today. Its dimensions – roughly 2.5 m x 5 m – are approximately the same as those of a typical Virtual Reality play area, meaning the user can move naturally and not need to learn a counterintuitive “teleport” control. An enclosed space with windows to look out of is less likely to cause vertigo in users. Finally, but perhaps most importantly: a scientifically accurate educational game would require a complete, validated reconstruction of the castle if using one of the towers; in this case, only one room needs to be reconstructed.

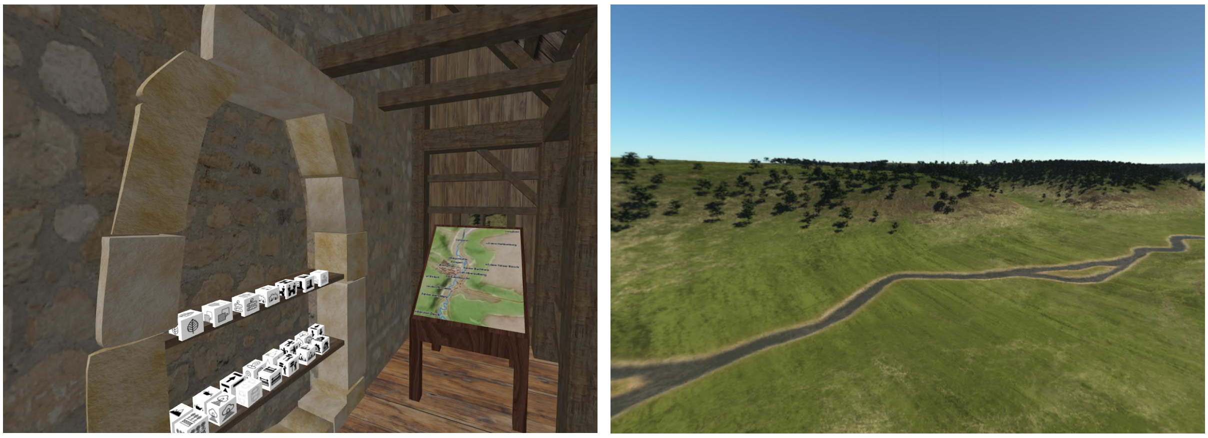

Fig. 1. Views of gameplay: room within the castle with map and symbol blocks (left), historical landscape (right)

Although a physically reconstructed room exists today, no record is available of the decision-making process for the reconstruction, so we cross-validated it using surveys of the ruins conducted in 1977, before the castle was partially rebuilt [Zimmer 1996]. The mostly-intact gable wall has a door leading out, a fireplace on the outside, and a window that looks across to the altar of the chapel in the tower on the northern side. The presence of the oriel is indicated by holes suggesting joists and rafters (their position makes them unlikely to be putlogs for temporary scaffolding) and four stone corbels to hold a lightweight floor. The original purpose of the room is unclear; Zimmer postulates that it was a latrine, though its size and placement above the path leading up from the town make that unlikely. The current interpretation given by the information boards in the castle declare it to have held the bath. A defensive structure such as a hoarding or brattice is also possible, though the provision or a fireplace is puzzling. The virtual reconstruction largely aligns with the physical reconstruction in situ, though some changes were made to the roof based on the location of the holes for the wooden beams.

The virtual room was given somewhat anachronistic paned glass windows (similar to the windows in the physical reconstruction) to allow users to see out, and a wooden door closing off the doorway to visually constrain the user to the space. The fireplace was repurposed as a niche to hold shelves for game objects.

The room was modelled in *Autodesk 3ds Max*[1], using architectural drawings based on those from the 1977 survey as a reference. To keep the polygon count low and allow the finished app to run smoothly on a number of devices, the geometry is simple and detail is mostly provided through textures with bump maps, though individual, existing stones were reproduced around the wall openings for added realism. Wood and stone textures were chosen based on the local landscape; some even taken from photographs of the castle itself.

The landscape was modelled in *Terragen*[2], based on the results of the preceding study [de Kramer et al. 2018]. It was rendered at high resolution using a spherical camera at the point where the viewer would be standing – with a 5 km radius, the 5 m movement allowed is negligible – and the rendering applied to a spherical skybox. This again significantly reduces the polygon count while presenting a photorealistic perspective of the landscape. As the landscape was represented in summer, with lush vegetation and ripening crops, the position of the sun was calculated for high noon at midsummer solstice in 1550, which minimizes shadows.

All symbols come from the *Noun Project*[3] and are used under license. They were chosen to correspond to name elements accurately – for example, they include a water mill rather than a windmill for the “mill” symbol.

[1] https://www.autodesk.com/products/3ds-max/overview
[2] https://planetside.co.uk/
[3] thenounproject.com

CONTENT

As the game is intended to show the connection between toponyms and landscape features, it highlights those features alluded to by names that can be found today – in street names, on maps, on signposts and in the local collective memory [de Kramer et al. 2018].

In its simplest form, the game would consist only of players matching symbols to names. Instead, names composed of multiple elements were chosen. This adds a layer of challenge by making users combine symbols to create full names. However, it also expands the learning effect – users are shown common elements and can infer their meaning. This helps with contractions, like "Birkelt" for "birch field", but also allows them to extrapolate meanings of common elements and apply them to other toponyms they encounter. This is enforced through repetition of certain symbols.

The 3D symbols for the map will be abstract models rather than photorealistic accurate reconstructions of each part, so they will have a relatively low level of detail.

PLATFORM

The app will showcase historical research, but also serves to demonstrate how modern technology can be used as a teaching tool at open days, lab tours, and conference visits. It is designed to provide a realistic experience in virtual reality, especially the astonishing sensation of depth when viewing the landscape from high above. As it is designed for the HTC Vive, interactivity is made possible using two controllers.

The virtual reality experience can easily be set up and run with two people and a power source; an internet connection is not necessary, as the app is stored locally. However, this presents a barrier to dissemination, as it relies on specialized equipment and operators. Consequently, a web-based version that can be viewed on computers or mobile devices will also be developed, which will use touch or mouse controls for navigation and interactivity.

The first version of the app used *A-Frame*, a web framework that allows fast and simple implementation of virtual reality project, and which supports the import of objects and textures, and uses native elements for movement and behaviors. Due to technical issues, this will need to be changed to another, more complex platform as the game is developed.

PROTOTYPING & DEVELOPMENT

CHALLENGES

A-Frame[4] was useful for the initial proof of concept insofar as it provided a portable, web-accessible, immersive environment for initial user testing. Nevertheless, it is not suitable for the envisioned game. Initial testing encountered a series of problems with the physics system, which is currently a separate plugin, and revealed that the system was designed for native objects and is not compatible with the more complex geometries generated in other programs. It will not, in its present form, allow the interactivity needed.

Instead, the content will be ported to a gaming engine such as Unity, which has support for complex geometries and prefab scripts for interaction and movement. It can be exported as *WebGL* for online display, and as a local app for use with common VR hardware.

INITIAL USER TESTING

The project has undergone two phases of early user testing: first in Cyprus during the EuroMed 2018 conference, and again in February 2019 at the *Forum Z: Who's Afraid of the Digital?* event in Luxembourg City.

At EuroMed, conference participants tried an early version of the immersive VR experience where they were able to walk around the castle room and view the landscape through the windows. This initial test revealed that the controllers provided necessary visual orientation even without interaction, and users felt safer holding them. Since interactivity was extremely limited in this version, it was difficult to gauge the interest of people in the app versus in the novelty of the VR experience itself.

[4] https://aframe.io/

During the *Forum Z* event in Luxembourg City, researchers and industry professionals had the opportunity to play an analogue version of the Larochette game, followed by full immersion in the VR prototype. The analogue Larochette game consisted of a paper prototype featuring a printed map from the game and all of the associated symbols. Participants were instructed to match the symbols with the location on the map as they would in the real game. During the event, fifteen people who tested both the analogue and the virtual reality game were asked to provide feedback. This consisted of written comments/suggestions about the VR prototype and an additional form for participants to draw symbols that they felt best represented the names of places.

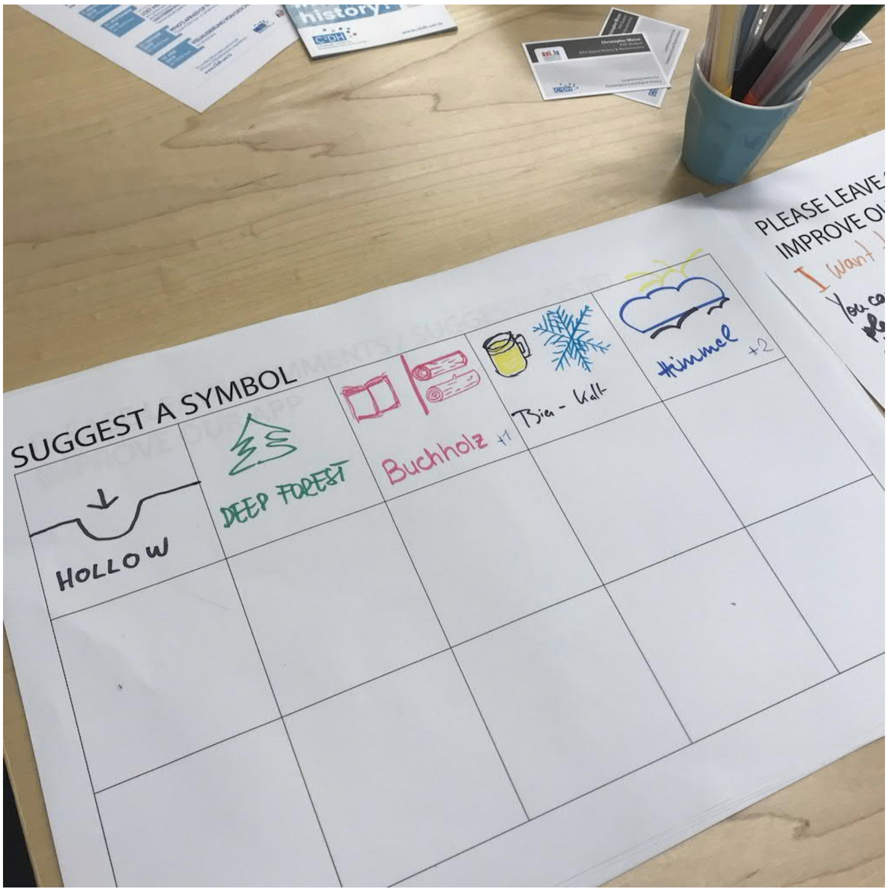

Fig. 2. User provided suggestions for symbols to represent different toponyms in the game

This test revealed that the difficulty level of the game needs to be adjusted for the average user. Useful changes include: clearly separating the names into elements, marking irrelevant prepositions, optimizing symbols, and providing feedback when elements have been combined correctly. Providing a list of names alongside the symbols so they can be matched while all are visible is also potentially a useful improvement. Alternatively, symbols could be matched to elements and then combined automatically, rather than combinations matched to full names – as some elements repeat – this would decrease the difficulty, like a crossword providing some letters through answers to other clues.

CONCLUSIONS

While virtual reality remains an emerging technology, users are often drawn to try it for the novelty alone. The app seeks to capture that interest and transform it into interest in local heritage without explicit teaching. This requires a subtle approach, a *meaningful environment* and a *suited and intuitive interaction paradigm* [Mortara et al. 2014] that harnesses the user’s curiosity and subtly guides them to explore the setting and discover rewards for completing tasks without ever stating them outright. To keep the user’s attention, the app will require careful balancing to be challenging but not frustrating. The premise is, at present, easily understood, but requires fine-tuning of the user interface and interactivity and level of guidance to meet this ideal.

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The Use of Holographic Showcases Inside the Museum's Context. Towards an Advanced Museology Creating a Dramaturgy Around the Exhibited Objects

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A new challenge, in the museological domain, is the use the holographic effect of Pepper's Ghost to develop a novel frontier in storytelling inside museums, integrating in the same space real and virtual contents, and creating a virtual dramaturgy around the real object. This integration has a communicative potential never seen before inside museums, because it works in perfect harmony with the museum visit and the real artifact is kept in the middle of a lively experience of mixed reality. Narration is a central issue, because it involves not only creative and technological but also "ethical" and cultural choices, inherent the scientific correctness and plausibility of contents, while using agile and multiform tools like the digital ones. Case studies will be discussed, presented and tested on the public in different European museums, in the framework of the EU project CEMEC. In fact within this project we have conceived the "box of stories" a holographic showcase where (a) integration of real and digital contents, (b) structure, (c) materials, (d) interior setup, (e) illumination, (f) narrative approach and dramatization, (g) scalability are designed as a whole. Since the holographic effect is an illusion of reality, there are specific rules and constraints regarding technical set up, perception and editing of contents that must be respected and that will be discussed.

Keywords:
Holographic Showcase, Emotional Storytelling, Mixed Reality, User Experience.

CHNT Reference:
Eva Pietroni et al. 2018. The Use of Holographic Showcases Inside the Museum's Context. Towards an Advanced Museology Creating a Dramaturgy Around the Exhibited Objects.

STORYTELLING INSIDE MUSEUMS, WORDS AND IMAGES WORKING TOGETHER

Learning does not arise simply from our reasoning, but also through curiosity, engagement, interest and attention; in one word, through motivation. In this process emotions play a crucial role, stimulating a feeling of self-identification, appropriation and elaboration of the meaning [Pietroni et al. 2018]. For the same reason narration is much more powerful than pure description, because this latter is not able to induce motivation, unless the beneficiary is already familiar with that specific content. When using narration, evocation or even dramatization, objects become the occasional points where history "coagulates", creating an expectation in the visitors. The tale is developed by including different perspectives, different rhythms, and it draws up a specific space-time dimension [Genette 1972]. Everything contributes to create an expressive unity: oral performance/recitation, layout, visual mood, soundscape, camera movements, lighting, and rhythms.

Despite narration is an atavic expressive form of human beings, and one of the most effective vehicles of involvement, today it is one of the weakest aspects in the cultural heritage communication, both in real and in virtual museums [Pietroni and Adami 2014]. In the field of Cultural Heritage, visualization usually aims at analyzing the object, providing a perfect perception of its shape, texture and structure, and it is often accompanied by descriptive explanations. Rarely visualization is conceived as visual storytelling, the union between word and image results still very weak.

Images and sounds have a great narrative potential which, to be expressed, need the knowledge of certain rules and grammars, as cinema, games and theater demonstrate. In the storytelling, words, images and sounds must converge in the creation of a coherent meaning (and feeling) for the spectator, each one using its own expressive means. Usually the story construction is a long and collective process that continues to be improved and reshaped until the final production: once all the historical or archaeological information has been acquired, a process of abstraction, subtraction and synthesis begins, aimed at distilling the essence. Some messages are made explicit, others implicit or subliminal [Galansino and Perov 2017].

The museum should be able to exhibit the artwork favoring the perception of its aesthetic consistency, but also the understanding of the cultural context in which the object has been originated: a process of readability, critical interpretation and elaboration of the meaning [Arnheim1954; Brandi 2000]. This is not obvious, because many artworks or cultural objects have lost their ability to be recognized and understood by the visitors. Their sensory dimension, their context, or their narrative value are almost inaccessible, also depending on their state of preservation and on the criteria of taxonomy followed by many exhibitions. In contrast, a tale is a sort of “reconstruction” of the object; it implies choices, both in making its form legible and identifiable (through a virtual restoration for instance) and, also, in reconstructing its context, meaning, and sphere of life [Antinucci 2014].

Storytelling and reliability inside museums

A story is a bridge between reality and imagination [Salmon 2007]. Usually museum curators prefer to be “neutral” regarding the artifacts, and they avoid telling or suggesting the visitors anything else beyond the pure evidence. Lives, emotions, context of usage, or interpretations are in most cases missing because not sure. Unfortunately, avoiding interpretations is not a neutral choice: if a visitor is left alone, without any support suggesting meanings and contexts of usage (that means interpretation and “reconstruction”, even if hypothetical), he/she will be free to understand and deduce everything, even false and erroneous significance. Omission is not positive [Antinucci 2014].In the creation of a narrative, certain and circumstantial contents regarding the artifact will be combined with plausible and probable ones, the latter pertinent to its cultural context but not completely sure for that specific object. An example will clarify this assumption. In the next paragraphs, a case study will be discussed in relation to our holographic showcase. It is the story of the Kunàgota sword, preserved in the Hungarian National Museum of Budapest. In this case there are, as starting points [Pagano et al. 2018]:

a) Certain information related to the object itself: the sword was discovered in an Avar tomb of the 7th century AD, near the village of Kunàgota, Hungary; it was part of the funerary good of an Avar warrior, it has been adorned with golden sheets showing figures coming from the Byzantine iconography and style. Such kind of decorations and figures can be often found on precious Byzantine caskets, of which there are many examples. These golden sheets have been broken and mounted chaotically on the Avar battle sword, being adapted to its different parts.

b) Certain information regarding the general historical context of the Avars: they were a population of warriors, they were often fighting against the Byzantines, they practiced looting; they believed in the afterlife, in the Blue Sky of “Tengri” (according to a shaman tradition of central Asia from where they originated).

c) Plausible and probable contents: the style and the dimensions of the golden sheets let us suppose that originally they could belong to a precious small Byzantine casket, for instance to contain jewelry. It is historically credible - even if not certain in this case - that the Avars took the casket as a looting, after winning a battle against the Byzantines. As the golden sheets were broken with a scant attention for the integrity of the figures, it is possible also to suppose that this work was made by an Avar goldsmith who did not understand the identity and the meaning of the figures. The sword was really used for war, so it can be assumed that the goldsmith made this work when the Kunàgota chief died, to adorn his sword in gold, before including it in the tomb.

Putting together these three levels of contents, a visual storytelling has been built, with soundscapes and characters (of whom user can hear the voices and see only the hands during the different actions) (Fig. 1a). Events have been dramatized and represented while happening: the small casket, containing jewelry is in a rich Byzantine house; the battle is ongoing and the casket is taken away by the Avars; the Kunàgota chief is dying on its deathbed and he talks to his son, asking him to make the sword adorn in gold and put it in his tomb; the goldsmith in its workshop, with his assistant, cuts the sheets and fits them on the scabbard, trying to understand what kind of figures they are; finally user can see the tomb connected to the Blue sky of Tengry (represented according to the original Avar iconography), from where the spirit of the Kunàgota chief speaks to us for the last time[1].

It is a very plausible story, even if some parts are imaginary. Nobody can say that this reconstruction is wrong (unless an expert will discover new evidences clearly contradicting it). [Antinucci 2014].

[1] https://vimeo.com/236305120

Fig. 1. a) Holographic showcase with the Kunàgota sword inside, Allard Pierson Museum, Amsterdam, 2017; b) Holographic showcase with objects of the Mytilene treasure inside, Byzantine and Christian Museum, Athens. 2018

The holographic techniques and the illusion of reality

Digital applications presented inside museums are commonly juxtaposed to real collections but not sufficiently combined and integrated with the museums' contents and the visit pathway.

Thus they do not completely solve the main issue of museums: communicate and contextualize the artifacts and their cultural message [Pietroni et al. 2019].

The intent of creating a "dramatic dimension" inside the museum showcase has recently brought us to experiment and apply an ancient representation technique, called Pepper's Ghost. It consists of an optical effect, similar to a hologram, taking place inside the showcase, in presence of the real artifact and interacting with it, producing a mixed reality.

Thanks to holography, it is possible to duplicate reality, create characters, objects, or scenes that do not exist and make them seem as they were in front of our eyes.

Real holography that is based on the use of coherent laser light appropriately projected, as theorized in 1947 by the Hungarian scientist Dennis Gabor (1900–1979), is still technologically not mature to be applied to performative arts, cinematic and multimedia. Thus the most used technique is Pepper's Ghost [Steinmeyer 1999].

The English scientist John Henry Pepper (1821–1900) brought some techniques, already invented in the 16th century in relation to *camera obscura*, on the stage of theaters to create magic effects, fascinating the spectators. The illusion consists in the perception of things, a place or a floating figure in the empty space, in a position where they are not in the reality - given that their real presence is in a secret place, hidden for the observers, located under the main stage or aside [Pepper 2012]. In this hidden room, real figures (characters, objects) moved in front of a powerful source of light. Once illuminated, these figures were reflected by an oblique mirror that was positioned with a corner of 45° between the hidden room and the spectators. Because of an optical effect, the reflected image was automatically projected on the stage. In this way, it was possible to create ghost effects - an illusion of reality. Virtual reality enters our space without the use of special devices.

Today Pepper's Ghost effect can be easily produced using digital technologies (Fig. 2). It is appropriate and easy to implement inside museums, in terms of integration with original artifacts, image quality, compatibility with preservation needs, scalability, adaptability, robustness, daily management, costs.

The use of holograms does not aim only at producing astonish reaction in the visitors for its magic. Through the hologram it is possible to change the traditional paradigm: if one includes the real artifact inside the holographic showcase, the attention still remains focused on the real artifact. Not its virtual replica, but the original itself, is the center of our attention throughout the experience: all the virtual animations, the fragments of stories originate from its real figures and details, thus creating an experience of mixed reality.

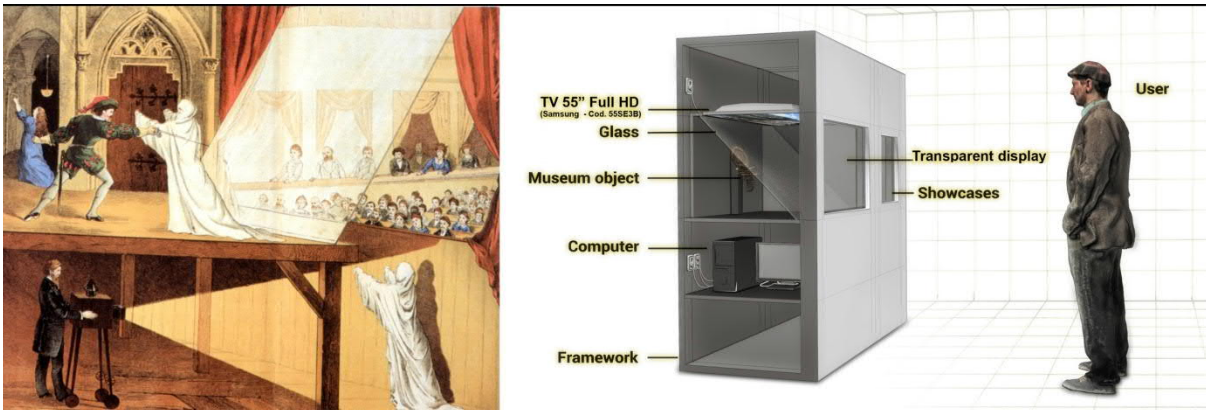

Fig. 2. a) Drawings showing Pepper's Ghost in theaters in the 19th century; b) Structure reproducing the same effect through digital equipment

The CEMEC project: the box of stories

The experimentation with holographic showcases has been carried on in the framework of the European project CEMEC (Connecting Early Medieval European Collections), still in progress (2015-2019), where universities and research institutions, museums and technical partners are cooperating to advance in the knowledge and promotion of the Early Medieval arts and cultures of different European regions and, also, in the museological sector [AA.VV. 2017]. This is done through the concrete realization of an exhibition traveling among the museums, where the holographic showcase has been presented and evaluated in relation to its impact on the public.

Efforts have been oriented on the creation of a holographic showcase, the so-called "box of stories, and on the definition of a coherent communicative format, where (a) integration of real and digital contents (b) structure (c) materials (d) interior setup; (e) illumination (f) perception (g) audio-visual grammar, (h) narrative approach, and dramatization (i) scalability are designed as a whole.

As already mentioned above, the virtual contents are projected in the same space of the real object and bring it back to life, to its sensory dimension, following a "dramaturgy". Real and symbolic scenarios can be evoked and represented, accompanied by emerging personages, voices, and soundscape.

This holographic showcase is rather demanding in terms of space, but its multimedia potential is great. First of all because of its dimensions: the front window is 120 cm wide, the depth is 140 cm, the height 80 cm. Up to 5 or 6 persons can see it at the same time and it is possible to simulate many events inside of it. Users can see more than one real object (or one big object). The inner space can host even a simple physical scenography and virtual characters can be projected in real scale.Fig.1b for instance shows how a real candle holder exhibited in the showcase is incorporated and contextualized in the virtual scene and thus brought to life.

The box of stories can be also integrated in a wider projection wall (4 meters wide), so that it is possible to alternate virtual animations inside the showcase or extending outside. This specific research has indeed evolved engaging experts in humanities, museology, psychology, curators and artists, engineers, working together and supported by the user experience evaluators. This integration has helped us to define some general guidelines, constituting the innovative value of this proposal [Pietroni et al. 2019].

The Kunàgota sword & Mytilene treasure

The box of stories has been used to tell the story of some objects of the 7th century AD which are:

- The *Kunàgota sword*. An Avar sword exposed at the National Hungarian Museum of Budapest (NHM), of which has been written in chapter "Storytelling and reliability inside museums".
- The *Mytilene treasure*. A set of 70 Byzantine objects from the Byzantine and Christian Museum (BCM) of Athens [Touratsoglou and Chalkia 2008]. They belonged to the wealthy family of a high official of the Byzantine administration, that lived on the Mytilene island, in front of Asia Minor coast. These objects were part of the domestic equipment. The sudden danger of an enemy attack could have obliged this family to bury the precious objects into the ground, to preserve them from possible looting. Three representative objects of the treasure, a golden bracelet, a candlestick and a *trulla* (a tool for water's spilling), have been included in such a box of stories.

In the holographic showcase, each object has been presented alternating (a) a short presentation, with a more descriptive style, to communicate the basic information (so called "neutral vision"); (b) a dramaturgy, which means scenarios where each object is contextualized in its original environment and shown during its daily usage. They are evocative and symbolic and combine 3D graphics and real actors (in the case of the Mytilene treasure). The *trulla* and the bracelet have been printed in 3D to be used by actors in their fiction.

RULES AND CONSTRAINTS TO CREATE GOOD HOLOGRAMS

As the holographic effect is an illusion of reality, in the concept of a showcase using Pepper's Ghost effect in a museum, there are specific rules and constraints that need to be respected, in the environmental conditions, in the setup of the structure and in the adopted visual grammar.

Environmental conditions

The quality of visual effects depends in particular on two aspects: a) the credibility of the images (see chapter "Visual Grammar for the 'ghost'") and b) the environment without visual, geometric or luminous interferences that can reveal the projection techniques and therefore the magic.

The environmental conditions inside the showcase, even if extremely controlled, cannot be completely independent from the outside. The museum environments are different and always changing and they cannot be easily be modified. Some expedients have been studied and adopted to minimize the influence of the exterior on the interior space, like internal masks, black and non-reflecting internal coverings; filters on external lights directly impacting the showcase. Being able to guarantee an area of partial darkness around the frontal window of the showcase helps both to improve the quality of the ghost and to more effectively hide mirrors, lights or internal reflections.

Set up of the holographic showcase and visibility of the real objects

On a practical basis, when designing holographic showcases, the visual quality of the overlapping between real object and the digital content depends on the materials used to produce the ghost effect in addition to the interior design of the showcase (i.e. lights, dark area, and relative position of the observer).

The image of the ghost can be broadcasted through a monitor (as in Fig.2) or by a projected image on a white screen; the 45° reflective material can be a glass, a Plexiglass, or a film to be mounted on a frame. In addition, the holographic case, like any other museum showcase, must be closed frontally by a strong transparent glass to protect the object.

For the CEMEC project, a 4K monitor, positioned on the ceiling of the showcase, transmits the image that is reflected by the semi-reflecting glass (4mm of thickness). A transparent shatterproof glass (8mm) closes the window on the front side. It does not create particular problems of visibility, even if it is necessary to pay attention to the reflections of the area in front of the showcase (Fig.3a). The reflective surface is a special 4 mm thick glass, which has the characteristic of having one of the highly reflective surfaces preserving a good index of transparency.

For a different and more direct vision of the object, alternative scenographic solutions were also tested, such as making the showcase background transparent. The technology usable here is the transparent Oled (Organic Light Emitting Diode) panel which allows to control the back transparency (Fig. 3b). If the spaces of the museum would allow the passage of the users in the back of the holographic showcase, this solution would guarantee on one side (from the back) the direct vision of the object without any interference of the holographic image. Whereas, the viewers place in front of it, would see the real objects, the holographic projection and a third level represented by what is beyond the window (the audience or an *ad hoc* outdoor scenography).

The object contained in the showcase has different ways of being part of the story: appearing by illuminating it with directional spots, disappearing by switching off the spots, vanishing behind the projected holographic image. Lights are therefore part of the dynamic compositing of the story. Finally, regarding the position of the observer with respect to the object, it is good practice to guarantee a tolerance zone on the front of the display window of a minimum of 50 cm, an ideal position both for perspective reasons and for scene requirements.

Fig. 3. *a) Lateral picture of the holographic showcase with 45° glass, back objects and frontal glass clearly visible; b) effect produced by the transparent glass at the back of the structure*

Visual grammar for the "ghost"

Visual grammar is related to the layout of the virtual animation inside the holographic showcase. Indeed in presence of the real objects, the designer of virtual contents has much more constraints to respect to create a convincing integration and a perfect mixed reality. These are some constraints [Pietroni et al. 2019]:

- *3D graphics:*3D is recommended to create a better illusion of reality.
- *Background:* virtual contents must be like apparitions floating in the empty space; usually a black background in the digital animation is suggested.
- *Image contained in the frame:* The illusion of reality imposes that virtual contents should be entirely contained in the frame, without cuts on their borders, as it happens in the stage of a theatre but differently from a cinema movie).
- *Scale:* when a real object is inside, the scale of the holographic projection needs to be real, correctly proportioned to create a precise correspondence between real and virtual contents.
- *Position of the real object on the stage:* The reflected image (ghost) lays on a well-defined plane of projection. The real object must be positioned in correspondence of this plane in order to create a perfect overlapping with the virtual contents and thus the illusion of reality.
- *Still camera:* Due to the illusion of reality, a unique camera position (coincident with the visitor's eyes) is needed.. Multi-camera would bring the visitor in a different experience recalling cinema.
- *Point of view, Field of View and Depth of Field:* it is important to keep a coherence between the point of view of real and virtual contents. Everything in the scene must be in focus, because of the illusion of reality.
- *Matching of lights and colors:* It is very important that virtual lights and shadows, set for the ghost, match with the real ones in terms of intensity and color.
- *Essentiality and charm:* In the holograms, less is more, rhythm is very important.
- *Sound spatialization:* sound spatialization (stereo, Dolby surround) is possible if the dimension of the holographic showcase is large enough and the space of the sound projection is wide.

INTERACTING WITH TECHNOLOGY INSIDE MUSEUMS

In recent years, it has been possible to see how new technologies have expanded the dimensions and capabilities of museum exhibits, turning visitors from passive observers to actively engaged participants. The holographic showcase is one of these and tries to set both museum curators' requirements and audience's expectations [Mancoff 2016].

In the holographic system, users can passively take part at the storytelling happening in front of them or become active by physically interacting with the content through buttons or special devices connected to the audio visual system.

There is not a unique solution in all museum contexts in term of interaction with holographic showcases, because this depends on the available museum space, the visitors' flow, the museum visit path and the type of target (children or families or experts…); nevertheless, interaction has to consider the kind the storytelling, the length of the story, and the general atmosphere provided to the users.

Active vs. passive museum visit

Compared to the didactic expository model (where the visitor can only receive information passively), interaction techniques turned out to be important tools in the exhibition design to improve the museum visitors' participation through open-ended activities. How interactivity can influence the type of museum experience? This aspect is strictly connected with the setup of the cultural institution hosting the digital product, and its location along the museum visit path.

Specifically about the holographic showcase, particular care should be taken in the design of the structure, in case of its integration along the visit pathway or in case of an entirely dedicated room. In fact this technological solution can be set up both interactively or with no interaction at all. In the former case, simple modalities can be applied as language selection and chapter's story selection; something more interactive can be the manipulation of 3D objects inside the showcase by mean of external sensors. In the latter case, instead, only the enjoyment of audio visual content is possible with the integration of a dynamic lighting system or inner mobile scenes like theatrical setup.

Interacting with the holographic system

In the case of the holographic showcases developed within the CEMEC project, it was necessary to conceive a communicative format that could easily adapt to the different spaces and visit paths of the museums in which the traveling exhibition was hosted. In the first venue (Budapest), a dedicated room was available, containing only the holographic showcase; in others, instead, the holographic showcase was located along the museum visit paths. Therefore it was decided to give preference to the narrative aspect rather than to the explorative/interactive ones. This choice was also determined by the desire to experiment and push to the maximum the expressive and narrative potentialities of the holographic showcase, enhanced by the mixed reality environment.

In the holographic showcase using Pepper's ghost, interaction is implemented at two levels: a) author- system and b) public-system. The first and more complex level consists into the author/director's ability, through specific software, to easily control and modify the scenic mechanisms, to calibrate the superimposition of real and virtual contents, and to organize the play out of the contents. Based on VVVV platform[2], this software helps to manage and synchronize all the events that are about to happen in the showcase. Multiple channels (video, audio, lights, and activation of scenic mechanisms) are organized in a "score", along a time line. In such a way the integration of the different elements to be played can be easily modified during the preparation and optimization of the narrative sequence, without editing the single contents, but only operating on the score. Some parameters can be exposed and controlled by keyboard (or MIDI controller) so that it is possible to simulate real-time events and make the creative process much faster.

The second level, the user one, even though the system is designed to support complex interactions, a very simple solution has been implemented, limited to language selection through an external push-button panel.

USER EXPERIENCE EVALUATION INTO CEMEC MUSEUMS

Evaluating the experience visitors make in museums with digital applications it is essential to understand what works and what not in terms of communication techniques, social participation, and cultural learning in each individual. "User eXperience" (UX) is composed by multiple factors which include the context and the conditions of fruition, the emotional and cognitive domain of the evaluated person and the technological domain of the proposed solution (in terms of interaction, content and usability).

For the holographic showcase, several evaluation have been carried out during the CEMEC project, trying to point out (a) the general feedback of users (appreciation and satisfaction); (b) the usefulness of contents told in such a manner (holography upon real museum objects); and (c) feasibility of the system into museum contexts [Pietroni et al. 2019]. Evaluation took place in Budapest (National Hungarian Museum—NHM), Amsterdam (Allard Pierson Museum—APM) and Athens (Byzantine and Christian Museum—BCM) during the itinerant CEMEC exhibition. Museum staff and CNR researchers followed the evaluations using the "multi-partitioned analysis", which addressed to identify and evaluate the impact of storytelling within the holographic showcases. For APM and NHM the evaluation was done on the holographic showcase hosting the Kunàgota sword; while at BCM the subject was the Mytilene treasure. The evaluation method used two techniques:

[2] https://vvvv.org/

- *Observations:* They allowed us to have an overview of the users' behavior toward the holographic showcase in terms of visibility of the digital product along the museum path, user's attitude toward it, time of permanence in front of it, type of visit (single or group), attention or distraction while watching the story inside the showcase, need for help to make the story starts.
- *Direct questionnaires:* They gave the chance to gather direct feedback of users to confront to what just observed by operators, finding a common sense and interpreting users' reactions putting comments into contexts of reference.

After 2 years of investigation and about 450 observed visitors and 280 interviewed, results confirmed the role of digital storytelling in museum learning experience and the relevance of emotional involvement in the process of meaning-making of the cultural contents. Some specific aspects are discussed in the following chapters. Just to summarize briefly, as reported in Pietroni et al. [2019], users were mainly women (51% out of the global users), around 60 years old (45% out of the global users), coming from Europe (northern countries). A great interest toward the new narrative approach and the holographic system has been registered for the Kunàgota sword, in the Hungarian and Dutch venues, and for the Mytilene treasure in the Greek location. In all cases, a marked sense of curiosity has been recorded: after observing the Kunàgota showcase visitors seemed satisfied and fascinated from what they have just experienced. The same goes for Mytilene treasure: the drawings and characters captured the attention and interest of all target groups, stimulating a sense of wonder in the eyes of the audience as resulted from the open comments.

What about the real object included in the holographic showcase and the related digital narrative forms? Do they match together producing an understandable vision of the Past? Is the real object well illuminated and clearly visible to visitors? Is the function, the decoration and the story of the museum object evident though the digital replica or not?

Real objects and virtual replicas: enemies or pairs?

As already expressed in the chapter about the visual grammar of the ghost, in order to obtain the most credible and emotional effect out of the holographic showcase, all the forms and the storytelling created around the physical artifact need to be well calibrated and have to happen upon or nearby it. This is because users - perceiving the exact collimation between real and virtual, the ancient object and its digitally restored version - start imaging how it would have appeared in the past [Miyamae 2013].

Events like the context of fruition, its usage and its function cannot be reproduced on the real object for several reasons (conservative, security, etc.); nevertheless, the digital replica can do it. So, virtuality in such cases helps visitors grabbing the sense of the exposed museum object while appreciating its value and understanding its function.

Visibility of museum objects

In the chapter "Set up of the holographic showcase and visibility of the real objects" the light functioning has been well explained. Due to technical constraints, lights inside the holographic showcase are directional respect to the object's position, while the environmental lighting are often not controllable due to museum constraints; in general lights are weak but some reflections still occur on the frontal glass of the holographic showcase. Information collected out of the evaluations reported that, in some cases, visitors were prevented to clearly observe the artifact due to the technical distance between the object and the frontal glass, provoking a sense of frustration and disappointment. In general, at the NHM, 65 % of users considered the visibility as good and also the lighting system (87 % said it was working well); at the APM, the percentages were higher with 82 % of users appreciating the visibility of the objects and 91 % of them noticing the good lighting system. In BCM, due to the different artifacts exposed, the reduced dimensions of the bracelet of the Mytilene treasure really influenced the visitors' opinion: only 57 % of them said that the visibility was good. Therefore, selecting the appropriate object for the holographic showcase means also taking into consideration dimensions and distance from the user's point of view in the museum room. A solution to overcome this problem can be a) to improve the light intensity and the object's illumination; or b) to use a transparent or semitransparent glass at the back of the holographic showcase, as mentioned above: this may allow visitors to see closer the museum objects, without any projection on them.

Readability of museum objects

The use of holographic showcase inside museums is an attempt to answer the need of bettering the museum objects readability, given the possibility to mix together real artifacts and its digital replica. In the case of the CEMEC museum objects, the digital replica served various scopes:

a) to analyze the virtual reconstruction of the *trulla*, ruined and with missing parts;

b) to visualize the virtual restoration of the Kunàgota scabbard with gold sheets, where time has damaged its original colors and decorations;

c) to confront the result of studies on reconstructions and restorations along the time, like in the case of the Kunàgota's casket;

d) to appreciate the details of the Mytilene bracelet, through enlargements and highlights of some part of the digital replica;

e) to visualize the construction techniques of the Kunàgota sword's decorations.

During the UX evaluation, people commented "Beautiful to see the explanation of the museum object appearing so intensively in front of our eyes and have the chance to attend it with all my families" and "Absolutely clear how the *trulla* was used in the past, it was unknown to me until now". These sentences give the feeling of how powerful holography is inside museums.

Understandability of museum objects

Visibility and readability are much connected with the understanding of the museum objects included inside the holographic showcase. Results coming from evaluations confirmed this intuition: regarding the content delivered, the majority of visitors paid great attention to the story; of the five questions about historical information, visitors reached almost the 80 % of correct answers both at APM and HNM while at BCM was registered a 93 %. The visitors' memorization rates were indeed high, especially if these results are matched with the ones coming from questions about elaboration and recalling of units of content, again favorable. Operators also noticed that once they finished the questionnaires, 40 % of APM visitors returned to the showcase to verify if they have correctly answered – showing their sincere interest toward this research and a great sense of curiosity. At a direct request, 74 % of visitors liked the storytelling at NHM, compared to 97 % at APM and 86 % at BCM.

CONCLUSIONS

Currently with museums increasing their audiences, updating visitors to participants and trying to make collections more user-friendly to the public, more sophisticated – technically as well as methodically – digital technology become an important part in the process of participatory the visitor.

Technology is a mean which helps us shaping the involvement in the digitally augmented reality. Public is usually attracted by the technological solutions. However, several surveys carried out inside museums or exhibitions, observing the people's behaviors, showed very clearly that the attention towards tools and devices is not long-lasting; it rapidly decreases if the cultural contents and narrations are not able to keep it alive and, similarly, if the interaction is difficult and not natural.

For such a reason, it is necessary to rethink technologies at a deeper level of usage. But how? By working on the cognitive and emotional domains! The emotional component is fundamental in museum learning experience because it is the "irrational" part of human being and it generates motivation – the first aspect that pushes people to face technological solutions and lets the learning process to take place.

Traditional museums have played an important role in making connections between different objects across time and space. Now they have to elaborate the stories around these collections to create a connection with their different audiences. They must multiply the layers of meaning and place greater emphasis on different perspectives. Valued both as a preserver of memory and instigator for ideas, they will empower people to seek answers and foster action.

To reach such a purpose it would be recommended to integrate into the working teams screenwriters, directors and scenographers, and musicians. The museum could thus become a place where it is possible not only to look at objects, but also to listen to their stories.

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Perceived Quality as Assessment Tool for the Test Case Amore e Psiche Domus in Ostia Antica

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Recent years have seen the development of many new ways for cultural heritage visualization; with the growing use of "Information and Communications Technology" (ICT) many 3D reconstructions, virtual tours and "Augmented Reality/Virtual Reality" (AR/VR) application has been developed to enrich the contents of museums, archeological sites and historical places. However, today only few cultural assets have an accurate 3D model with a detailed informative content. In fact, the costs due to the creation of virtual content are still high and they can be addressed only for the most iconic or important monuments. Inside this frame the project RECIPE (REsilience in art CIties: Planning for Emergencies) founded by ESA/ESTEC[1] use a crowdsourcing approach, involving tourists and interested people, to acquire cheaply the photos necessary to create photogrammetric models. Such a models to be correctly used inside different level of recording and monitoring tasks, require developing procedure to evaluate their quality. This work discusses, with reference to a study case, only how to validate models by proposing a methodology based on dimensional and color error calculation together with structural indices, such as SSIM and PIQE. Besides to avoid influence generate by different cameras, focus and positioning in photos taken by tourists, the used photo data base has been produced with a professional device following the state of art rules in SfM. At least, it is also discussed the possibility to implement the 3D models in a virtual reality environment to increase their diffusion on new multimedia and interactive plat-forms.

Key words:
Quality assessment, photogrammetry, structural similarity.

CHNT Reference:
Laura Pompei et al. 2018. Perceived Quality as Assessment Tool for the Test Case of Amore e Psiche Domus in Ostia Antica.

INTRODUCTION

During the last century, with the growing of Computer Technologies, many new technological applications have been developed for the digital visualization of cultural heritage. One of the main goals of the digitization process is to support preservation and conservation issues. Visiting and maintaining archaeological site difficult to access is a complex problem especially if it is placed in dangerous areas such as places affected by earthquakes or conflicts. In Italy, the "Central Institute for Cataloguing and Documentation"[2] was found in 1975 precisely to discuss and cope with this awareness. The Institute published in 2004 the Code of Cultural Heritage and Landscape[3] that defined how to establish, increase and update the national documentations of cultural heritage. Also the "Carta del Rilievo" (relief charter), the main Italian document about preservation of cultural assets, discuss the various aspects involved, including: accuracy of the surveys, dimensional and geometrical characteristics of the monuments, the context and the sustainability for restoration, the criteria of cost-benefit analysis before interventions. This topic is still under

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[1] ARTES 20 Demonstration Project, 1-AO6124
[2] http://www.icr.beniculturali.it/
[3] http://www.iccd.beniculturali.it/

discussion in Europe, where the “National Digitization Plan” (PND) is currently being implemented at national level, in line with the EU directive (2011/711/EU). Inside this framework, the development in the geomatic field has allowed to improve the accuracy of the relief methods, and consequently the digital representation, with the use of photogrammetric and laser scanner techniques. However, these technologies are very expensive, and their economic impact can be reduced using a crowdsourcing approach in which large group of people can contribute to generation, implementation, management and analysis of data to produce open source materials. Perhaps one of its greatest advantages, besides the distribution of repetitive tasks to a large amount of people, is that the participation in crowdsourcing gains a sense of ownership that motivates further participation and affects positively the outcome of projects.

Most crowdsourcing projects regarding cultural heritage have the aim to create a dedicated online platform, where users can share the photos they taken of monuments. Those platforms work as complex photographical database that can be used for different purposes. A famous example is about the ancient city of “Palmyra”, an archaeological area destroyed during the Syrian civil war in 2013. The site’s photos were collected through an important media awareness campaign, which involved a wide audience of users. The project, known as “NEWPALMYRA”[4] was encouraged by the UNESCO Convention of Krakow in 2017. A recent evolution of the project is “PALMYRAVERSE” a platform which involves the interaction between 3D models in a VR and AR environment. Another example of crowdsourcing project is “PROJECTMOSUL”[5] which has now changed its name to REKREI. By accessing the website, the user can view a global map of the destroyed archeological site and can decide to upload new photos. Moreover, some crowdsourcing project are related to the digitalization of the cultural heritage stored in museums and archives. For example, project MICROPASTS [Bonacchi et al. 2014] was born from the collaboration between the Institute of Archeology of the University College of London and the British Museum; it was originally focused on the findings of the Bronze Age unearthed in Great Britain. The volunteers, educated by professionals, have been involved not only in the phase of digitalization and georeferencing of the artifacts, but also in the photo-masking procedures. The project has catalyzed the interest among users, especially the younger ones, for 3D models obtained with data coming from crowdsourcing. Another example is the ACCORD project, founded by the UK Arts and Humanities research council's community and digital design at the Glasgow School of Art Archeology Scotland, University of Manchester [Jeffrey et al. 2014]; it engages existing community groups in the process of designing and producing 3D records and models of heritage places, many of which they have ongoing relationships with, by the availability of photogrammetric consumer level techniques. The use of crowdsourcing approaches is also encouraged in Italy by authorities through regulations as L.D 91/2013 "Valore Cultura", L.D. 83/2014 "Art Bonus" and L.D. 94/20149.

The present work is part of the project RECIPE (REsilience in art CIties: Planning for Emergencies) founded by ESA/ ESTEC (ARTES 20 Demonstration Project, 1-AO6124). RECIPE main objective is to provide low cost updated 3D models of cultural assets, using, as source of information, photos taken by commercial portable devices, provided by collaborative tourists through a crowdsourcing model. Moreover, RECIPE will make available selected photos assessing the status of the building or artifacts of interest along time, in a sort of real time monitoring, and will implement virtual reality. RECIPE is based on existing “Structure for Motion” (SfM) software for the 3D modelling integrated with two satellite assets: EGNSS services, for the characterization of the point from where the photos have been taken and EO services to capture the real proportion of the building without the need of costly and lengthy survey of the site. This goal is possible by means of a specifically developed smartphone application which attract people giving away the photogrammetry models they have made and some discounts to tickets of museums and archeological sites in exchange to the participation to the project. The elaboration of 3D models to be usable in monitoring and recording taskrequire to reach an appropriate Level of Accuracy (LoA) by a proper use of SfM technologies and to be comply to the main guidelines, as those developed by AHDS, Guides to Good Practice for CAD and Virtual Reality (2002), the by Virtual Archeology Special Interest Group (VASIG) [Grande and Lopez-Menchero 2016] and by the Cultural Virtual Reality Organization. (CVRO) [Frischer et al. 2000].

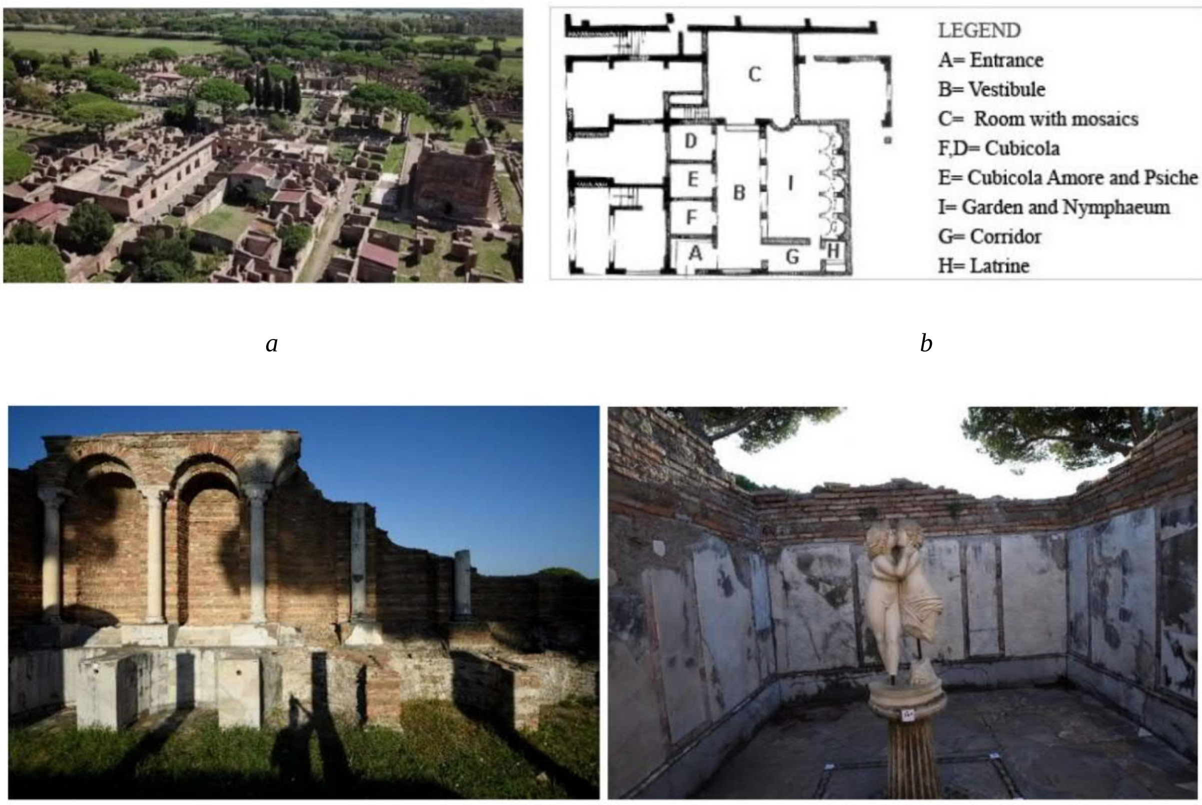
This paper only focused on the method to assess the quality of 3D model, that will be used to valuate RECIPE results; inside this frame, to avoid influence generate by different cameras, focus and positioning in photos taken by tourists, the data base photos are collected with a professional device following the state of art rules in SfM. At least, it is also discussed the possibility to implement the 3D models in a virtual reality environment to increase their diffusion on new multimedia and interactive platforms.

[4] https://www.newpalmyra.org/
[5] https://projectmosul.org/

The proposed approach involves the use of some structural and non-structural indices typical of the computer vision and medical field, in particular the Mean Absolute Percentage Error (MAPE), the “Perception based Image Quality Evaluator” (PIQE), the “Structural Similarity” (SSIM), the “Signal to Noise Ratio” (SNR), the “Peak Signal to Noise Ratio” (PSNR) and “Mean-Squared Error” (MSR) have been chosen for the assessment. Structural indices suppose that the human visual system is highly adapted for extracting structural information from the scene, and therefore a measure of structural similarity can provide a good approximation to perceived image quality [Wang et al. 2003].

CASE STUDY

The “Domus of Amore and Psiche” sited in the archaeological park of ancient Ostia was chosen as case study for its wideness and historical importance. The site is the biggest archaeological site in Europe and it is in the southwest of Rome, about 8 km from the coast (Fig. 1. a). The site is famous worldwide for its ancient buildings and mosaics. The name “Ostia” comes from the latin word “oris” [/ˈoː.ris/] which means “mouth” because it was placed at the mouth of the river Tiber. The “Domus of Amore and Psiche” (Fig. 1. b) is an ancient domus that was built in the second quarter of fourth century. The old owner probably was a Hercules’s priest who built a temple in the south of the house. The building has the typical structure of roman domus: the entrance, south oriented, is the vestibule which is connected to three *cubicula*/bedrooms and to another room sited in the north of the house; this room is famous for its opus sectile on the floor. Following the entrance, there is a tiny garden, separated by a marble colonnade which is placed along the east-side of the vestibule. A nymphaeum (Fig. 1. c) is located behind the garden and consists in two rows of five semi-circular niches decorated with columns in the upper part. Finally, a small latrine was placed in a corridor connected to the vestibula. The domus takes its name from the statue of “Amore and Psiche”, discovered in the bedroom (Fig.1. d).



a *b*

c *d*

Fig. 1. a) Aerial view of Ostia Antica, b) Amore e Psiche Domus plan, c) Nymphaeum, d) Cubicula with Amore and Psiche statue

METHODOLOGICAL APPROACH

Nowadays, many researches supplied guidelines for SfM applications in order to provide reliable results to assess 3D models quality for cultural heritage purposes. One of the most relevant work is "The Photogrammetric Applications for Cultural Heritage" [Bedford 2017; Koutsoudis et al. 2014], which discusses all aspects of photogrammetric processing in depth. Other important works, providing the latest developments in the field are [Stylianidis and Remondino 2016; Patias 2006; Fonstad et al. 2012]. Considering the guidelines and good practices, the photogrammetry campaign has been conducted in order to obtain the best possible results in terms of "Level of Accuracy" (LoA). All the followed steps involved in the process are described in detail in the next paragraphs

Measurement campaign

The measurement campaign was carried on the 23rd of June 2018, under a cloudless sky condition from 10 am to 15 pm, in order to have as far as possible a uniform illuminance condition. To reduce the sun effect on photos they were taken in this time span, when the sun reaches its zenith, reducing the shadow projected by the ruins which could lead to reduce 3D texture quality. For the campaign a NIKON D810 full-frame equipped with a GPS receiver MARREX MX-G20 MKII and with a photographic lens of focal length of 17 mm was used. During the field campaign a photographic database of 780 horizontal "Tagged Image File Format" (TIFF) photos has been collected with a resolution of 7360 x 4912 pixels. The TIFF format has been chosen for its suitability due to its lossless quality. All photos were taken with parallel-axis technique and with large overlapping areas (70 %-80 %) in order to capture the same scene at least in three different images. More photos have been taken for important details, such as columns and mosaic floors. Moreover, during the photographical campaign a relief has been made; the building shapes and dimensions has been measured by an EDM (Electronic Distance Measurement) device (Leica DISTO S910, error of 0.010 % at maximum distance range of 300 m). The relief data were used to aid the reconstruction process with the help of 68 markers that have been placed in the site to properly dimension the model. The distance between the markers has been taken placing the EDM device on a tripod in the centre of every room and measuring the distances between every visible marker. This method is important to understand the error made by the reconstruction process: each marker, in fact, highlight a specific point in both the real building and the reconstructed model. From this analysis 35 of the scale bars has been obtained from the 61 points and has been used as dimensional input for the photogrammetric program; not all the markers where used during the reconstruction process leaving 30 points to validate the results, comparing the measured value with the distance in the 3D model. This is important to do not affect the results with the input data: if all the markers were used as input the measured error would be modified due to the scale bars constraints.

SfM software

Agisoft PhotoScan Professional 1.4.1 has been chosen as reference software in this study[6]. As general statement, the quality of the photos used in photogrammetry is related to the final quality of the reconstruction; blur, shadows, changing of lights, foreign objects and bad exposition must be avoided as much as possible. As quick check on the image quality the "input quality imagine index", created by Agisoft PhotoScan, has been used. It provides a value based on the sharpness level of the pictures in a range from 0 to 1; the photos with a quality value less than 0.5 units has been excluded from the photogrammetric processing. In this case, 771 imagines of the photographical database satisfied this quality threshold. Fig. 2 show the final reconstruction output obtained at very high settings. The obtained model is made of more than $15x10^9$ triangles and 40 textures of 8128 x 8128 pixels each.

[6] Agisoft PhotoScan Professional 1.4.1 Manual, DOI: https://www.agisoft.com/pdf/photoscan-pro_1_4_en.pdf

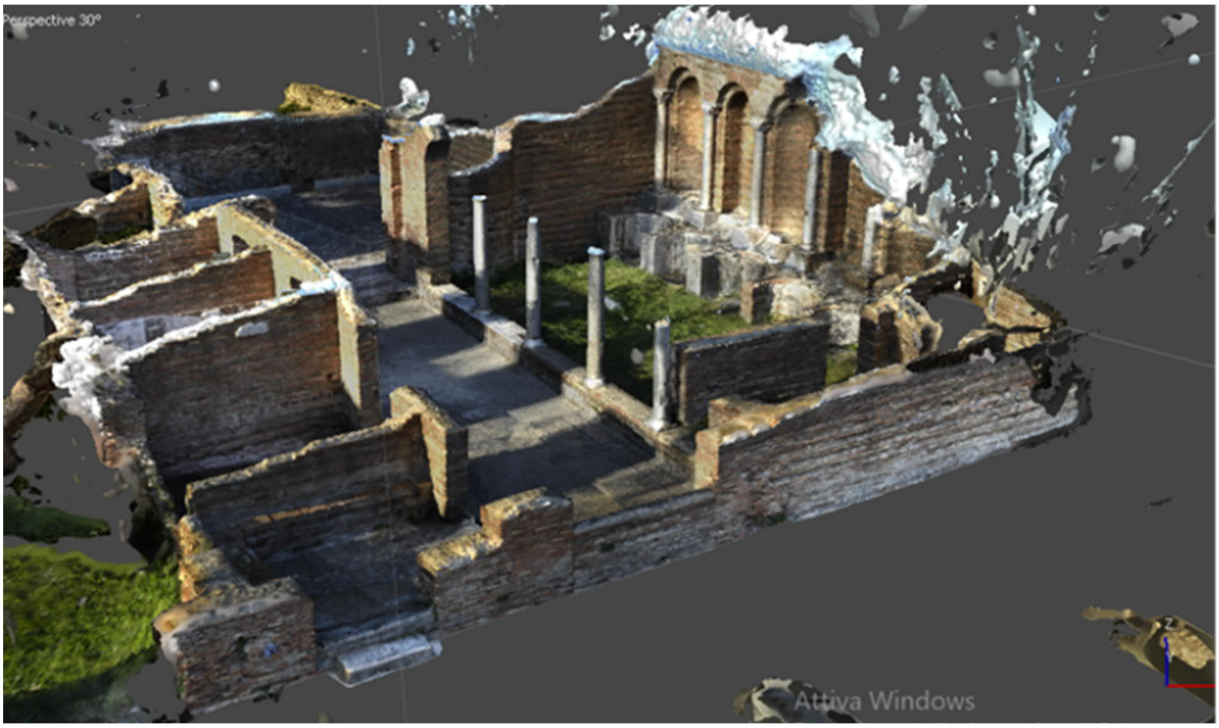


Fig. 2. Final reconstructed model

Dimensional errors and perceptual quality

To validate the model quality, it is proposed a "three-dimensional methodology" which takes in account dimensions, colours and perceived structure. The methodology involves not only the absolute pixel colour value coming from a singular pixel analysis, but it considers also the inter-relation between pixel in order to analyse the "true" representation of an object and the clearance and discernibility of its details. This methodology is useful where dark areas and hidden details could degrade the quality of the representation. Hence, for this study, the following indices have been calculated: "Mean Absolute Percentage Error" (MAPE), "Perception based Image Quality Evaluator" (PIQE), "Structural Similarity" (SSIM), "Signal to Noise Ratio" (SNR), "Peak Signal to Noise Ratio" (PSNR), and "Mean-Squared Error" (MSR). Their mathematical formulation and the recommended thresholds for SSIM and PIQE are discussed. The recommended values for SNR, MAPE and PSNR are not reported because these metrics are more useful for comparison purposes between different reconstruction of the same model; moreover, they do not consider the perceived quality but only the difference between the original photo and the virtual model. The colorimetric analysis, based on "International Commission on Illumination" (CIE) [Sharma 2003] recommendation CIE76 [Upton 2016], CIE94 CIEDE2000 [Lindbloom 2016], and the Euclidean distance in sRGB [Hughes 1998] space, was already performed by the authors [D'Angelo et al. 2018]. Regarding the dimensional error the best approach is to use a regression calculation, which involves the measurement of distance between every couple of markers on site and on the 3D model. Some authors as [Fritsch and Klein 2017] recommend the "Iterative Closest Point Algorithm" (ICP) but this method requires a deep knowledge of dense point cloud of the model that is not always easy to elaborate. An alternative method is to use a distortion matrix: considering a grid of points on the object surface, identified by shapes or edges, is possible to calculate the distances between the points in the reconstructed and real object [Pedersini et al. 2000; Arias 2005; Wang 2004]. A vector analysis, based on the MAPE parameter, has been performed to validate the geometrical accuracy between the real building and the reconstructed model. The formulation is reported below:

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{(A_t - F_t)}{A_t}\right| \quad (1)$$

Where At is the real measured value and Ft is the distance in the virtual model.

The structural analysis compares the shapes and colours information contained in two images. In order to compare a 3D model with the photos taken during the relief the used methodology can be reassumed as following: the camera position calculated by photogrammetric software, which is the point where the photos are supposed to be taken, has been used to render an image of the virtual model. Then, the original photos and render where scaled to the same resolution (N x M pixels, varying with every couple of images; It is not necessary to get high resolution due to the importance of the shapes not of the number of pixels) and converted both in RGB space before applying the calculations. Since the used indices are full reference metrics, the calculation must be made with uncompressed format such as Tagged Image File Format.

The fist metric considered is the Signal-to-Noise Ratio, it is a widely diffused index used in science and engineering to compare a signal to the level of background noise. It is expressed in Decibel as shown in the formula (2).

$$SNR_{dB} = 10\ log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) \quad (2)$$

The Mean-Squared Error measures the average squared difference between the real values and what is estimated. Given a noise-free M×N pixel monochrome image I and its noisy approximation K, MSE is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad (3)$$

Peak Signal-to-Noise Ratio is another diffused metric which is formulated as SNR but it evidences the maximum difference between a signal and the environmental noise. It can be defined trough the MSE (4):

$$PSNR_{dB} = 10log_{10}\left(\frac{MAX_I^2}{MSE}\right) \quad (4)$$

Where MAX_I^2 is the maximum possible pixel absolute value, it is expressed in dB as for SNR. For the photogrammetry purpose the signal is the RGB value of the original photo and the noise is the colour difference between the original photo and the render of the virtual model.

The structural similarity is a model for predicting the perceived quality of a digital content; it is perception-based metric and considers the image degradation as a perceived change in structural information. It is based on the idea that the pixels have strong inter-dependencies when they are spatially close. The index is usually used for measuring the similarity between two images, one compressed and one not, but in this work, it is proposed as evaluation metrics for 3D model quality assessment. The model was developed in the University of Texas at Austin and at New York University [Venkatanath 2015]. To calculate SSIM the model, some render of the virtual model has been be sectioned into samples and compared with the section on a reference photo. As stated before, the render position was calculated by the software as the shot position. The SSIM index mathematic can be reassumed in following equation:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (5)$$

Where x and y are the two sample images (real and virtual) of the same size in pixels; μ is the average value between pixels of x and y; σ is the variance of x and y as stated by subscripts; σxy is the covariance, and C1 and C2 are two variables used to stabilize the denominator:

$$C_1 = (k_1L)^2, C_2 = (k_2L)^2 \quad (6)$$

Where K1 = 0.01, K2 = 0.03. L is the dynamic range of the pixel values calculated as below:

$$L = (2^{bits\ per\ pixel} - 1)$$

The index is symmetrical hence x and y can be changed in order. The three components, of which the index is made, can be calculated separately:

1. Luminance (l):

$$l(x, y) = \frac{2\mu_x\mu_y + c_1}{\mu_x^2 + \mu_y^2 + c_1} \quad (7)$$

2. Contrast (c):

$$c(x, y) = \frac{2\sigma_x\sigma_y + c_2}{\sigma_x^2 + \sigma_y^2 + c_2} \quad (8)$$

3. Structure (s):

$$s(x, y) = \frac{\sigma_{xy} + c_3}{\sigma_x\sigma_y + c_3} \quad (9)$$

Where C3 = C2/2 and:

$$SSIM\ (x, y) = \left[l(x, y)^{\alpha} * c(x, y)^{\beta} * s(x, y)^{\gamma}\right] \quad (10)$$

The three constants α, β and γ are weights that can be reduced to 1 to obtain the form showed in equation (2). SSIM can be applied both in luminance space (Grey scale) or in RGB space; in the present work all indices have been analysed only in RGB space. A SSIM value of 1 indicates a perfect match between images and a SSIM ≥0.65 indicates the recommended matching between images [Venkatanath 2015].

The last metric used for the validation purposes is the Perception based Image Quality Evaluator. It calculates the no-reference quality score for an image through a block-wise distortion estimation and through a Gaussian noise analysis. The evaluator generates a spatial quality mask that indicates the high spatially active blocks, noticeable artefacts blocks, and the noise blocks in the image. It is also possible to visualize the spatial quality masks by overlaying them on the image. The evaluator is useful to assess if the output image has a good quality and every part is clearly discernible. A quality scale for the images is given in the Table 1: a low score value indicates a high perceptual quality and high score value indicates a low perceptual quality [Sheikh 2013].

Table 1: PIQE quality scale

Quality Scale	Score Range
Excellent	0-20
Good	21-35
Fair	36-50
Poor	51-80
Bad	81-100

RESULTS AND DISCUSSION

The results of the study show a good agreement between the 3D model and the photos, for clarity purposes they were divided into two categories: dimensional errors (Table 2) and perceived quality (Table 3). In the dimensional error table, the column “Max.” indicates the maximum relative error between the scale bars in the whole database, the column “Metric” indicates maximum error on a segment, the column “MAPE” indicates the error calculated with (1) and the standard deviation is calculated on MAPE values.

Table 2: Dimensional errors

Errors model scaling			
Max.	**Metric**	**MAPE**	**Standard deviation (σ)**
3.04 %	2.32 mm/m	0.049 %	0.0212
Validation scale bars			
Max.	**Metric**	**MAPE**	**Standard deviation (σ)**
8.6 %	3.76 mm/m	0.051 %	0.0156

Concerning the perceived quality results, Table 3 presents the average results of all the metrics mentioned in the previous paragraph.

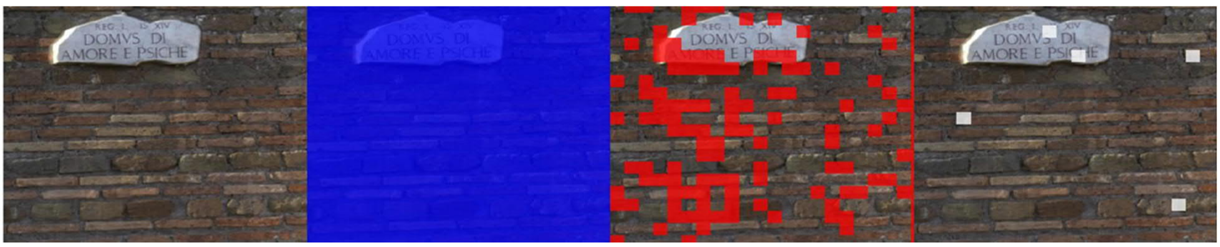
Table 3: Imagine quality results

SSIM	PIQE	MSE	SNR	PSNR
0.65	24.84	1031.50	10.70 dB	19.30 dB

The most clear and significant images analysed with the SSIM and PIQE metrics are in Figures 3, 4, 5, 6, 7, and 8 where it is possible to see the differences between the reference and reconstructed image in terms of perception. The three images were chosen to show high, medium and low SSIM and PIQUE results.

a *b* *c*

Fig. 3. SSIM = 0.746, a) Reference Imagine, b) Modelled imagine, c) SSIM index map



a *b* *c* *d*

Fig. 4. PIQE = 24.16, a) Distorted Imagine, b) Activity mask, c) Noticeable artefact mask, d) Noise mask

a *b* *c*

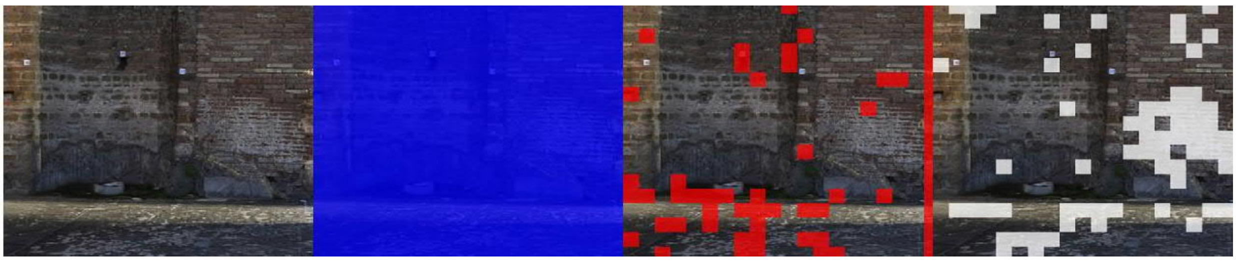
Fig. 5. SSIM = 0.548, a) Reference Imagine, b) Modelled imagine, c) SSIM index map

a *b* *c* *d*

Fig. 6. PIQE = 27.05, a) Distorted Imagine, b) Activity mask, c) Noticeable artefact mask, d) Noise mask

a *b* *c*

Fig. 7. SSIM = 0.819, a) Reference Imagine, b) Modelled imagine, c) SSIM index map



a *b* *c* *d*

Fig. 8. PIQE = 20.97, a) Distorted Imagine, b) Activity mask, c) Noticeable artefact mask, d) Noise mask

The “SSIM index map” visible in the Figures shows through a Grey scale the difference in terms of pixel luminance intensity between two imagines. The map is made by two layers, the luminance masking and contrast masking. The luminance masking is the phenomenon whereby the image distortion tends to be less visible in bright regions, while the contrast masking is the phenomenon whereby distortions become less visible where there is significant activity or "texture" in the image. Naturally, the SSIM measures also the presence of noise.

PIQE activity Mask is composed of high spatially active blocks in the input image (e.g. Fig. 8. b). These blocks are the regions with more spatial variability caused by factors such as artefacts and noise. The Artefacts Mask is composed of blocks in activity Mask that contain blocking artefacts or distortions, as showed with the red squares, and the noise Mask is composed of the blocks in the activity Mask that contain Gaussian noise, as showed with the white squares.

IMPLEMENTATION IN VR REALITY

This paragraph discusses about the methodology followed by the authors to implement the photogrammetry models in a virtual environment. As first step it was considered witch software use; it is common to use a real-time development platform for games as developing environment to create a virtual reality program. They offer a complete, mature and versatile development platform, rich of support and documentation. For this study has been chosen Unity, which is a free to use software for study or learning purposes. The procedure followed to create the virtual environment can be reassumed by following:

1. export and clean the model, create texture maps
2. import into Unity and create a virtual environment
3. optimize basing on the application

The export file type chosen is the object with the texture, provided by the photogrammetry software. The following cleaning process, has been performed with the use of an open source software called “Meshlab”; the process is important to remove all the artefacts including isles (piece of meshes that are not part of the real model), high-density edge poles, self-intersecting nodes, zero-area faces, feature points outside any primitive, overlaps, to fill holes and to control the vectors normal to surfaces. On Meshlab it was possible to perform all the tasks using the algorithms included in the software. Moreover, the model has been simplified as much as required by the application, controlling the quality of the result step by step. After this step it is possible to operate on a better 3D model, clean and faster to render. As a part of this step the Normal, Albedo and Occlusion maps have been made. These maps are important to increase the perception of the light and depths. The second step has been to import the model into Unity creating a virtual environment, filled with sounds, information, and animations. The aim was to create immersive environment able to give the impression to be on the site. In fact, the experience can be enriched with informative layers, to add historical/cultural information, teleportation beams, to move through the environment, and sound effects to maximize the immersive perception of the VR environment. These features have been coded into scripts (C# or Javascript, the two main programming languages supported by Unity) and game objects loaded into the Unity environment. However, some content is freely available online and needs only to be costumed on the specific project. The third and last step has been the optimization. It was composed by many sub-steps to avoid motion sickness and to grant the global performance during the virtual experience. To address such challenge may there are some constraints: first, the real time rendering must be fast, a rendering frequency of more than 90 fps is recommended, and delay must be lesser than 11 ms[7]. Moreover, where huge environments are present and where is necessary to move by teleportation beams, a fade effects had been added during the teleportation process to avoid motion sickness. Direct movement using controllers has been avoided because it is a common cause of discomfort and during simulations [Krueger 2011]. Moreover, before the developing of this study a questionnaire on colour and space perception in virtual environment has been delivered to stakeholders to grant the quality of the virtual environment and to check the acceptance of this new media. The statistic sample was not wide enough to consider this test as “significant”, but it placed the basis of this work, permitting to focus on the main aspects discussed. During the test a group of 30 people has been invited to evaluate, on a scale from 1 to 10, a virtual simulation answering to 30 questions about dimensions, colours and general perception of some elements specifically chosen. The results have been showed that objects that presented albedo, normal and occlusion map was seen more realistic then others with only albedo map. At the same time, the lighting has been found realistic and close to the real one. At least, testers have been found uncomfortable and dangerous the presence of wires connected “Head-Mounted Display” (HMD).

CONCLUSIONS

The results show how the considered 3D model is geometrically and perceptively similar to the original in term of geometry and perceptive accuracy. Dividing the results in two topics it is possible to get the following conclusion:

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[7] https://help.irisvr.com/hc/en-us/articles/215884547

1. Geometry: The mean difference between model estimated dimensions and real measurements is lesser then 1% which is barely noticeable, the maximum error is 0,016 mm and is present at the distance of 8.56 m in the mosaics room, which is the widest room in the building.
2. Perceptive: The model shows a good perceptive quality compared to the real photos (SSIM = 0.65) and all the images are clear and well detailed (PIQE = 24.84).

Indexes are useful for the validation process in order to compare results with an optimal target. The last goal of this research is the application of the developed validation methodology both to support the next phase of the RECIPE projects, involving crowdsourcing resources, and to increase the knowledge of suitable model “prerequisite” for virtual reality representation. The second part of this study concerns the path to integrate a photogrammetry model into a virtual reality environment. Therefore, authors exposed a useful methodology to create a virtual environment.

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A Petrified Petrifying Eyesight: A Story for the MEDUSA'S HEADS from Istanbul, Turkey

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The Basilica Cistern, *Yerebatan Sarnici* in Turkish, is the largest of all the hundreds of ancient cisterns that rise below the city of Istanbul. In the North-West corner of the cistern, the bases of two columns reuse the carved blocks with the face of Medusa. The origin of the two heads is unknown; it is possible to say the same for a third (double) head located in the Archaeological Museum of Istanbul. These three/four heads of Medusa are masterpieces from the late Roman art. The research presented here starts from a digital photogrammetric study of this set of Medusa's heads, this allowed to obtain a 3D digital model to study its morphology and shapes, then the model has been collocated inside the 3D virtual reconstruction of the cistern to have an overall view. The assumption formulated here, with the cross referencing obtained during the research phase and digital photogrammetry, lead us to the idea that the heads may come from a Doric temple dedicated to Athena, in this specific case used as a metope, or from the triumphal arch dedicated to Constantine in Constantinople. The aim is therefore to bring back to life, using a process of virtual reconstruction, with contemporary technology, such as virtual reality, an architectural element from the past, through a virtual journey that traces the history of these stone giants, placing them in their hypothetical original context with augmented reality.

Key words:
Photogrammetry, Virtual Reality, Istanbul, Medusa, Sculpture

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INTRODUCTION

Working as scholars in the fields of built and Cultural Heritage, it is possible to see many interesting elements in complex historical context, it may happen often to meet the beauty of architecture parts and complex or fall in the fascination coming from the ruins [Macaulay 1953]. For a long time in the past, interacting with these influences meant to make drawings in place, operating measurements, taking pictures, creating a mix of different media describing the item seen somewhere; a long work most of the time made with accuracy and dedication. In the very recent years, the progressive and from a point rapid evolution of photogrammetry has gifted all the people involved in such operations with a great tool: the possibility to create good or even excellent fully textured 3D models out of a set of pictures taken with proper quality and strategy. The digital transformation of photogrammetry brought an extreme simplification, moving the complexity of the workflow from the need of proper hardware, preprocessing and long procedures to the need about taking correct pictures and then applying proper processing accordingly to the final use intended in the research. These specific operations are not easily recognizable in place: any person taking pictures around a piece of the patrimony may be at work for the production of a 3D model [Pucci 2013] and indirectly, any picture taken (i.e. by tourists) and shared on the internet may be used for the creation of a 3D model [Samer et al. 2011]. Then it is clear how much these innovations influenced the production of 3D models and their dissemination around the web, the academia, the conferences, in papers and books. The proper use of these tools allows to "bring home" (or to the laboratory) a good quality 3D model, fully exploiting the properties of the camera

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in use and the condition created by a procedure highly compliant with Cultural Heritage projects. The combination of these specific models with virtual reality environment completes well the intention of sharing and presenting items in their environment as well as in their hypothetic reconstruction. The immersive experience is not only “spectacular” or useful for learning/teaching purposes, it is also a good occasion to check and verify proportions, impressions, perceptions in an environment coming from a reconstruction or sited far away. Very interesting pieces like the “Medusa’s Heads” from Istanbul and their “hidden stories” are a great subject of investigation, especially using multiple tentative in defining the original architecture to which they belonged. Knowing the limit due to the impossibility about solving out of all the doubts on their real use/destination, but defining solutions that (even if just on the base of a process of exclusion) may contribute to a better knowledge about these impressive findings.

THE “CISTERNA BASILICA”

The Basilica Cistern is part of one of the most special and symbolic categories of buildings in Istanbul: the underground ones. Built in 532 AD by Justinian to regulate the water supply of Constantinople, it has the dimensions of a large cathedral: 138 x 65 meters, it can contain 80.000 cubic meters of water [Önlü 2010]. The ceiling is supported by 336 marble columns, two of which are held by two protomes representing Gorgons (Fig.1). The cistern takes its name from the fact that it was built under a large public square on the first hill of Constantinople, the *Stoa Basilica*, a great *Stoa* built about the 3rd-4th century during the early Roman age. It was meant to be the centre of commerce and a cultural hub, and then it was destroyed by a fire in 476 AD. After the Ottoman conquest of Constantinople, the Ottomans used the water of the cistern to irrigate the gardens of the Topkapi Palace. After installing their relatively modern water system, however, the Ottomans stopped using the water of the cistern [Mango 1978]. Forgotten by the city authorities, it was not discovered until 1545, when the French scientist Petrus Gyllius was researching Byzantine antiquities in the city. He was looking for remains of the *Stoa Basilica*, and when local inhabitants told him they were able to get water lowering the buckets into a pit below their basement levels, he had a great indication. The Basilica Cistern has undergone several restorations since its foundation. During the 1985 restoration, 50.000 tons of sludge were removed from tanks, and platforms built all over to replace the boats once used to visit the cistern. The cistern opened to the public in its current condition on nine September 1987 [Barsanti 1990].

MYTHS, FRAGMENTS AND BUILDING BEHAVIOURS

The heads of Medusa in the Istanbul cistern are clearly fragments coming from a previous building, probably elements for an arch or from a frieze. Their re-use as basements of columns is clearly done for some practical choice: two large, well usable blocks, no matter if they are sculpted or not, recognized by the workers of the cistern as excellent parts for various building necessities. They may be parts of some ruined architecture (maybe the Constantine’s Gate, but it is a hypothesis impossible to verify), or something never completed (and then coming from a courtyard, as it may suggest the similar block with the heads 3 and 4, still belonging to a single stone block, which sculpting was interrupted before the separation in two parts). This block is preserved in the Istanbul Archaeological Museum and shows similar size, features and sculpture style of the protomes in the cistern. So, even if these stones are depicting a myth capable to petrify an enemy, and for this reason being an excellent symbol to put like a “shield” on the entrance of a gate, their destiny was being used to support columns, placed underwater, with these interesting faces turned on one side or completely upside down. Such a result is not clearly done with an “architectural” choice, it is somehow a vernacular approach to these pieces, and it is a specific practical behaviour, a re-use of a stone that may be sculpted, but first of all it is a “usable” stone for its material quality, not really for its artistic or heritage values. The choice about turning them on one side or the other was probably guided by the condition of the piece or by its workability.

Overall, centuries later after this construction choice, the discovery of such pieces was quite precious: inside the beauty of the enormous space of the cistern, two weird elements from a distant past, hidden in the depth of the subterranean architecture, ready to capture the attention and the curiosity of many scholars and tourists. These heads have a great symbolic and evocative value: they open a window into an older past inside the ancient cistern, they show the presence/end of myths in that society and link them to the classic age, they bring to the public the fierce strength of the Medusa’s legend in a deep part of an underground building, entering the scene at the end of the visit and communicating something like “I have a story to tell”, but this is done by stone lips, capable to suggest nothing more than an impression.

In the will of investigating and develop graphic and "architectonic" hypothesis about these parts, from 2014 a personal research project started developing its structure. The project has foreseen four sessions: the 3D digitalization of all the usable elements connected to the protomes in the cistern to better understand shape and size of these parts; the definition of the state of knowledge about these elements and the myth of the Gorgons; the developing of virtual reconstructive hypothesis, the development of presentation and communication solutions based on Virtual/Augmented realities tools suitable for sharing, and transferring information about the "Medusa's heads" and their architectures.

To bring on these operations the choice was using photogrammetry because of its easy operational conditions, simplicity in the transport abroad of all the needed tools, excellent maneuverability in any conditions. The production of digital 3D models for real time visualization was the aim of the following modeling. Thus, the models were also optimized to produce a 3D printed version of the protomes. A better understanding and control of the shape and hypothesis development about the use of these elements was possible thank to these physical models

For the virtual/augmented realities it was preferred to optimize the 3D models in two different solutions, one oriented to "on-site" presentation, with a structure based on the use of an *Oculus Rift*[1] viewer and a virtual environment developed in *Unreal Engine*[2]; the other oriented to "on-line" presentation, with a structure based on common display and/or personal devices, optionally used inside cardboard/cardboard-like viewers.

PHOTOGRAMMETRY OF THE HEADS ONE AND TWO

The photogrammetry of the heads 1 and 2 was the most complex and difficult of the series. The shooting was done operating freely during a visit to the cistern, acting like tourists, gathering the data accordingly to a very preliminary documentation plan. At the time of this first survey (2014) obviously the two heads were well known, but no digital survey was available, nor detailed drawings, nor complete images of all the sides of each element. Most of the pictures online were taken by tourists and showing almost the same side and/or point of view. The low lighting in the space of the cistern sometimes caused the picture to have micro-blurred issues, often in the pictures could be seen the use of flash lighting. These conditions produced the need to go in place for taking directly the pictures, with no options about using some crowd sourcing operation for gather picture sets to be used for photogrammetry reconstructions, like those well experimented in the past by the research group from the "Dipartimento di Architettura" (DIDA) University of Florence [Mancuso and Pasquali 2015] and accurately explored by other scholars [Grün et al. 2004]. To produce a well working set of images, the camera in use was a Nikon D800e digital SLR with a 36.3 Megapixel unfiltered sensor. A camera capable to get high resolution images keeping a low level of noise even in high ISO settings, a proper condition for the low light of the cistern. After some evaluations, the lens used for the two photographic sets was a Sigma Zoom 12-24 mm F4.5 set on 20 mm stopped down at its full opening: F4.5. The choice of a significant wide-angle lens was due to more than one aspect: with a wide angle lens the risk of micro-blurred images at low shutter speeds is reduced; the strong perspective may be useful in the photogrammetry process; the wide field allows to work easily in the quite narrow space around the heads and avoiding the tourists walking around. The camera sensor was set at ISO 6400, in this way the shutter was operated at a speed about 1/3 and 1/8 accordingly to the lighting conditions. All the shots were taken with the camera handheld, so there was the need for a certain skill in keeping a stable position and avoiding any significant shaking while shooting (Figs. 2 and 3). The head with the face of Medusa turned upside down, named "number 1", was covered with 135 shots, from these a sub-selection of 109 produced the photogrammetry. The head with the face of Medusa turned one its right side, named "number 2", was covered with 60 shots, from these a sub-selection of 40 produced the photogrammetry. The logic of sub-selection was connected to the presence of shaking-blur, shadows from visitors and lights from their cameras.

PHOTOGRAMMETRY OF THE HEADS THREE AND FOUR

The heads 3 and 4 brought no particular difficulties if not those connected to the larger size of the block (with some minor problem in getting elements from the top part of the stone. The block has quite raw characteristics: only the protomes are well defined and clearly similar to those from the cistern. This condition of partially completed

[1] www.oculus.com
[2] http://www.unrealengine.com

element, seems to support the theory about an ongoing artefact, something never completed, maybe belonging to a set of many other parts disseminated around the city. So wrong, one of the faces is largely lost, only part of the chin, the lips, the lower part of the hair and parts of the cheeks remained (Fig. 4). During the survey at the Istanbul Archaeological Museum, the operators reached the courtyard of the museum on a cloudy day of July 2017, an ideal weather for taking photogrammetry pictures in open spaces. The camera in use was the same of the 2014, with the use of a 24-120 mm F4 Nikkor Zoom lens, used at 24 mm. Most of the shots were taken with the camera handheld, with an ISO setting of 160 and the diaphragm set at F8, obtaining a shutter speed of about 1/180, quite good for capturing correct stable images and a proper depth of field, keeping the stone in full focus and blurring the background. The overall number of shots was 192, all taken in NEF raw format.

PHOTOGRAMMETRY AND POST PROCESSING

The following processing was developed in five main steps: 1) checking and selecting and/or editing the images, with the pre-processing of the RAW file and the extraction of optimized JPG files. 2) generation of 3D models using *Agisoft Photoscan*[3], using a classic processing starting from the alignment, the creation of a dense cloud followed by the generation of the mesh (done at the maximum number of triangles) and in the end the creation of the texture. 3) post processing of the resulting model in *Raindrop Geomagic Studio*[4], with the refining of the polygonal mesh, its decimation to a lighter model, keeping almost all the details of the protomes (Fig. 5) then these bases were used to develop the "Virtual Reality" (VR) environment 4) development of specific reconstructions about all the main hypothesis on the original positioning of the heads. This was done with classic modelling procedures in *Maxon Cinema 4D*[5] and then exporting the results into the *Sketchfab.com*[6] platform. This part was not only useful for displaying, but quite valuable for appreciating the architectural result and the complexity of the composition, and, finally, the "realism" of the result in front of the pure abstraction. 5) Development and assessment of the VR environment, with the space of the cistern reconstructed to link together all the products of this research, offering the virtual space of the cistern with a full connection to the state of knowledge about the Medusa's heads.

VIRTUAL RECONSTRUCTION

Using the Agisoft Photoscan software it was possible to have proper bases to analyse and study the shapes of the four protomes, their peculiarity, comparing the dimensions, trying to find a common thread that could lead to put them in their original context and historical period. Just analysing the position of the two protomes inside the Basilica Cistern it is easy to understand that these big pieces of stone no longer have the apotropaic symbolic function of the horrid that drives away the horrid, but takes on a pragmatic character. It is quite evident that in this case the "spolia in se" (the remain, the re-used fragment in itself as an object representing a value from the past) has become "spolia in re" (the remain becomes a part used for practical aims) [Settis 1984]. The three hypotheses formulated for the possible belonging of the four Medusa's heads are a temple, perhaps dedicated to Athena, given to the mythological link between the two figures [Wilk 2000], realised or to be realised before the deconsecrating of the pagan buildings by Theodosius [Bassett 2015]. The others are the belonging to one of the arches of access to the forum of Constantine (in this case it seems more likely to be the head of the archaeological museum), or the belonging to the Stoa Severiana [Adam 1994]. For what concern the proposal of the belonging to the Arch of Constantine we based our research on archaeological sources such as the writings of Pausanias the Periegeta, (2nd century AD) in which he describes his travels; the Patria Costantinopolitarum, also known as Scriptores Originum Costantinopolitarum (6th century AD), a collection of Byzantine historical works on the history and monuments of the Byzantine Empire [Freely and Çakmak 2004], inside there is a part focusing on the ancient sculptures of the city, and in these writings the author describes the two marble Medusa heads as belonging to the *Proconneso* that was recognized as a work wanted by Constantine. It is impossible to say if they are the same protomes, but it is certain that Medusa was a mythological pagan figure easily used by Constantine. These heads were just inside the Forum of Constantine, which is also the place where the head now at the Archaeological Museum was found just beneath some houses in 1869. [Barsanti 1992]. In fact, it is hypothesised that this great stone was the keystone of one of the two arches giving access to the Forum (Fig. 6).

[3] http://www.agisoft.com
[4] au.3dsystems.com
[5] https://www.maxon.net/en/
[6] http://www.sketchfab.com

The references for the reconstruction of the arch were the triumphal arches from the Roman Age, such as the Arch of Constantine in Rome [Kaldellis 2016*;* Russo 2016].

For the hypothesis of the Stoa, it was a little bit more complicated to find an adequate number of sources to come and support a possible solution, because there is not so much information about the *Stoa Severiana*. The respective places of discovery of both the two protomes in the cistern and the two of the large keystones match the first and last part of the Stoa, the location of the cistern coincides with the beginning of the arcaded road (Fig. 7).

The last hypothesis of re-contextualisation of the ruin is the one of the temples dedicated to Athena, because of the strong connection between the two mythological figures. It could be a temple built or to be realized in the Byzantine period and destroyed during the period of Theodosius. For the proportioning of the temple, the key element was found in the metope, one of the heads was used as metope, the sizing was done following the studies about the proportions conducted by Vitruvius, Vignola and Palladio [Pollione and Migotto 1999; Rykwert 1996] *(*Fig. 8).

THE ONLINE CONTENT

The software used for the making of the VR is *Unreal Engine*[7], it is a graphic engine developed by *Epic Games*[8] software house. The first version of this software was created for *Unreal*, a first-person shooter game and across the years the development continued, adapting the software to the new hardware technologies and bringing it to other platforms. The process following to use the software was to export the models in FBX format from *Maxon Cinema 4D*[9] and import them in *Unreal Engine*. Then the cistern has been optimized and rebuilt to make the visual performance as smooth as possible. The texture of the materials has been recreated and applied to each single element.

For sharing the models in a VR environment, it was used a different solution, adopting the platform *Sketchfab.com*. It is a 3D models Platform, used to publish, share, and discover 3D, VR and "Augmented Reality" (AR) contents. One of the most interesting parts of this platform is a 3D and VR model viewer that allows users to move freely within the 3D scene using the mouse or Google cardboards or other headsets, creating easy to access and use solutions for general VR experiences. The 3D viewer is immediately functional in the *Sketchfab* website or in its mobile apps and can also be embedded in external websites (Fig. 9).

THE VR EXPLORATION

The aim of virtual reality is to simulate a real environment through electronic technologies, giving to the experiencer the impression of being really immersed in that environment. Today the term has also taken on a wider meaning and indicates all those simulations that allow some kind of interaction with this kind of environment, as it happens in example in video games, even when the simulation is not total, but involves only certain senses. Creating a virtual environment is not easy and requires time, research and investments. Videogames have played an important role in the growth of this sector, creating a huge market by acting as a flywheel for technological development. As already mentioned above, the purpose of this work is to virtualise the ruin, in order to create new opportunities and new tools for studying and understanding the built heritage. The software *Unreal Engine* was used again to rebuild the cistern and to offer a format that can be reused in any museum context.

With interactive virtual visits, which is a type of active communication, that is possible to provide for the visitors offering them a picture "as much complete as possible" of the ruin and of the current context in which it is located, creating the possibility to offer personalized learning experience in which they can choose what visualize and which information extract accordingly to their personal interests, with an effective active participation of the users.

With the currently available technologies, the use of interactive virtual visits can take place in many ways. For those who will visit the Basilica Cistern and the Archaeological Museum it is possible to imagine an easy solution using QR codes for accessing the documentation getting a clear idea about the nature of the heads and using the whole set of 3D models, Rendering 360, and VR (Fig. 10).

[7] http://www.unrealengine.com/
[8] http://www.epicgames.com
[9] https://www.maxon.net/en/

CONCLUSIONS

Nothing like a real place, nothing like a real video game... On the way to digital heritage the whole academic world is just experimenting. This is correct, sometimes the research uses "from the shelves" tools, and sometimes it finds interesting innovation. In all the cases the creation of the digital heritage environment makes it easier to share and gather information and knowledge for scholars, students, and pupils.

The creation of a new digital resource from the survey of a valuable cultural heritage element which previously was simply documented by basic pictures, is an innovation, a step forward in enhancing the possibility of digital learning and sharing. In the path to create digital tools for learning and communicating cultural heritage and architecture the scenario seems still open and a lot is in need about being discovered and defined.

Thus, well consolidated practices are ongoing and the presence of easy to access and operate digitalization tools together with high performance services like Sketchfab.com [Verdiani et al. 2018] are giving a great contribution to the global digitalization of heritage. In this vast transformation one of the most strategic aspect is the integration of contents and the interrelationships between a specific model, other models and a proper set of contents.

Such an improvement may work greatly in the development of future approaches between even very different media, bringing together state of the art, hypothesis, and intellectual speculations [Verdiani 2017]. That is what was tried with this research about these Medusa's heads, with this paper as a first resume of the state of development of an intricate puzzle, almost impossible to solution, but for this, fascinating and challenging.

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FIGURES

Fig. 1. Rendering of the interior of the Basilica Cistern, Maxon Cinema4D

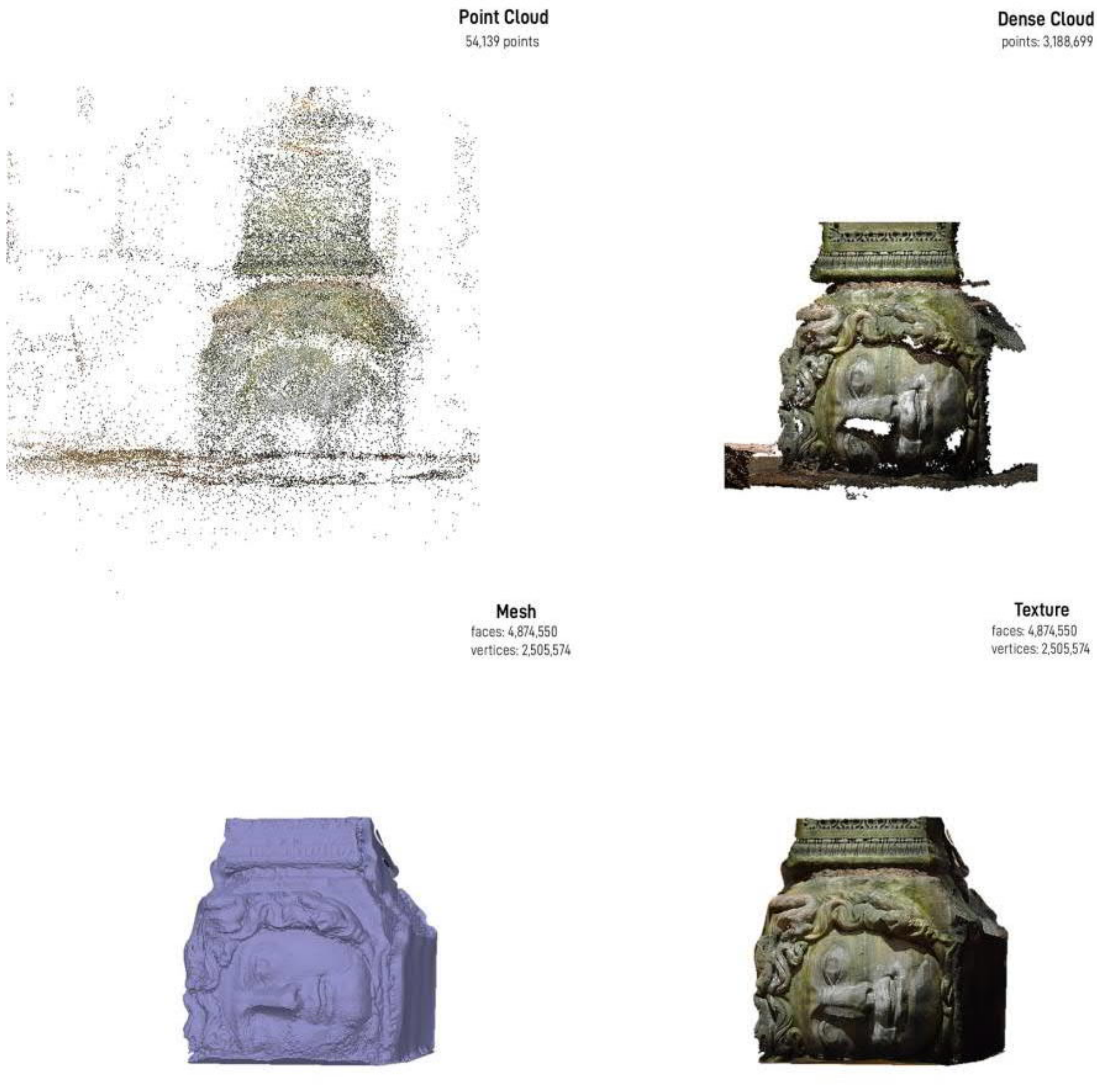

Fig. 2. Photogrammetry of the head of Medusa number 2, inside the Basilica Cistern, Agisoft Photoscan

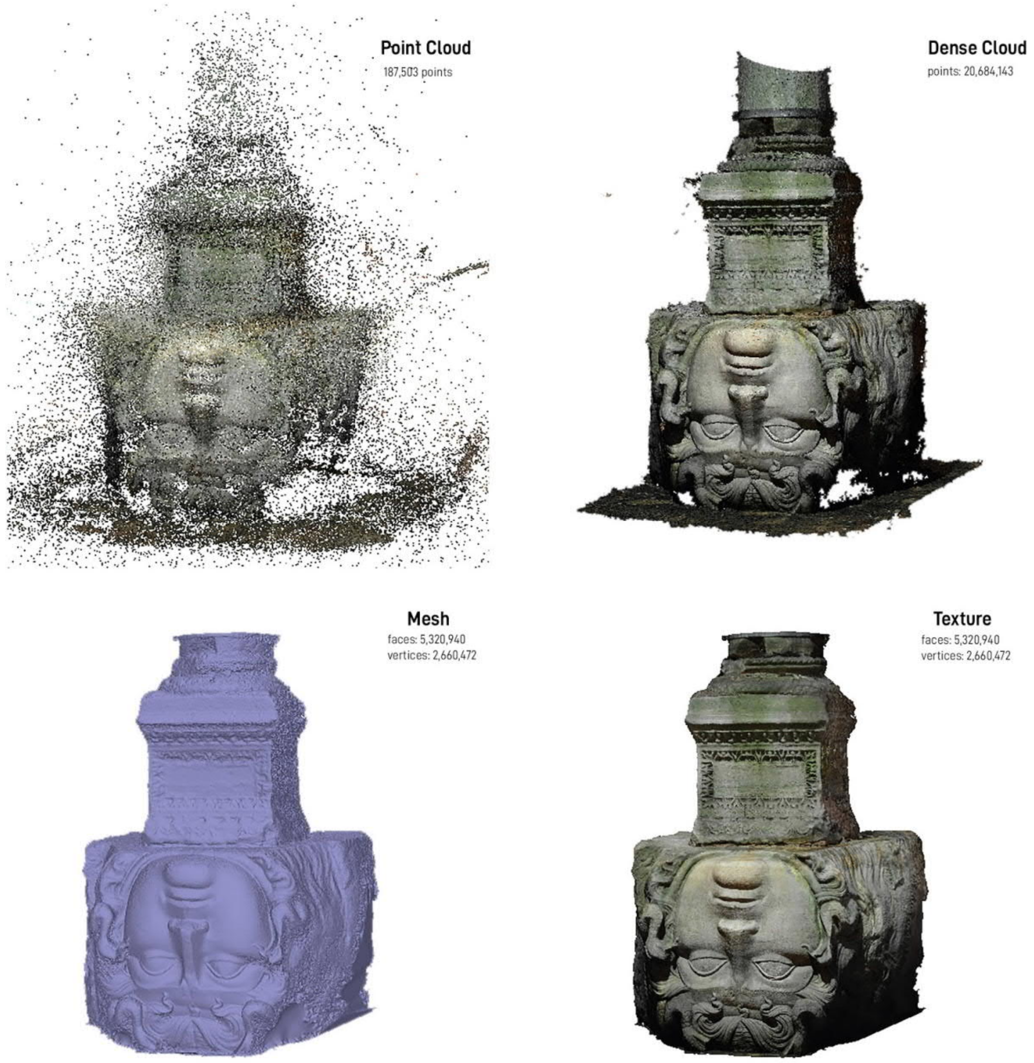

Fig. 3. Photogrammetry of the head of Medusa number one inside the Basilica Cistern, Agisoft Photoscan

Fig. 4. Photogrammetry of the two protomes preserved at the Archeological Museum in Istanbul

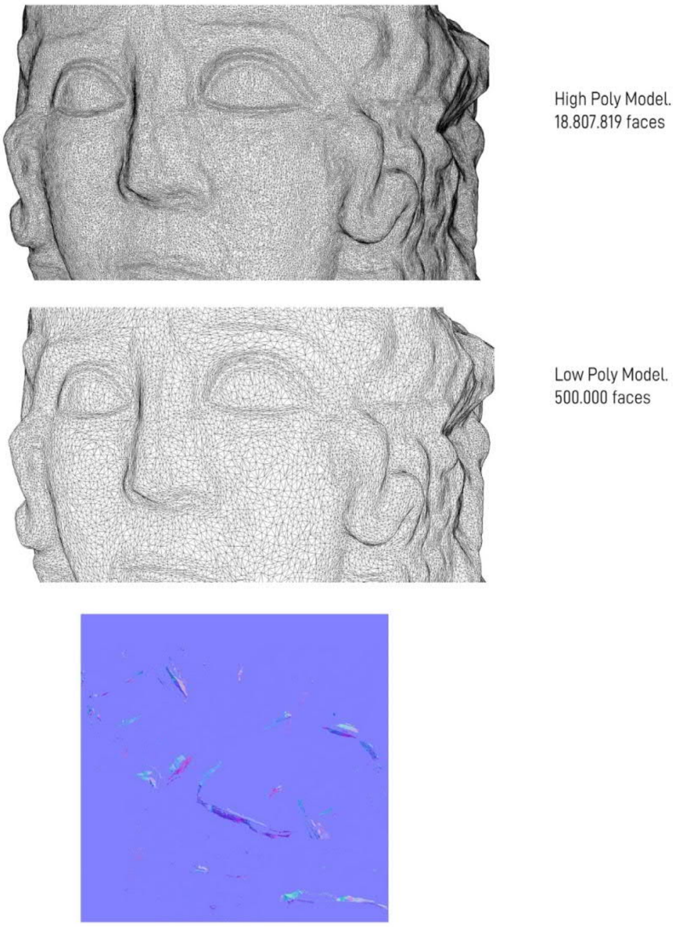

Fig. 5. "Baking" process on the 3D digital model, a series of features are calculated and organized to allow a faster computational performance in the visual rendering phases

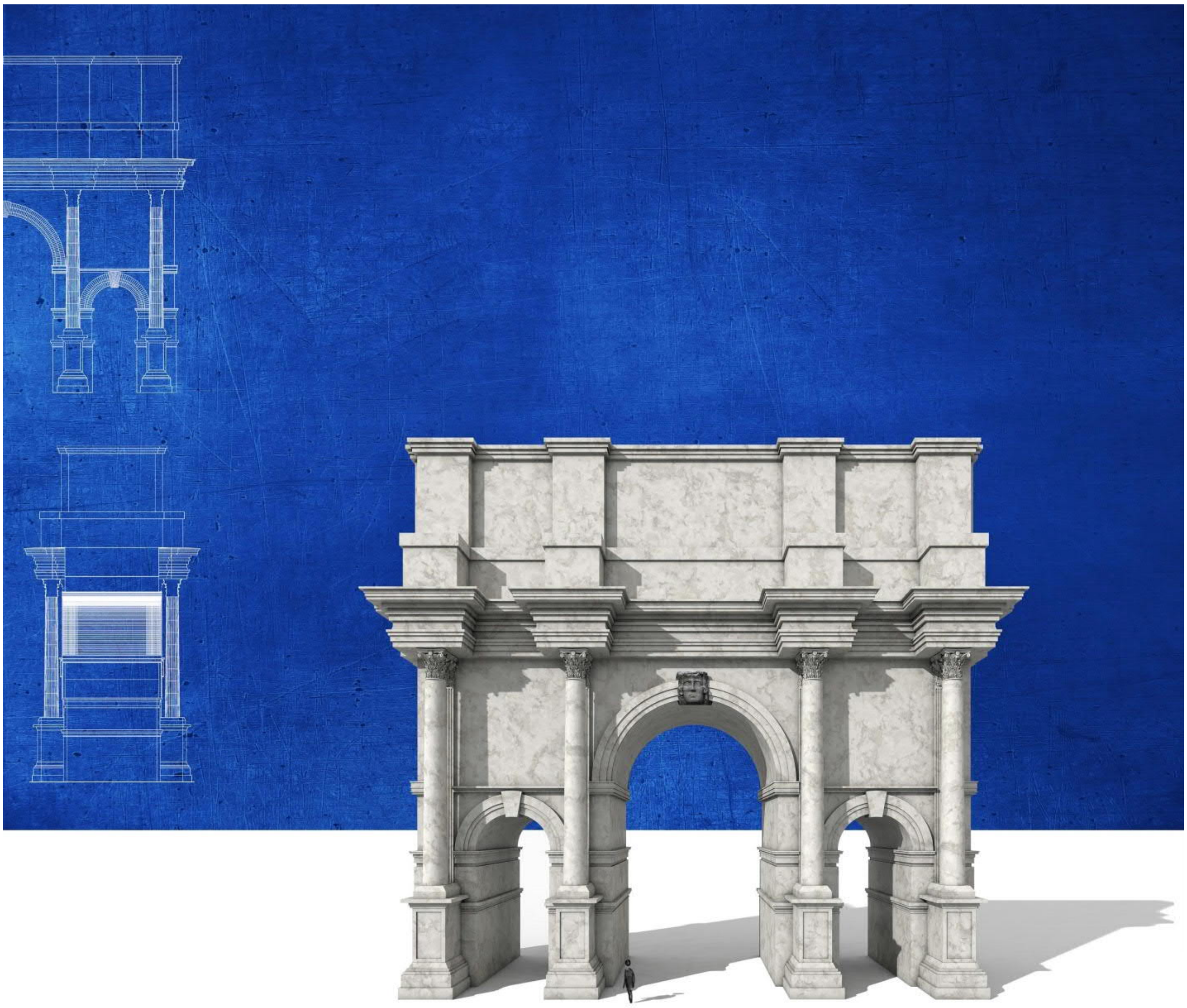

Fig. 6. Model of the first hypothesis of virtual reconstruction, Arch of access to the Forum of Constantine, Maxon Cinema 4D.

Fig. 7. Model of the second hypothesis of virtual reconstruction, Stoa Severiana, Maxon Cinema 4D

Fig. 8. Model of the third hypothesis of virtual reconstruction, Temple dedicated to Athena, Maxon Cinema 4D

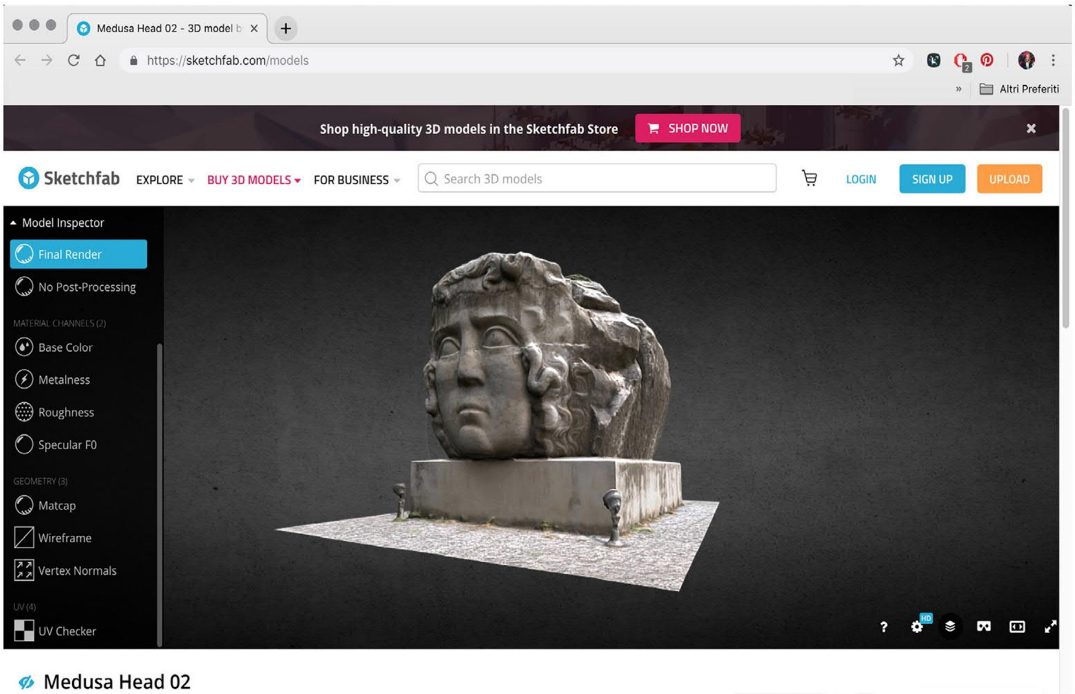

Fig. 9. Screenshot from the Sketchfab Platform, used for sharing online the 3D models and the VR content

Fig. 10. Example of QR code to be scanned, it allows a direct access to multimedia contents

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The Revival of Back-filled Monuments through Augmented Reality (AR)

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The development of three-dimensional (3D) models and the use of Augmented Reality (AR) in the field of cultural heritage consists an innovative process the recent years that provides the visitors of archaeological sites with additional information. This has been made possible due to achievements in digital technologies, communications, devices and developments in software engineering. Nevertheless, the research to fully make use of these new methods continues, as the potentials of new technologies have not been exploited. In archaeological sites, the production of 3D models for AR is focused on the virtual reconstruction of ruined monuments at their original form, aiming to give visitors the third dimension (height, volume etc.), especially to those who do not have special knowledge of archaeology. This paper describes an innovative approach of using AR for maintaining the memory and the information of monuments, as they have been originally excavated, but that are going to be back-filled due to the particularity of their material or their location. Also, the system architecture of the proposed scheme is described considering two study cases, a Neolithic settlement in the archaeological site of Halai, Lokris and the remains of a Classical Temple on open field of a hill in Thebes, Boeotia. Both mentioned monuments are under the direction of the American School of Classical Studies in Athens (ASCSA).

Key words:
3D modeling, Augmented Reality (AR), Digital Culture, Digital Heritage, Greece.

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INTRODUCTION

The expansion of "Information and Communication Technologies" (ICTs) has been proved to offer great possibilities in the field of culture by developing new ways of enhancing visitor's experience in sites with cultural interest, changing the way people experience their environment. One of the most promising technologies that provides the user with an integration of digital contents with real images is "Augmented Reality" (AR) [Vecchio et al. 2015].

AR technology supplements reality rather than completely replacing it, as it provides a way of presenting physical objects in their surroundings with additional virtual descriptions or graphic content. The computer-generated data is overlying the real-world and the user can see virtual and real objects coexisting in the same space [Noh et al. 2009].
Until nowadays, the dominant trend of the AR implementation in archaeological sites is the production of "three-dimensional" (3D) models for the purpose of virtual reconstruction of ruined monuments at their original form, aiming to give visitors the third dimension (height, volume etc.), especially to those who do not have special knowledge of archaeology. In the field of urban heritage, AR focuses on superimposing 3D models of historical buildings in their past state onto the real world or to visualize *in situ* the effect restoration projects.

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There is number of studies that demonstrate the application of augmented reality in cultural heritage concerning the "reconstruction" of monuments and historical places. One of the first projects was the ARCHEOGUIDE, a prototype AR mobile system, a personalized electronic guide that provided users with 3D reconstruction models and helped them navigate at Greece's Olympia archaeological site [Vlahakis et al. 2001]. In the case of the archaeological park of Bastia St. Michele in Cavaion Veronese in Italy an AR application was applied in order to promote the comprehension of the medieval religious complex, offering people a virtual tour around a 3D photorealistic environment of the entire archaeological site and the religious complex of San Michele [Morandi and Tremari 2017].

However, the ways to go beyond the current uses of AR are still being explored, as the potential of the new technologies in terms of digital content, usability, accuracy and end-user services, have not been exploited yet [Han et al. 2013; Olsson et al. 2012]. Within this concept, this paper proposes a system architecture which deals with the innovative idea of using AR for maintaining the memory and the information of monuments, as they have been originally excavated, but that are going to be back-filled due to the particularity of their material or their location, within the concept of the upcoming evolution of the Fifth Generation (5G) wireless communication networks and the developments in the field of "Cloud Computing" (CC), "Mobile Edge Computing" (MEC) or Fog infrastructures, sensors and "Internet of Things" (IoT) devices and services [Siountri et al. 2018]. The proposed scheme is going to be considered described through two study cases, a Neolithic settlement in the archaeological site of Halai, Lokris and the remains of a Classical Temple on open field of a hill in Thebes, Boeotia. Both mentioned monuments are under the direction of the "American School of Classical Studies in Athens" (ASCSA).

The remainder of the paper is organized as follows: Firstly, current uses of AR technology in the cultural heritage topic are described. Furthermore, the use of AR in cases of back-filled monuments is also studied. Subsequently, the proposed system architecture is described, while the final section concludes our work.

AUGMENTED REALITY TECHNOLOGY IN CULTURAL HERITAGE

AR refers to a manner of presenting supplementary information or graphic content with the help of a smart devices, such as mobile phones and tablets (but it can also work with special viewing glasses) that receive the real world (existing environment) and projects it in the screen augmented (virtual environment) using video, pictures (maps, graphics), sounds, vibration etc.

AR technology has become one of the research areas with high demand and interest in several applications (entertainment, education, commerce, art, medicine etc.). The research in the field of AR dates back from the 1960s [Kounavis et al. 2012]. However, the debut of smartphones in 2007 enabled precise location determination and featured components required for AR applications such as cameras, gyroscopes, solid state compasses and accelerometers [Haugstvedt and Krogstie 2012].

Today, all the virtual elements are all tagged associated to a specific geolocation, so even if the user moves towards the virtual element it would show a different angular viewpoint of the virtual elements. An AR application is considered [Vecchio et al. 2015] to manage the following tasks:

1. Objects detection within the scene
2. Overlapping of digital contents with the real scene
3. Management of huge amount of data with several formats, such as texts, images, video, sounds associated to a specific cultural asset

In sites with cultural interest, AR can improve visitors' experience with a time-navigation or with the integration of 3D models, data and storytelling that can increase the audience awareness of the uniqueness of a place [Antonczak and Papetti 2017]. Augmented reality, therefore, becomes an instrument of intersection between history (in its scientific issues of relationship with sources, philological interpretation, critical analysis and presentation) and memory [Brusaporci et al. 2017].

So far, AR applications in the field of cultural heritage is focusing to digitally reconstruct buildings and places as they were during a certain historical period, to get informed about the architectural characteristics of a building and to learn about the history associated with the location. ARAC Maps is a characteristic project that combines historical and archaeological information to enhance archaeological maps by using 3D models on archaeological ruins over the ancient landscape [Eggert et al. 2014].

Nonetheless, augmented reality could allow visitors and scientists to re-discover cultural heritage, tangible or intangible, by simply loading contents from a remote repository and visualizing them as virtual layers of information in an alternative way [Pierdicca et al. 2015]. For example, *ARtifac*t , a tablet-based augmented reality system, was developed in order to provide researchers and restoration specialists with an *in situ* diagnosis, such as layers representing data acquired through various imaging modalities (i.e. infrared thermography and ultraviolet fluorescence) of the artifact under observation [Vanoni et al. 2012].

THE USE OF AR IN CASES OF BACK - FILLED MONUMENTS

The use of new technologies and especially the implementation of AR models improves the understanding of “hidden” or “missing” cultural heritage, like the “Hacking the Heist” AR experience [Bruno et al. 2016], which is allowing visitors to see paintings that were stolen from the Isabella Stewart Gardner Museum, Boston, Massachusetts, USA. On the other hand, AR models enhance the accessibility of the underwater Cultural Heritage and allow any user to live an immersive learning experience with a distinct emotional reaction. In this context, many interdisciplinary and co-operative projects have been (/are) implemented at the scientific forum, such as the VISAS project [Bruno et al. 2016] (Virtual and augmented exploitation of Submerged Archaeological Sites) that develops an integrated package of services for *“improving the visitors’ experience and enjoyment”* [Bruno et al. 2016].

In addition to the aforementioned examples, this paper proposes the use of AR technology to provide three-dimensional content of antiquities that are not visible to users (residents and visitors of a region) using service models, cloud and advanced communication technologies. More specifically, to apply AR to monuments that are going to get back filled with protective materials or being partly or fully detached from their original location, in order to be protected (moved in a neighboring site, stored or exposed in a museum collection) e.g. antiquities of high aesthetics, such as mosaic floors.

a *b*

Fig. 1. Examples of excavated antiquities in city centers of a) Chania, Greece (© Maria Andreadaki- Vlazaki) and b) tram works in Piraeus, Greece that are proposed to be back-filled (© see footnote[1])

This idea can be easily implemented through photogrammetry or laser scanning documentation, when they are still visible (Fig. 1). Although the ‘artificial’ visual representation cannot replace the values of the tangible heritage, the AR technology can contribute to the protection of the intangible properties and the “conquered knowledge” of the past of a place.

Acts like backfilling or detachment of monuments are very common in the field of archaeology. In most cases the difficult, but necessary decision of back-filling a monument aims to protect the integrity or the existence of the antiquity itself, due to adverse weather or human factors in open archaeological sites, in order to inherit it to the future generations that may develop new techniques of preserving the material or the structure of the findings.

[1] https://www.keeptalkinggreece.com/2018/05/07/piraeus-tram-ancient-greece-cover/

Unfortunately, the implementation of big scale, high importance and national interest constructions e.g. national highways, bridges, ports or metro stations sometimes impose even the destruction of the excavated historical structures found during the works.

As a result of the above, the memory of the original position, morphology and integration into the existing environment of the monument is lost. Augmented reality can provide a solution to this dilemma of “existence or nonexistence” by offering to users (residents and visitors of a region) a dynamic and interactive experience of culture and heritage with the potential to bring history back to life and at the same time preserving crucial information to the researchers. The Neolithic settlement in the archaeological site of Halai in Lokris is considered as a study case of future implementation of this scheme idea. Halai is situated on the North Euboean gulf and was originally excavated by Hetty Goldman and Alice Walker Kosmopoulos during the earlier 20th century. The Cornell Halai and East Lokris Project followed in the 1990s [Coleman et al. 1999], under the direction of ASCSA. The Neolithic levels at the NW side of the hill that later became the classical acropolis date roughly to 6000-5300 BC. Small buildings are densely grouped together, although with at least one outdoor area, and they were built over several times on the same plans. In 2018 the Hellenic Ministry of Culture approved the back filling of the remains of the two out of three construction phases of the settlement in order to protect it from the deterioration of the construction material and the vulnerability towards natural disasters, human misuse, flora and fauna, leading the majority of the findings to be covered in the near future with protective materials. The proposal (Fig. 2) could be enriched with an AR application that would both digitally preserve the heritage elements and provide the audience with a more engaging historical experience, instead of limiting the visitor’s information to 2D images on the two information signs that are going to be placed in situ.

However, the acceptance of AR in the Archeology field remains questionable. The remains of the foundation of the Temple of Apollo Ismenios are situated on a pine-covered hill between the cemetery (Aghios Loukas) and the Electran Gates in Thebes, Boeotia. The temple was built in 371 BC and replaced a previous temple built circa 700 BC which had still been in use in the fifth century BC [Symeonoglou 1985]. It was excavated by A. Keramopoullos (1906-1929). In 2011 three geophysical surveys were implemented by the geophysicist Dr. Rob Jacob assisted by Emily Bitely of Bucknell University [Bitely et al. 2015], under the direction of ASCSA.

During the preparation of the conservation proposal, the fear of losing the “memory” of the monument, as it is not situated in a well-organized archaeological site, led the Archaeologists in competence to keep the fragile remains of the foundation of the Temple visible, even though it is at great risk due to the material’s vulnerability.

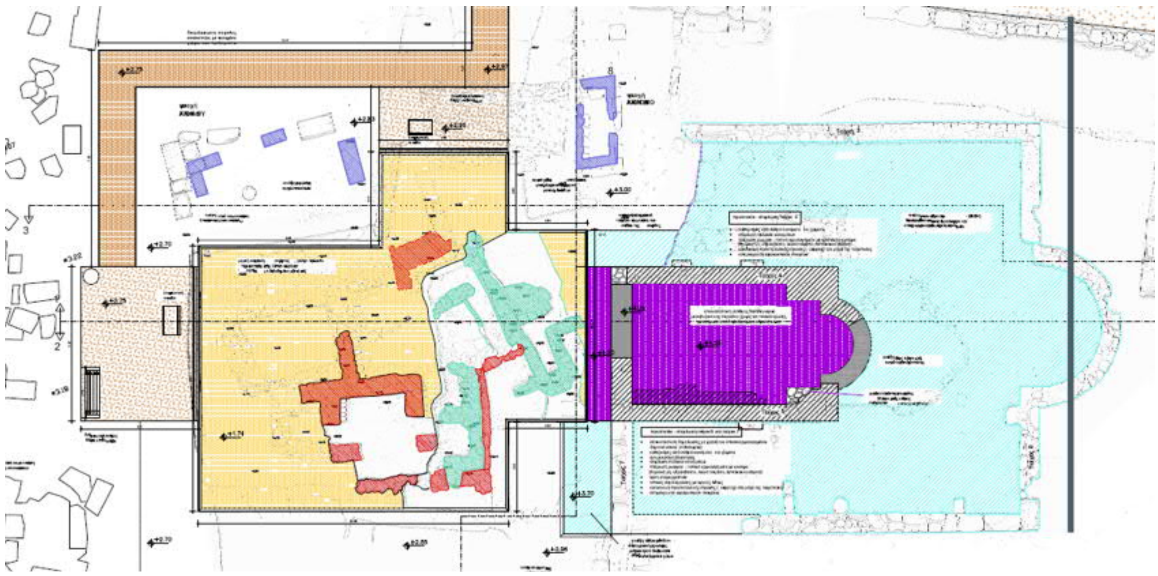

Fig. 2. The partial back-filling of the Neolithic settlement in the archaeological site of Halai in Lokris

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THE PROPOSED AR SYSTEM ARCHITECTURE

In this section the design of the proposed AR system architecture is described. In general, AR needs tracking to superimpose virtual content over real environment views. Depending on the type of the "theme" detection, AR can be implemented a) with markers (marker-based) or not (marker-less), b) with the help of sensors or c) by hybrid tracking, a fusion of the aforementioned tracking methods.

In the case of marker-based applications we distinguish three subcategories of theme detection a) by pattern, b) by outline and c) by surface. The augmented reality implemented by a pattern that consists either by two-dimensional barcode (QR Code), which is primarily a flat, square, black and white shape placed within the actual scene, or an image defined by the system as a template derived from the actual scene. The system in both cases recognizes the template (a barcode or an image of the real object) and then augments the actual scene or object with virtual elements such as video, image, sound and 3D models. The AR applications that recognize the outline allow the user to interact with the objects without the risk of interference of light or movement (e.g. hair, face, head as far as it concerns humans). Finally, augmented reality that detects surface uses specific elements of the theme's environment (e.g. floor, walls etc.) with the help of smart device's tools, such as GPS and compass, to keep the direction of the object and the overlapped information synchronized and displayed correctly [Kipper 2012]. Marker-less application detects and recognizes geometric features in the real environment to provide virtual objects over the real environment with real-time camera pose tracking. However, until nowadays, rendering could be slow due to the large amount of processing required [Papagiannakis et al. 2008].

Three methods are available for creating AR models, namely the photogrammetry, the 3D scanning and the use of a generic 3D modeling program. In the case of photogrammetry, a series of photos of a real-world object is taken. Subsequently, the photos are combined, while at the same time additional information can be added, using the appropriate photogrammetry software in order to create a complete AR model. Accordingly, in the case of 3D scanning, a real-world object is digitized directly using a 3D scanner with the appropriate software. Finally, as already mentioned, 3D modeling software can also be used in order to create AR models from scratch. However, this technique requires more time than the aforementioned ones, while at the same time it is more difficult to produce fully optimized AR models. On the other hand, the use of a 3D modeling software is necessary in cases where AR models about damaged monuments need to be produced. Also, this technique can produce AR models that represent the same monument in different historical periods.

Taking into deep consideration the upcoming advancements in the ICT, the proposed system architecture allows an easy and effective interaction with the real-world environment that can be applied to well organised archeological sites, as well as to back - filled antiquities that are situated in public spaces, frequently without an easy access or efficient signage.

The user moves inside a place with cultural interest, his/her position is monitored through GPS equipment sending a notification to smart devices (smart watches, mobile phones, tablets etc.). Augmented Reality models are presented to the user according to his current position. Also, the user can scan NFC tags and/or QR codes using his device, in order to present additional information or AR models in cases where GPS coverage is poor (e.g. in indoor or underground places).

The operating principles of the "Smart Cultural Heritage as a Service" (SCHaaS) model [Siountri et al. 2018] are applied. The SCHaaS model combines "Software as a Service" (SaaS), "Platform as a Service" (PaaS) and "Infrastructure as a Service" (IaaS) functionalities (Fig. 3), to provide a fully virtualized environment for services implementation, deployment, maintenance and usage.

Specifically, IaaS provides the appropriate infrastructure for offering PaaS, since it lets the user to create a virtualized infrastructure consisted of several "Virtual Machines" (VMs) [Piraghaj et al. 2016]. Thus, VMs created using IaaS are provided as PaaS to software developers along with the specific usage rights. Consequently, PaaS provides the appropriate components for offering SaaS, since the applications created and deployed using PaaS, can be offered as SaaS to users.

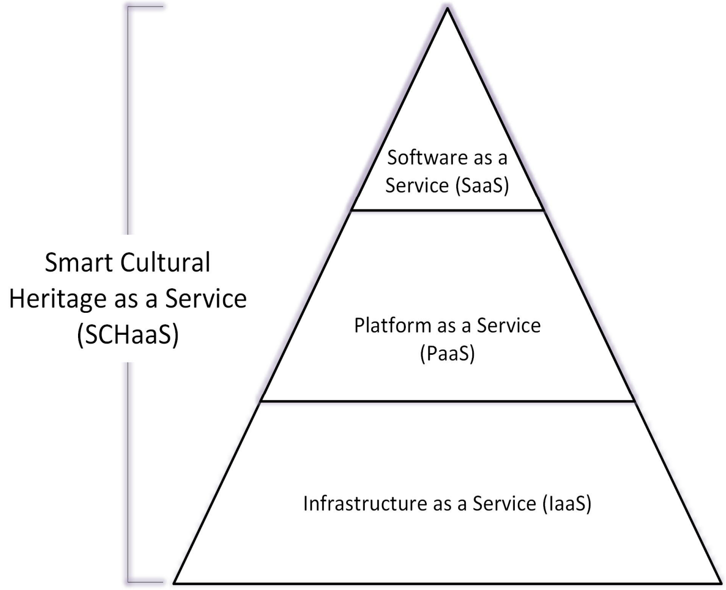

Fig. 3. The Smart Cultural Heritage as a Service (SCHaaS) delivery model

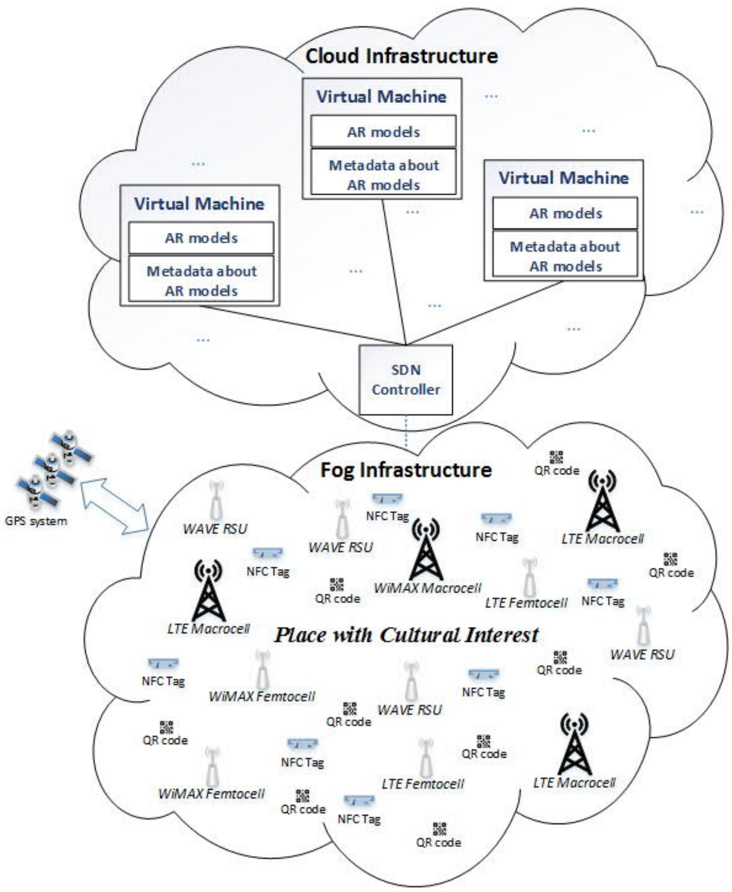

Fig.4. The proposed system architecture

Fig. 4 presents the fully virtualized 5G architecture of SCHaaS, which includes a Cloud and a Fog infrastructure. The Cloud includes a set of VMs, while each VM includes AR models about monuments, as well as additional information (metadata) about these models. Accordingly, the Fog infrastructure is built upon a place with cultural interest. This infrastructure includes network access equipment (such as LTE, WiMAX and WAVE cells), as well as “Near Field Communication” (NFC) tags and QR codes installed to specific positions.
The system functionality is presented in the sequence diagram of Fig. 5. As the user moves inside a place with cultural interest, he interacts with the Fog infrastructure and retrieves AR models. Specifically, the AR models can be retrieved by the user either by acknowledging his geographical position using GPS equipment or by scanning NFC tags and/or QR codes using his device. Subsequently, if the requested AR models already exist to the Fog, they are immediately presented to the user. On the contrary, the Fog interacts with the Cloud infrastructure through the “Software Defined Networking” (SDN) controller, retrieves the requested AR models and, finally, transmits them to the user. In this case, the Fog caches the aforementioned AR models, in order to immediately transmit them to future users.

Therefore, the proposed architecture proposes an innovative architecture that combines AR technology, the use of the proposed SCHaaS delivery model as well as cloud and advanced communication infrastructures, in order to provide users and researchers information and data that may be lost associated to a monument or archaeological interest place. Additionally, due to the proposed systems functionality this important information is associated with the geolocation data, providing real time information, while at the same time preserving the data for future study in a cloud environment.

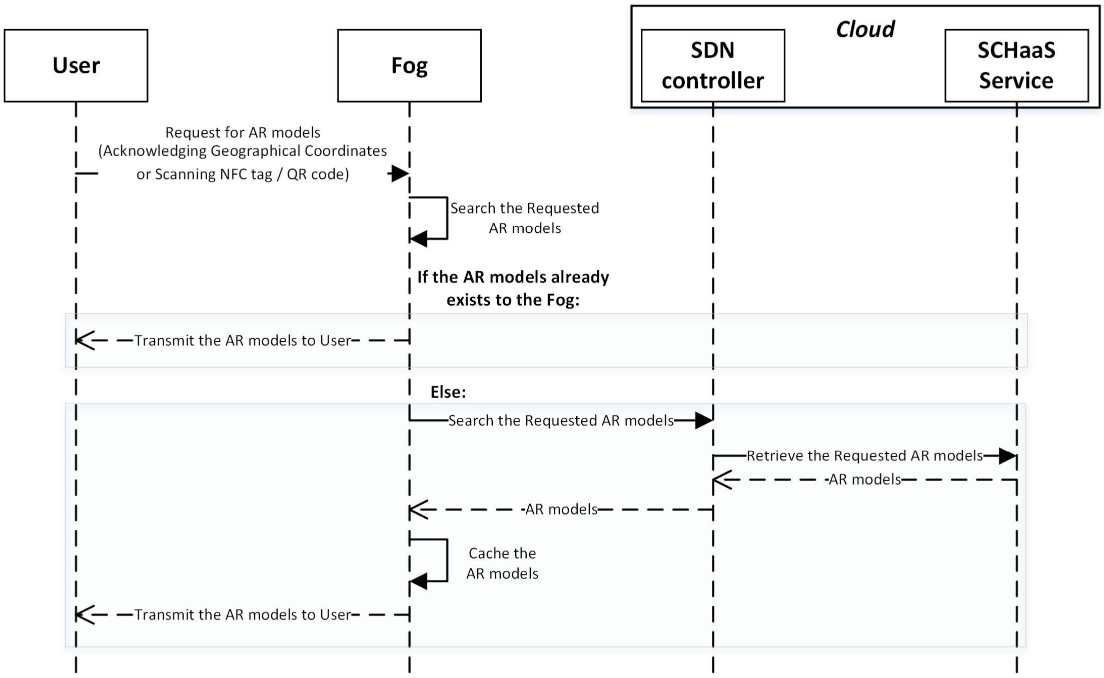

Fig. 5. The sequence diagram that describes the functionality of the proposed system

CONCLUSIONS

In this paper, a multidisciplinary research concerning management and the use of technology for the digitization, representation, documentation, and communication of cultural heritage knowledge has been analyzed. AR technology can offer a gateway concept between the real world and the virtual world, rich in new content and services that can be applied to the “Smart Cultural Heritage as a Service” (SCHaaS) and “Smart Tourism as a Service” (STaaS) models.

AR can lead to the revival of “covered” or “well hidden” antiquities, making them accessible and visible to public again. The advances in the communication field and the up-coming 5G technology will make the idea fully applicable to users, contributing to the preservation of the memory “as it was” not in the common sense of reconstruction that prevails today, but “as it was found” turning the ruins into the main theme of interest.

The work described refers to the design of an AR system architecture. The proposed architecture includes a 5G network infrastructure as well as AR models about monuments. As mentioned, as the user moves inside a place with cultural interest, he retrieves AR models through the network infrastructure. Specifically, the AR models can be retrieved by the user either by acknowledging his geographical position using GPS equipment or by scanning NFC tags and/or QR codes using his device.

Future work includes the implementation of the proposed system architecture considering real-world scenarios. Furthermore, a multidisciplinary research will be performed concerning both innovative cultural heritage management and the use of technology for the digitization, representation, documentation, and communication of cultural heritage knowledge is necessary in order to convert AR to a gateway concept between the real world and the virtual world, rich in new content and services.

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Virtual Karam Collection: 3D Digital Imaging and 3D Printing for Public Outreach in Archaeology

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Archaeological museums are often perceived as repositories of relics, entrusted to preserve ancient material culture in perpetuity but at the same time committed to making it accessible. The fear of deterioration often denies access or imposes limits on the interactions between visitors and artefacts. This contribution will present the results of the Virtual Karam Collection, a digitization project of archaeological heritage consisting of a collection of artifacts that has limited access and is not properly shared and communicated with the public: The Farid Karam Lebanese Antiquities Collection of the University of South Florida's Libraries. 149 objects were 3D scanned and the digital models were shared with the public using an ad hoc web platform. It is clear that digital renderings cannot replace real objects; however, the digital surrogates and replicas make up for it by being available for experimentation and manipulation. In order to overcome the obvious limitations on tactile interaction with digital media, an alternative system was used, employing realistic 3D printed copies and having student stakeholders in the collection participate in creation of the replicas. The promising result of this project offers a new perspective on the practice of virtual mimesis of ancient artifacts as strategic educational tool both for people with visual impairments and cognitive disabilities, and for the general public which can learn more using the touch interaction.

Key words:
Digital Heritage, Accessibility, Touch Interaction, 3D Scanning, 3D Printing.

CHNT Reference:
Davide Tanasi et al. 2018. Virtual Karam Collection: 3D Digital Imaging and 3D Printing for Public Outreach in Archaeology.

INTRODUCTION

The digital revolution in the sciences and humanities has encouraged the development of a wide range of new approaches to museum practice that are encompassed in the concepts of digital museology and digital heritage [Smith Bautista 2014; Hermon and Hazan 2013; MacDonald 2006]. This 'digital turn,' which has increased in intensity and scope throughout the past decade, has transformed museums–informing new approaches to public outreach, education, collections management, exhibit design, marketing, public relations, and leadership [Stobiecka 2019; Biehl and Harrison 2014; Srinivasan and Huang 2005; Baustista 2013]. These changes have also fueled a reassessment of the role of museums in the 21st century – in particular, raising the issue of how digital technologies enhance or undermine the museum standards and best practices set forth by national and international organizations [Mairesse and Desvallées 2009; Merritt 2008]. This concern is also prescient for digital heritage professionals who must navigate the confluence of material culture, preservation, and access in diverse contexts [Cameron and Kenderdine 2007].

There are still critical lacunae in the discussion of cultural heritage accessibility and the question of how the virtual museum can become a more inclusive and participatory institution. Learning from objects is a multisensory experience, and the use of haptic technologies, which recreate the sense of touch, are gaining traction in museology because they offer a new way of learning and teaching through objects [Chatterjee et al. 2008]. Haptic technologies limit direct human interaction with authentic objects, while still providing the engaging tactile experience of handling models. This not only aids in preservation, but also promotes the posterity of museum collections. It also

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demonstrates that haptic technologies can be mobilized as tool of cognitive accessibility for people with cognitive or physical impairments [Stanco et al. 2017]. While haptic technologies are still in development and expensive to integrate into museum settings, 3D printing in the past decade has exploded in its commercial availability and its potential for cultural heritage applications and can serve as a substitute for haptic technologies in today's cultural heritage sphere as they perform many of functions of haptic technologies mentioned above. Though 3D printing requires material inputs on top of the digital models, it is recognized as a useful tool in both archaeological research and outreach [Balletti et al. 2017; Dolfini and Collins 2018; Wilson et al. 2018]. Recent studies on engagement with 3D digital surrogates of museum objects have shown that both older and younger populations have emotional responses to 3D that are similar in type and strength as they do when engaging with physical objects in a museum [Alelis et al. 2015]. It is worthwhile, then, to explore if 3D prints of artefacts can also be experienced in meaningful way.

This short contribution details a project consisting of the scanning and dissemination of a collection of antiquities that has been largely inaccessible to the student body and the general public that it was donated to serve in a quasi-museum setting at the University of South Florida. Deploying well-established technologies, the "Institute for Digital Exploration" (IDEx) scanned and disseminated the collection online, with the ultimate goal of creating 3D printed and artistically rendered surrogates for the artefacts in the collection, in order to evaluate the effectiveness of using low-cost 3D printed digital rendering to engage stakeholders of the university collection. The contribution first provides a limited history and description of the collection itself, before discussing the methods used to scan the objects, process the data, and create the 3D printed artefact surrogates. The authors comment on the method that the data was curated throughout the project, then conclude with the results of the project thus far and outline future avenues of research for the project.

THE FARID KARAM LEBANON ANTIQUITIES COLLECTION

The Farid Karam Lebanon Antiquities Collection was donated to the "University of South Florida" (USF) Libraries Special Collections in 1998 by Farid Karam with the stipulation that the artifacts would be exhibited to the student body. Consisting of 149 artifacts from Lebanon, the collection belongs to a wide chronological and cultural range from the Bronze Age to the 13th century CE (Figs. 1-2). These artifacts, according to the USF Libraries' documentation, were wholly collected beginning in 1962 by Farid Karam in Lebanon prior to his immigration to the United States in the 1970s. Unfortunately, the collection lacks any other provenance information. According to internal documents of the USF library, the collection was purchased legally in Lebanon and imported legally into the USA. While publishing unprovenanced material can be problematic [Argyropoulos et al. 2011], research on the Karam collection does not increase the monetary value of the objects in any way, as they are in the trust of USF libraries in perpetuity. It was decided, therefore, that digitization of the objects for the university and global community would not be antithetical to current archaeological ethical standards. The collection consists of metal, stone, ceramic, and glass artifacts. The 48 metal artifacts are in part medical tools dating to the Hellenistic and Roman periods and in part Bronze Age toggle pins and other decorative objects. There are three alabaster artifacts, consisting of a large *alabastron* and two *unguentaria*—one of which is a double vial. Of the 20 ceramic artifacts there are eight lamps, dating from the Second to Thirteenth Centuries AD, and a series of unassociated undecorated ceramic bowls. There are 76 glass artifacts, largely comprised of glass unguentaria from the first four centuries of the first millennium, with a few glass vessels dating to the Hellenistic period.

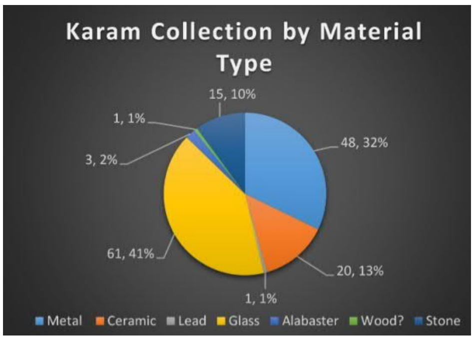

Fig. 1. Pie Chart indicating the different classes of materials in the Karam Collection

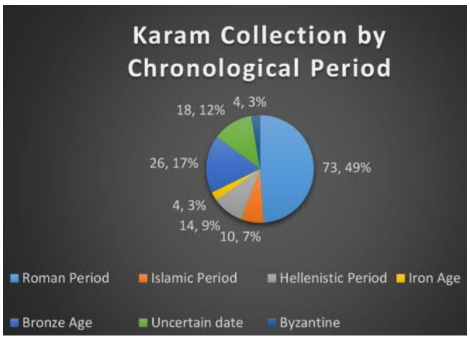

Fig. 2 Pie Chart indicating the chronological range of the Karam Collection

Though USF Libraries Special Collections has done everything it can to make the collection accessible, including hosting class visits and displaying photographs of particularly representative objects, the Karam Collection is unable to be fully exhibited due to lack of financial, material and human resources. In a letter from Farid Karam, he expressed interest in making the collection accessible online and creating a permanent digital exhibit in this way [Karam 2008] (Fig. 3). To respect Karam's wishes and make the collection accessible to the student body, a 3D scanning campaign was carried out by the Institute for Digital Exploration (IDEx) in the academic year of 2017-2018. The project was expanded to incorporate 3D printing of these artifacts to make them more accessible to students and those with disabilities, such as being blind or hard-of-sight, allowing them to engage with the collection tactilely. The first step of the project was that to update the obsolete graphic documentation (Fig. 4), producing new high-quality digital color pictures (Figs. 5-6) and to revise the historical and archaeological interpretation of the artifacts.

Fig. 3. Current setup of the Karam collection in the USF Library's Special Collection, stored in grey cardboard boxes

Fig. 4. Format of graphic documentation available at the USF Library's Special Collection for the artifacts of the Karam collection, color digital pictures

Fig. 5. New graphic documentation of the artefacts of the collection, produced at the beginning of the IDEx's virtualization project, selected glasses from IDEx website[1]

[1] http://history.usf.edu/idex/page13.html

Fig. 6. New graphic documentation of the artefacts of the collection, produced at the beginning of the IDEx's virtualization project, selected ceramics from IDEx website

METHODS

The virtualization of the artifacts was carried out by employing a combination of two techniques: 3D scanning and digital photogrammetry which already largely proved their potential in the field of Heritage Studies [Lerma 2010; Chapman et al. 2013].

Laserscanning

A Faro Edge ScanArm laser scanner was used to digitize 44 of the 48 metal objects. Due to their small size and complex geometry, it was challenging to capture them with other techniques or devices. However, the fact that the scanner is not able to capture color represented a major limitation as those problematic objects should be experienced in full color to be appreciated by the public and to communicate relative data about their state of conservation. In other occasions, like with the Roman limestone bust of the bearded man (Inv. no. 63) such a scanner was employed to create a high-resolution 3D model to better study stylistic features not immediately visible via direct examination (Figs. 7-8). The ScanArm created geometrically accurate digital models with a margin of error of less than one millimeter. Multiple angles and positions of the same artifact were necessary in order to capture all sides of the artifacts. The artifact was scanned in one position and moved to another position. The arm scanner collected data directly in the Geomagic Wrap 2015 software. Upon completion of the data collection with the arm scanner, Geomagic Wrap 2015 served as the processing software as well (Fig. 9). This digital data was cleaned, the different positions were aligned and merged, and the final model was exported as an OBJ file for dissemination and analysis. The OBJs were then uploaded to the IDEx Sketchfab page to integrate them into the IDEx website[2] for dissemination and public engagement (Fig. 10).

[2] http://history.usf.edu/idex/index.html

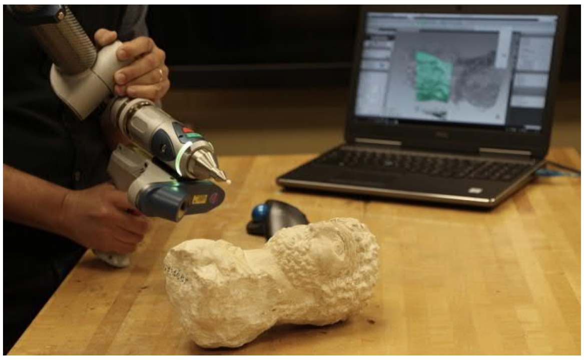

Fig. 7. 3D scanning of a Roman limestone bust from the Karam Collection (K63) with a Faro Edge ScanArm laserscanner

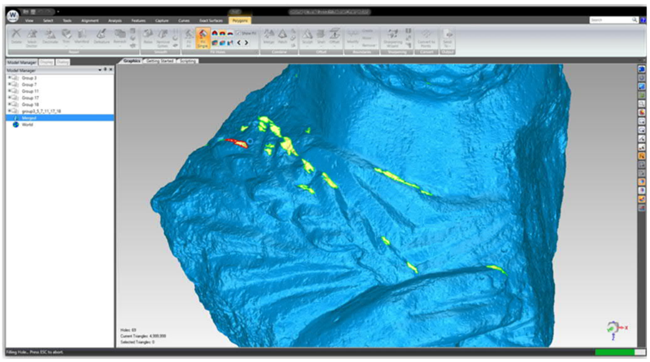

Fig. 8. Analysis of stylistic features of the bust examining the 3D model with Geomagic Wrap 2015

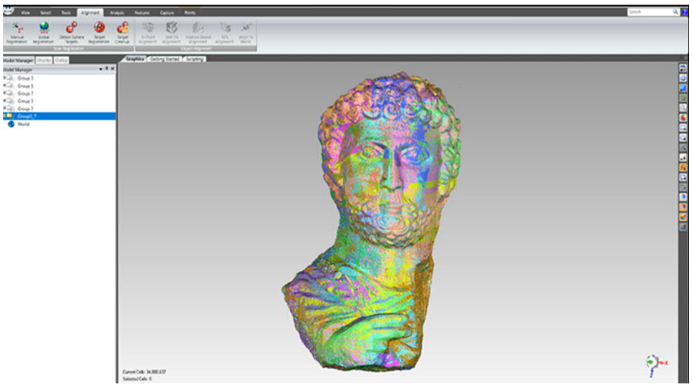

Fig. 9. Registration phase of the scans in Geomagic Wrap 2015

Fig. 10. 3D model of the Roman limestone bust of a bearded man (K63) from the Karam Collection

Digital photogrammetry

The digital photogrammetry survey was carried out on the majority of the artifacts using a Nikon D3400 at 6000 x 4000 px resolution for each image. This technique has already become the most popular among archaeologists and curators in museums for its low costs and high-quality results [Olson 2016]. Most objects were captured in two or three positions, with the camera taking photos from two or three angles for each object position, depending on the geometry of the object, from a 45-degree angle and a 90-degree angle at a horizontal from the object. Most artifacts were captured in an AmazonBasics lightbox with the automated turntable Orangemonkie Foldio 360 wireless turn table to ensure consistency and repeatability (Fig. 11). There were several artefacts with complex geometry or difficult to capture surface (e.g. many of the well-preserved translucent glass objects) that required several more positions or camera angles. Several artifacts, due to their size were captured free-hand by physically moving around a table upon which the artifact was placed. As with the arm laser scanner, the artifacts were captured in multiple artifact orientations in order to capture all sides and angles of the artifacts correctly. Photographs were taken with a scale and color checker. In general, the light conditions were favorable enough to keep the camera's settings on automatic, though certain objects required manually setting the aperture and shutter speed to better capture the data. Upon completion of the data capture, the images were brought into Agisoft Photoscan Professional 1.4.4 for the processing phase which consisted of the alignment of the pictures to the construction of the point cloud and the production of the mesh to the generation of the textured 3D model (Figs. 12-15). If there were any issues with the digital models that were untrue to the physical artifact, edits were done in Geomagic Wrap 2015 to ensure fidelity of the digital versions. Upon completion of the textured mesh, the artifacts were exported as an OBJ with a 4k JPG texture file for dissemination and analysis. These OBJs and texture files were uploaded to the IDEx Sketchfab for integration into the IDEx website.

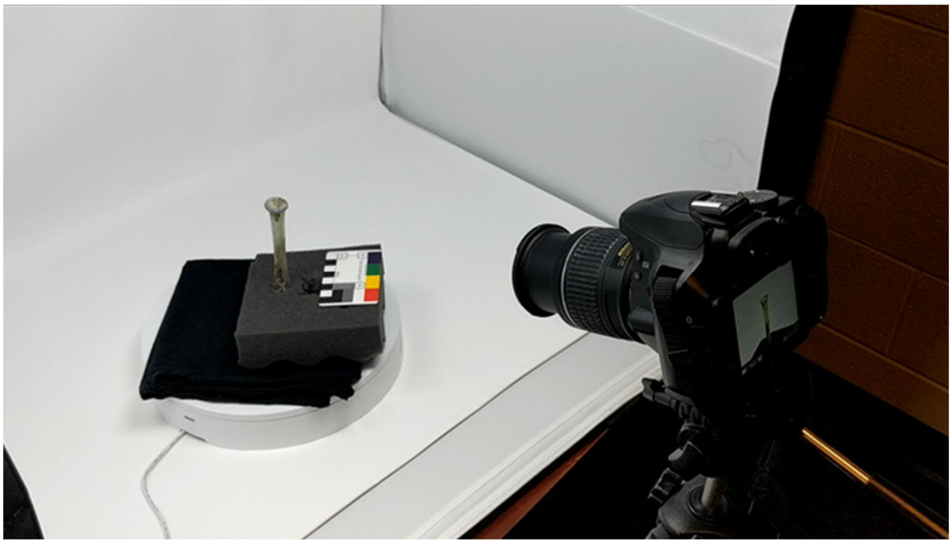

Fig. 11. Acquisition of the Karam Collection artifacts with a Nikon D3400 and the setup with the AmazonBasics lightbox and Orangemonkie Foldio 360 wireless turn table

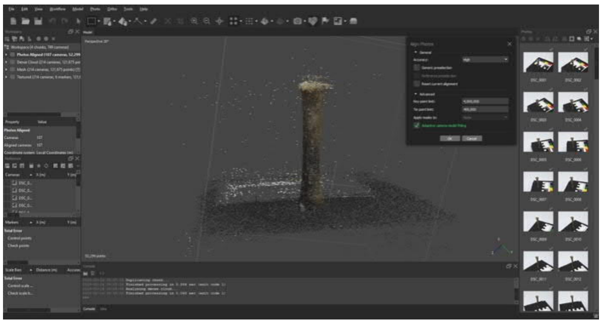

Fig. 12. Processing phase with Agisoft Photoscan, sparse cloud built on aligned photos

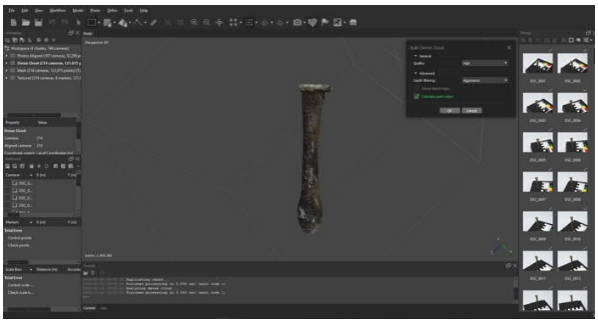

Fig. 13. Processing phase with Agisoft Photoscan, clean dense cloud

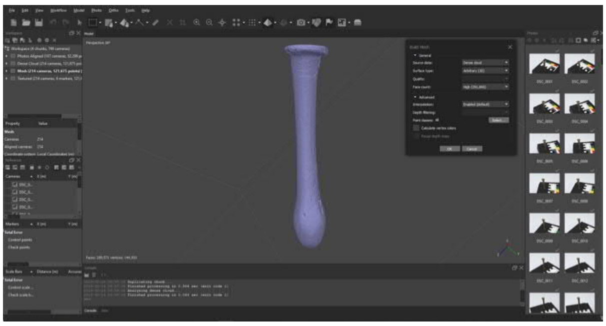

Fig. 14. Processing phase with Agisoft Photoscan, clean merged mesh

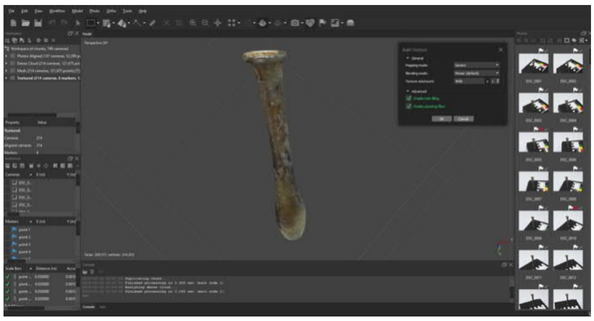

Fig. 15. Processing phase with Agisoft Photoscan, final texture

3D Printing and artistic rendering

The 3D prints were made using the Creality 3D printer CR-10 S5 with the Ultimaker Cura 3.4 and 3.5 software (Fig. 16). Objects were printed with white eSun PLA Pro. OBJs of each object were imported into the Cura program and situated in such a way that would use the least amount of support material, thus leaving fewer artifacts from the printing process. The printed objects were then cleaned and marked with their catalogue number using tape. All 149 3D models of the artifacts were 3D printed in scale 1:1. Subsequently, IDEx student interns started to paint them using acrylic colored paints in order to render artistically the original appearance using the 3D model as reference (Fig. 17), a practice which proved to be very effective both for students, who are learning about those ancient artifacts and deepened their knowledge through the direct tactile interaction with them, and to the public thanks to engaging power of the touch interaction [Means 2014; 2015; 2017]. In some cases, results of this artistic process were outstanding, with 3D prints effectively resembling the originals (Fig. 18).

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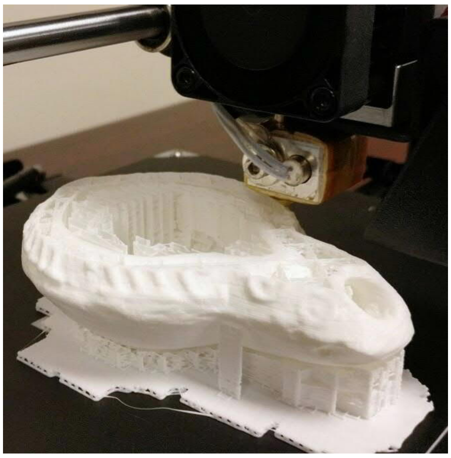

Fig. 16. 3D printing of the 3D model of a Roman lamp with a Creality CR-10 S5

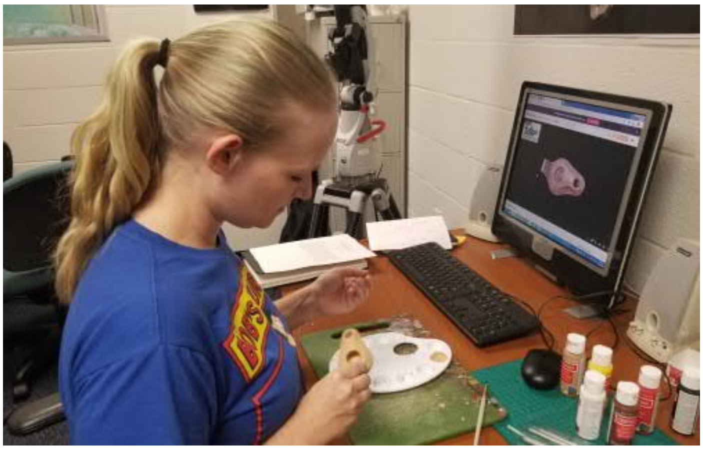

Fig. 17. An IDEx student intern painting the 3D print to render artistically the original appearance using the digital model as reference

Fig. 18. A comparison between the 3D models of three Roman lamps (left), photographs of the original lamps from the Karam Collection (center) and 3D printed and painted replicas (right)

DATA CURATION

The digitization of the artifacts and the processing of the 3D models went hand in hand with an in-depth archaeological and historical research to revise the first and very preliminary classification of the objects, to interpret their function, to define their typology and chronology. The amount of metadata generated by this exercise was systematized through a custom-built database where information was organized following the USF Libraries' metadata schema [Mi and Pollock 2018] (Fig. 19). In order to abide by the 7th Seville Principle (Scientific Transparency) of the International Guidelines for Virtual Archaeology (2013) [Lopez-Menchero Bendicho 2013] paradata were meticulously gathered during the capturing and processing phases and organized in order to be shared in accordance with the definition of paradata presented in the glossary of the London Charter: "information about human processes of understanding and interpretation of data objects. Examples of paradata include descriptions stored within a structured dataset of how evidence was used to interpret an artefact, or a comment on methodological premises within a research publication. It is closely related, but somewhat different in emphasis, to 'contextual metadata,' which tend to communicate interpretations of an artefact or collection, rather than the process through which one or more artefacts were processed or interpreted" [Denard 2013]. However, although the theme of heritage paradata has involved several authors [Apollonio and Giovanni 2015; Bentkowska-Kafel et al. 2012], who in the last decade have proposed various application of the London Charter directions to create paradata schemas, there is still no models to which the consensus of scholars have agreed upon. Therefore, the authors have decided to structure paradata in form of concise lab notes that detail the method in which the data was collected, with particular attention paid to the data capture of particularly complex artefacts in order to provide the essential information for transparently communicating the methods used and allowing individual users and researchers to reproduce or improve upon these methods

DISSEMINATION

While the USF Libraries' specialists have decided to disseminate the collection through their own online platform, Digital Collections[3], using the un-textured models, a minimal version of the metadata and no paradata – due to technical constraints imposed by the design of the platform itself – the authors have decided to embrace a different model. Without entering into the debate of the best 3D Web Viewer/Platform [Scopigno et al 2017], a compromise was disseminating the collection through a combination between the popular online repository Sketchfab and a website designed ad hoc. All the 3D models where first slightly decimated uploaded on one of IDEx's collection on Sketchfab[4] to allow the public better access to these models, regardless of the device on which they attempt to view the models and to provide the textured models to meet public expectations regarding virtualization of the Karam Collection. Subsequently, a website dedicated to the Virtual Karam Collection virtualization project, has been designed on purpose[5] (Fig. 20). The website consists of a landing page that introduces the history of the collection, the artifacts, and the digitization project, with pictures and videos highlighting the main stages of the production process. From the landing page, visitors can access another page through which they can browse the collection. Clicking any of the artifact images brings the visitor to a page detailing that artifact. A separate webpage was created for each artifact to present the technical and historical metadata and paradata alongside the 3D model hosted by Sketchfab and embedded into the webpage (Fig. 21). An agreement between IDEx and USF IT Research Computing will guarantee long term maintenance and longevity to the data beyond the experience of IDEx itself.

[3] http://digital.lib.usf.edu/karam
[4] https://sketchfab.com/cvast/collections/the-farid-karam-antiquities-collection-at-usf
[5] http://virtualkaram.com

IDEX Code	1
Title	Toggle Pin
Alternative title	R30-00001
Creator	Stephan Hassam
Contributor	NA
Acquisition date	11/15/2018
Record creation date	11/21/2018
Language	English
Country	Lebanon
Location	Tampa, FL
Cultural heritage type	Syrian Middle Bronze Age
Time period	1500-1200 B.C.
Dimensions	12.2x0.2-0.7
Materials	Copper Alloy
Description	The head of the pin has a rectangular cross section, which it maintains past the bulge around the eyelet, before tapering into a rounded section about two thirds down the shaft. The eyelet is 3 cm below the head.
Digital format	OBJ
Imaging technique	Laser Scanning, Geomagic Wrap 2015
Equipment	Romer AbsoluteArm
Paradata	Scans were captured in two positions with a stabilizing clamp to hold the artifact off the table. The first position was captured and then the artifact was rotated 180 degrees and the clap was moved. Upon scanning, the two positions were registered, cleaned, and merged in Geomagic Wrap 2015.
Subject	Copper Toggle Pin
Keywords	Karam Collection, Copper
Hashtags	#Karam
Affiliations	Department of History
Institution	University of South Florida
Holding location	USF-Tampa Library Special Collections
CHO Identifier	Farid Karam Lebanon Collections of Antiquities
Institution identifier	http://history.usf.edu/idex
Resource identifier	https://sketchfab.com/models/6fd6b89b699749b3b1e6b9996144b27c
Resource link	http://history.usf.edu/idex/page13.html

Fig. 19. Metadata schema used to curate historical and technical data for the artifacts of the Karam Collection

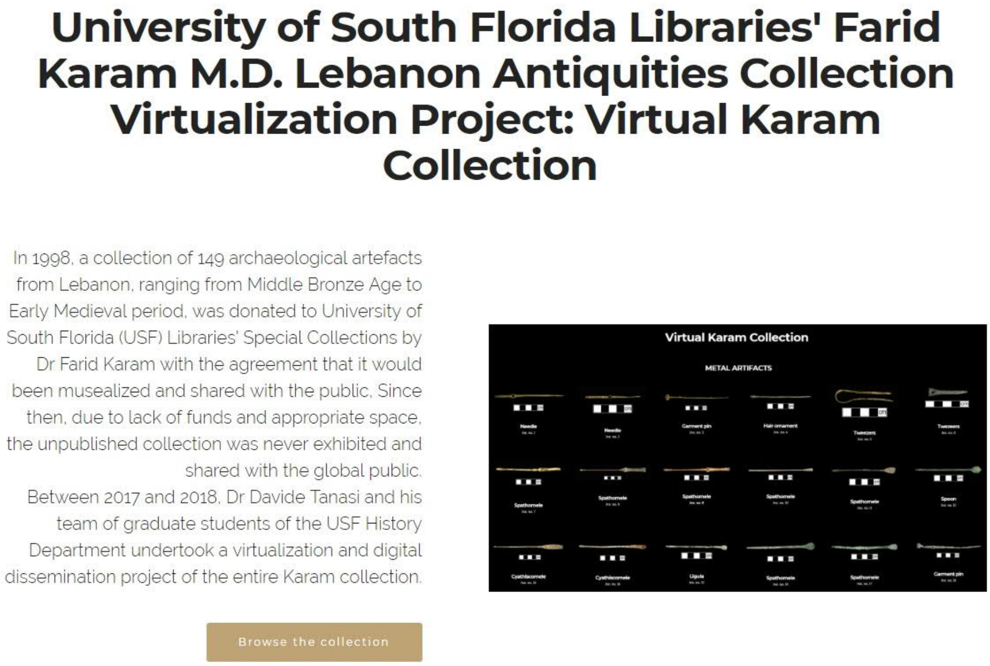

Fig. 20. Virtual Karam Collection website (http://virtualkaram.com)

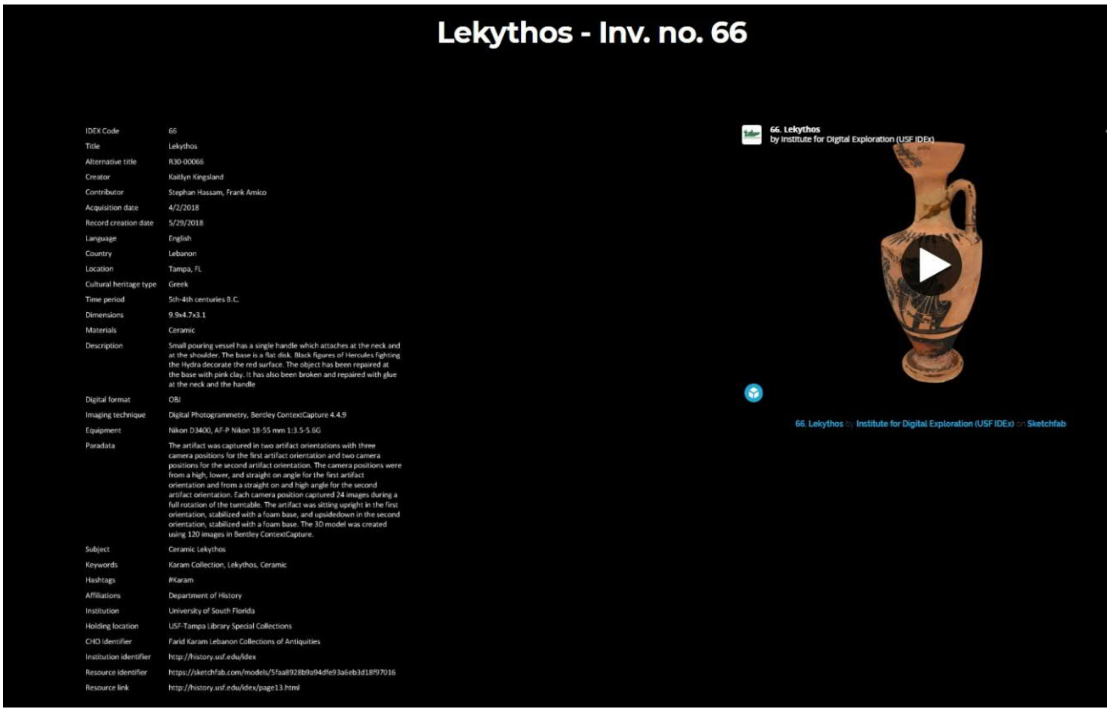

Fig. 21. An example of an object in the Virtual Karam Collection website *with its metadata and paradata displayed next to the embedded Sketchfab model*

DISCUSSION

After more than twenty years since the donation, the Virtual Karam Collection's online publication fulfills the wishes of Dr. Karam by providing a digital exhibit of his artifacts to the USF student body as well as the global community. The digital models, along with the accompanying metadata and paradata, allow researchers and the public to view the digital artifacts more holistically. The website page also sorts the artifacts by materials, allowing individuals to find artifacts of similar material to their artifact. The Virtual Karam Collection essentially serves as a virtual comparative collection for researchers, something which is usually done with images and drawings. With 3D digital artifacts, individuals can manipulate virtually the artifacts in a way in which methods such as photography and written description cannot. The collection will also remain preserved as it existed in 2017 and 2018, allowing conservators to understand how the artifacts are faring in the future. If desired, the process could be repeated in order to continually preserve track the artifacts' change over time.

The accessibility to the Karam Collection has been finally greatly improved. The collection could only be seen by scheduling an appointment with Special Collections and then, researchers, would be able to view the artifacts for only a limited amount of time. Now, individuals can remotely view and research these artifacts while providing an educational tool the community. Researchers can spend as much time as they like with the artifacts without risk to the artifacts themselves. Accessibility is greatly improved via the 3D printing as well, as those with visual impairments or cognitive disabilities are able to physically touch the printed objects. Without a 3D printed version which can easily be replaced if broke or lost, these individuals would not be able to engage with the artefacts through touch. Dolfini and Collins recently published on the utility of object replication in research on archaeological materials [2018]. While their criteria and goals were different, they noted the ability of object replication to inform and deepen research objectives, as well as its use in teaching and public engagement, which is the focus of this contribution. Experimentation involved in the replication of the 3D objects is an exercise in object research in and of itself. Students become acquainted with the variations in the color of the fabric of ceramic objects, while engaging with color differentiations in the ceramic fabric. When it comes to the metals, variations in color of the oxidized metal raises questions of preservation and chemistry that cause different color variations within the metal artefacts. Coupling the monochromatic 3D print with the textured 3D models online, students' ability to interact with the object was enhanced as they could physically touch the object, rotate it, and understand the various aspects of the artifact's 3D printed surrogate while engaging with the texture of the 3D models, which they could rotate as well. In the process of painting the objects, the students had to engage with the objects in a critical way in order to accurately reproduce the colors and shading, questioning material colors, inclusions, and methods of production which are key questions in any archaeological analysis of an assemblage or museum collection. Anecdotally, the interns, who had little to no archaeological or art historical training, began asking questions about objects through the process of handling them and artistically trying to recreate them through painting, demonstrating the great potential for the project in increasing learning outcomes and engagement with a non-expert public.

CONCLUSION

The scanning campaign consisted of a heuristic exercise in developing a workflow and methodology for capturing, processing, and disseminating 3D digital data of the complex collection. With the developed workflows, the Karam Collection was ultimately digitized using two different methods, dependent upon the differing materials, shapes, and sizes of the artifacts themselves. The collection was disseminated online via the IDEx website with the 3D models hosted on Sketchfab. In terms of the Virtual Karam Collection, exciting new outreach and research is possible upon completion of the digitization campaign. Though there is a small body of literature dedicated to the tactile interaction with objects and artifacts, further research to develop and better understand the effectiveness of 3D printed and painted artifacts in education is necessary. The Virtual Karam Collection project shows promise in generating data on museum replica usage and audience engagement with "inauthentic" objects.

With the entire collection now online as IDEx's Virtual Karam Collection, the next step is to request DOIs for each 3D model through the USF Libraries in order to structure each webpage with the 3D model, the metadata, and the paradata as a catalogue entry in a born digital catalog of an exhibition. A physical exhibition using both the 3D printed and painted object surrogates is planned for the future. These will be accompanied by access to the 3D digital surrogates on the website, provided by fixed interactive screens, so that visitors can both touch the physical object and see the digital scans. Data will then be collected on emotional and intellectual engagement with the objects in both digital and physical form both quantitatively and qualitatively through surveys and visitor observation.

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Exploracity – An Innovative Platform Offering New Services for the Enhancement of Tourism and Cultural Heritage

DAVIDE PANTILE, ETT S.p.A., Italy

The "Exploracity" project is an innovative platform offering new services for the growth and the enhancement of Tourism and Cultural Heritage. Financed by the MISE, included in the National Digital Program of Italy and created by ETT S.p.A., this innovative mobile app solution makes a visit to the city an immersive and highly evocative experience. Exploracity is a software platform, assisting the discovery of the local area through the use of innovative tools, which may be proposed as a model for other cities. The city of Genoa is the first on-site experiment.

The use of geolocation tools with virtual and augmented reality makes Exploracity fast to manage. Using this app, visitors receive the first notions and historical reconstruction of the city's cultural development. Visitors install the selected route on their mobile devices and are guided on many interactive discovery tours of real places, enriched with multimedia content together with augmented and virtual reality. All this makes a sightseeing visit an immersive and highly suggestive experience.

The Exploracity project proposes a new idea of tourist flow management, enriched with edutainment (educational entertainment).

Good visitor feedback, both Italian and foreign, encourages ETT to continue to implement cutting-edge technologies to create better engagement in the cultural heritage sector, both at the Italian and international levels. This attractive experience certainly marks a very important step in re-evaluating the role that new multimedia technologies have within the enhancement processes, improving both historical and cultural content.

Keywords:
Tourism, Cultural Heritage, Innovation, App, Virtual Reality.

CHNT Reference:
Davide Pantile. 2018. Exploracity – An Innovative Platform Offering New Services for the Enhancement of Tourism and Cultural Heritage.

INTRODUCTION

The "Exploracity" project, financed by the MISE (Ministero dello Sviluppo Economico – Minisrty of Economic Development), included in the National Digital Program of Italy and created by ETT (*Electronic Technology Team*) S.p.A., is an innovative platform offering new services for the growth and the enhancement of Tourism and Cultural Heritage. Exploracity is an innovative mobile app that transforms the visit of a city into an immersive and highly evocative experience. Exploracity is a software platform, assisting the discovery of the local area through the use of innovative tools, which may be proposed as a model for other cities. The city of Genoa is the first on-site experiment (see Fig. 1).

The use of geolocation tools, mixed with virtual and augmented reality content, makes Exploracity the perfect tool with which to plan a personal tourist route. The goal of the platform is to make a visit to the city an immersive and highly suggestive experience through the use of new technologies. It offers visitors the opportunity "to live" the old city, its forts and monumental gardens, its churches and museums etc. on many different routes. Visitors can experience the city's most unexpected and secret corners. ETT is based in Liguria, the region of which Genoa is the principal city, and was, therefore, the natural choice for this task. The historic city of Genoa is the ideal context for the development and display of new technology potential for the promotion of tourism and Cultural Heritage.

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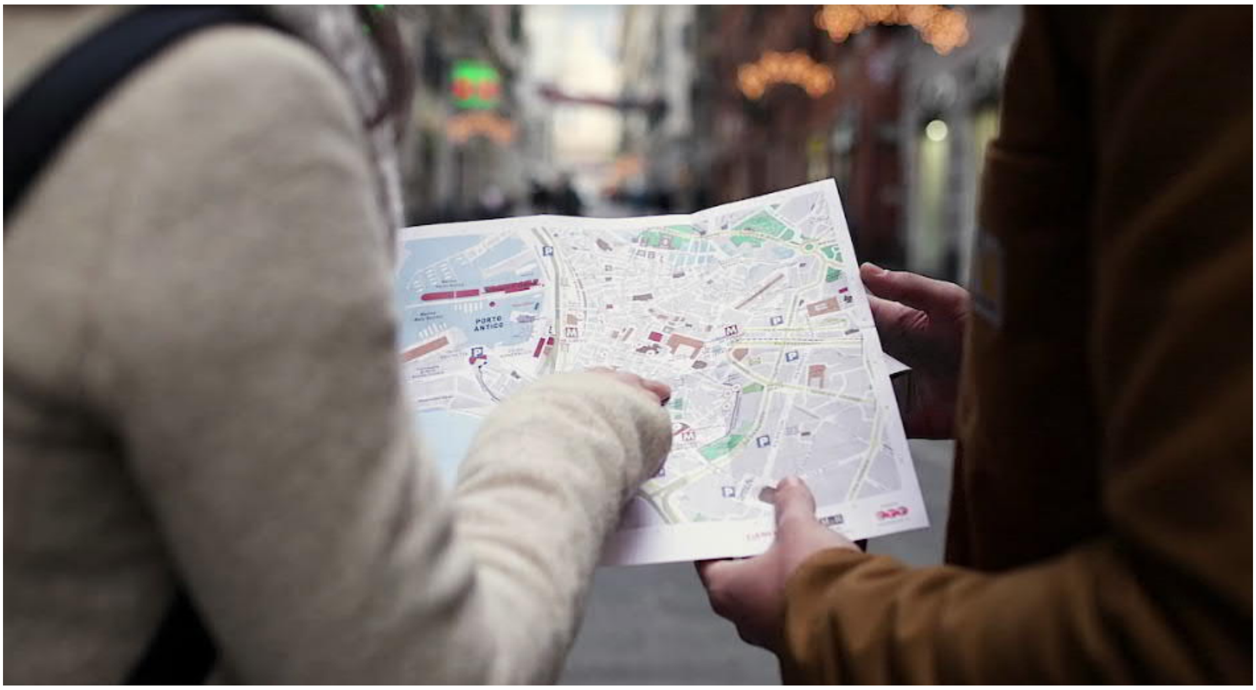

Fig. 1. Exploracity is a software platform assisting the discovery of the city of Genoa

Fig. 2. The discovery of the city through cardboard VR visors

Discovery of the city starts at the Porto Antico “Tourist Information Office” (IAT –*Informazioni Accoglienza Turistica*). Some mini virtual cultural-route experiences are offered to visitors, with touch-screen interaction and cardboard VR (Virtual Reality) viewers (see Fig. 2). Here they receive the first notions and historical reconstruction of the city’s historical and cultural development.

The Genoa fit-out consists of:

- An information touch monitor with a photo and video gallery showing the main points of interest (POIs), as well as a games section for younger tourists
- A virtual reality station, taking visitors on a virtual flight over the city of Genoa, during which POIs may be selected and virtually explored in 360-degree vision
- A second virtual reality station, with a faithful period reconstruction offering the experience of an exciting virtual walk, balanced on a high and narrow bridge within the Porta Soprana towers
- A mobile app, enriched with multimedia content in virtual and augmented reality, guiding tourists on an interactive discovery of city monuments and making a sightseeing visit an immersive and highly suggestive experience.

This is the most complete multimedia tourist app project in Italy. For the first time, access to cultural content on the tourist scene has been considerably enhanced, showing relevant content in an immersive way thanks to augmented and virtual reality. Each itinerary, with its multimedia POIs scattered around the city, supplies videos, images and historical information on buildings, gardens, churches and museums, and gives VR and AR experiences.

THE PROJECT: PRESENTATION AND TECHNOLOGIES

The "Exploracity" project was promoted by the city of Genoa and produced by ETT S.p.A. It is the most complete multimedia tourist app experience in Italy and offers an incredible, complete and immersive view of the city of Genoa.

Here are some of the mobile app’s main features:

- Usable on iOS and Android devices
- Available for free download (Google Play and App Store)
- The free version contains:
  - The first three Points of Interest on the Mediaeval Genoa route
  - A Game: *Ancient Crafts*
- Tourists can buy additional premium content at the Tourist Offices (IAT):
  - The Mediaeval Genoa route map for € 6, showing all 15 POIs
  - The Mediaeval Genoa route map and Cardboard VR for €10, showing all POIs and with six virtual reality features that may be used with Cardboard
- Content is unlocked by location markers near POIs
- All content, when unlocked and downloaded, remains available on personal devices and may be consulted at will.

The 15 Medieval Genoa route sites are located in the historic center of Genoa, although only the first three are free. Various routes include a combination of historical information, images, virtual reality and immersive technologies that, together, create a new way of interpreting a tourism experience (see Fig. 3).

Virtual reality content is available in six locations, including Palazzo San Giorgio and Sottoripa [Pessa 2016], Piazza Banchi, San Lorenzo [Di Fabio et al.1998] etc. The route commentary is available in four languages (Italian, English, French and Spanish) and content is activated via geolocalisation.

The *Ancient Crafts* game is free and can be downloaded from the Exploracity app. This section of the app is available in two languages (Italian and English) and content is activated at each location.

Tourists may use mobile devices to access general and historical information on site, as well as when triggering virtual reality and augmented reality content while using Cardboard.

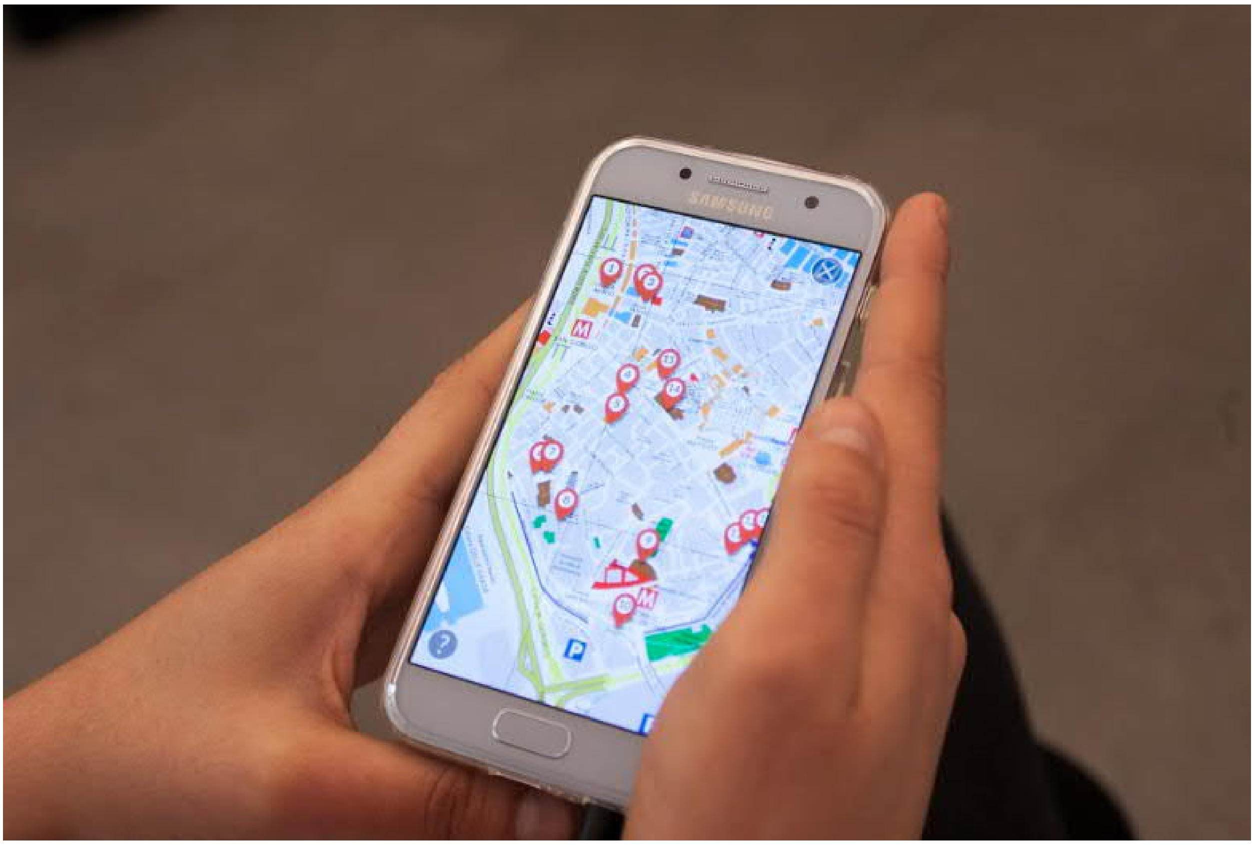

Fig. 3. The App points of interest (POIs) on the map

Information is presented at every location and, when using Cardboard, tourists can immerse themselves in 360° videos or pictures and discover two different cities at the same time: today and in times past. ETT employs a special 3D tracking solution that makes use of the most advanced computer vision algorithms. The AR (Augmented Reality) function recognizes details of buildings and tracks them in real-time. VR or AR elements appear and visitors have an increasingly magical sense of being part of the scene. While using Cardboard, users can see both the real object (a building, church, monument or square) and the superimposed virtual element (augmented reality reconstruction). While listening to explanations and seeing various original monuments, churches, streets and squares, all clearly visible in their ancient magnificence, visitors can admire each secret corner of the city.

This augmented reality technology, which fully respects historic content, is a new opportunity for upgrading tourism. ETT is working in this direction by implementing these augmented and virtual reality solutions in order to let users experience a new kind of city visit. This experience leads to in-depth knowledge of the history and importance of the most important monuments of Genoa.

With this innovative project, ETT has put into place a whole range of solutions; increasing opportunities to requalify the tourism market by offering innovative solutions while respecting the historic and cultural constraints of the location.

Every Italian city is of enormous artistic and historic value and every technological touristic solution has to work on this great value. The blending of traditional methods of enjoyment with innovative digital solutions creates a new cultural tourist experience.

In the Exploracity project, the POIs blend into the city and the planned routes were designed to allow easy interaction with information and city spaces, offering an extraordinary and immersive visitor experience. Visitors experience the emotional and immersive context in the chosen areas of interest by following a logical narrative thread. Although places may be physically separated, they are constantly united through the storytelling technique.

This experience, and these solutions, mixed with virtual reality, gives participants a new kind of visit experience, leading to in-depth knowledge of history and the life of Genova and its people.

The multimedia content is designed to encourage the discovery and the direction of tourist flows around the city, thus avoiding the risk of crowding and the subsequent reduction of quality and enjoyment of the visit.

The entire project is modular and completely adaptable, making it suitable for frequent changes in tourism patterns and technology. At the same time, Exploracity offers many different routes engaging varying tourist targets: from the discovery of castles [Stagno 2005] and monumental Ligurian gardens [Cappellini 1929; Mazzino 2006] to secret routes taking in churches and little squares around the city. Every route can be chosen according to whatever appeals to the visitor.

Since multimedia support must always be able to harmonise and adapt to accurate target analysis, new potential audience types are profiled so that content may be created in line with user expectations.

The project:

- Combines technology and creativity to surprise the visitor
- Stimulates new connections, physical and/or digital, between ancient cultural content and the urban space in which it is located today
- Transforms the historic city centre into a place that goes beyond conservation, making it a lively and attractive hub for cultural tourism
- Helps new forms of visit personalisation, adjusting to the needs of each visitor
- Creates new ways of interacting between visitors and the city, with particular regard to the pre and post-visit phases
- Starts a dialogue between city and visitors
- Involves new generations through the use of familiar technologies and methods

CONCEPT, CONTENT, AND THEORETICAL BACKGROUND

The tourism industry is currently in need of technology-based value-added integrated services, highly dynamic and offering interactivity and entertainment. Augmented and virtual realities have thus far proved to be technologies that can provide tourists and the local population with much more personalized content, as well as services tailored to their particular needs. Specifically, these tourist guides can display content-on-request as tourists travel around the city, exploring the cityscape and sites. It would be fair to say that mobile applications allow users to explore the world by adding new layers to their reality, and this makes for a new highly-dynamic interactive experience. Moreover, as these applications are, on most (if not all) occasions, accessed from mobile devices with GPS, tourists can gain additional benefits and navigate interactively, with the help of indications from the selected locations [Kounavis et al. 2012].

Besides this, AR-VR application information is delivered through the use of various multimedia formats. Such formats range from sound and image to video clips, 3D models and hyperlinks that may direct the user outside the application. This combination of AR-VR technology, the availability of various multimedia content and the careful design of the application can, all together, permit tourists to create favourite POI lists; complete with embedded multimedia files. Then, while geolocation and AR tags trigger the delivery of multimedia content, the content itself could be designed to provide further connectivity between the AR application and other sources, offering additional benefits to tourists. This suggests that mobile AR-VR applications can offer further added value to tourists by introducing the concept of connectivity and the sharing of experiences.

It is important to explore emotions, as they are central to our lives and decision-making processes. The emotion of nostalgia is common among visitors of all ages to a cultural heritage destination [Baloglu et al. 1997].

These considerations are the foundation of the Exploracity project, where the experience content and multimedia narration are elaborated at the emotional level. Emotional and balanced storytelling can help users experience the splendor of ancient Genoa, fixing it in their memory and winning their hearts.

The goal for the producers of Exploracity was to find the right way of giving new life to city cultural content, to refresh its image in the collective consciousness and to communicate its importance, so that familiarity with it would stimulate deeper knowledge. The whole tourist route proposal concentrates on experiential and emotional visitor involvement. Using this pioneering mix of technologies and new models for accessibility and visitor flow management, the visitor experience becomes a great opportunity for vivid involvement. By proposing a technically accurate and active personal experience, visitors are offered a new visit approach that narrates, in the best possible way, each historic and informative element with emotional involvement [Choi et al. 2007].

Milgram's study shows how the mixed reality experience is characterized by a combination of real and virtual environments where, if the real world occupies the left of the continuum, the virtual world is at the other end. Exploracity, with its new technology, overlaps augmented elements in the real world (augmented reality) or directly substitutes the real world with virtual vision (virtual reality) in a continuum [Milgram et al. 1994] (see Fig. 4).

Fig. 4. Mixed Reality (MR) Continuum

Apps for tourist tours are steadily becoming more and more common and VR options have the power to transport users to places they might never be able to visit in real life. The challenge is to combine these two options: offer a new on-site vision of reality.

This idea of a new tourism offer is the basis of the Exploracity project, proposing an immersive offer in which the tourist-observer has a new option when discovering the space around him, by creating a mixed experience environment. Real-world and virtual world objects are presented together, in the same new tourist experience [Echtner et al. 1991].

ETT has expanded the conventionally held view of the "tourist tour" by proposing the new "emotive tour" with specific "mixed experience" solutions and with different classes of hybrid content. The 3D tracking system on this project uses the most advanced computer graphics. For example, the entire AR system recognizes three-dimensional spaces around the POI view of the city and carries out real-time tracking. This recognition system elaborates a reconstruction and overlays it on the real view, giving users the illusion of being in the past and increasing the effectiveness of this immersive experience. This technology lets users see the city and its monuments as they originally were, offering the most incredible tourism experience.

The project proposes a catalogue of continually developing experiences that present a new model of Genoa’s cultural features. New technologies enable virtual and augmented reality visits, with route planning and outdoor/indoor geolocation. The historic life of the city is also narrated.

Using this innovative mix of technology and new models for accessibility and visitor flow management, the visitor experience turns into a great opportunity for vivid involvement [Gunn 1988]. Thanks to the app, visitors are able to see ancient lost architectures, hear the sound and voices from the past, living an immersive experience through History.

The Exploracity app provides information on demand, thus minimizing the effect of information overload on the one hand and the negative effect of irrelevant information on the other. Information overload can occur when tourists are overwhelmed by the information transmitted regarding historical sites, museum exhibits, navigation data and so on. Apps of this type can significantly help by transmitting the city's most important facts.

CONCLUSION

The Exploracity project offers an “edutainment” (educational entertainment) experience. Good visitor feedback, both Italian and foreign, encourages ETT to continue to implement cutting-edge technologies to create better engagement in the cultural heritage sector, both at the Italian and international levels. This attractive experience certainly marks a very important step in re-evaluating the role that new multimedia technologies have within the enhancement processes, improving both historical and cultural content.

Based on what has been achieved so far, all the virtual and augmented reality fit-outs developed in the cultural field can certainly offer rewarding aesthetic and learning experiences, otherwise difficult to obtain, but this is not enough [Goulding 1999].

The starting point for the conception and development of such projects is the awareness that the past and the present can both be conveyed simultaneously, through new media, whilst contributing to research into the cultural heritage which our country (and others) can benefit from. It is about enhancing the audience experience, thus guaranteeing both the protection and conservation of art as well as providing an engaging interpretation [Dunkley et al. 2011].

Results are user appreciation and a significant visitor number growth.

Very considerable is how the Exploracity model was used to develop some others apps: its infrastructure made possible to improve the company ability to acquire new clients such as:

- Gorizia Castle Visit App: a mobile app that supports the visitor, structure in 16 POIs with content delivered on 6 different paths intended for different targets. The app consists in AR and gaming content.

- Palazzo Besta Videoguide App: a mobile app for the visit of Palazzo Besta in Teglio, a Renaissance Palazzo hosting an important series of frescos. Visitors can use this app bringing their own device and downloading the app for Apple App Store and Google Play Store. It provides 360° VR content and uses a wayfinding mechanics through Low Energy Beacons.

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