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An Integrated VR/MR Framework for User-Centric Interactive Experience of Cultural Heritage: the ArkaeVision project.

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An Integrated VR/AR Framework for User-Centric Interactive Experience of Cultural Heritage: the ArkaeVision project.

Abstract:

The ArkaeVision project is aimed at enabling a new way of enjoying Cultural Heritage through a more engaging and culturally-qualified user experience. The main goal is the creation of a technological infrastructure for the permanent enhancement of cultural resources. Hence, ArkaeVision represents a user-centric integrated system able to offer different modalities of exploitation of Cultural Heritage assets, including virtual representations of monuments, works of art and objects, as well as the stories associated to them. ArkaeVision therefore introduces a new communication paradigm, made of game-alike exploration of a 3D environment, virtually reconstructed, with elements digital fiction and an engaging storytelling, applied to two case studies: the exploration of the Hera II Temple of Paestum with Virtual Reality (VR) technology, and the exploration of the slab of the Swimmer Tomb with Augmented Reality (AR). The emotional component is fundamental in ArkaeVision, because it generates the motivation and leads people to use immersive viewers, as the HTC Vive, which allow the learning process to be activated more quickly [Goleman D., 1995]. Also the involvement of users through gamification is well expressed in ArkaeVision. This model of action (and interaction) designed for the public allow to emphasize the role of users through a system that is "guided" by their choices and times, to increase users' engagement within the virtual exploration, and to favour the content understanding by direct experience. Evaluations conducted on a preliminary prototype suggested that the communicative approach is very promising for education and engagement into cultural heritage experiences.

Keywords: virtual reality, augmented reality, gamification, digital storytelling, user experience design

1. Introduction

Recent technological developments in the Virtual and Augmented Reality and the consequent possibility of introducing new interaction paradigms for experiencing Cultural Heritage, have led to the concept of *interactive thematic virtual environments* (ITVE). In such environments it is possible to physically immerse a "visitor" into an alternative world, in order to interactively live the "stories" associated with an artefact or an artwork, producing a customised event of cultural entertainment. From a certain point of view the work of a painter or a sculptor is already in itself similar to something virtual, being the representation of something that has existed in the past, or that still exists, but which is no longer visible or it is visible in a different form from that of the artist's point of view. In this sense, virtualising a work of art brings it back to its original conditions: we contemplate, perceive and experience the work where it was born, in its place and in its time, it is the visitor that goes from work and not vice versa.

The ArkaeVision project, aims at extending the experience of Cultural Heritage through different levels of semantic and perceptive augmentation of monuments, works of art and ancient artefacts. The project proposes a platform able to integrate cultural information, including real-time information, into an ITVE, allowing users to access the stored information from a database while recalling other real-time information from an external source, produced by the *gamification* activated and running under the platform. This to unveil the stories associated with the cultural elements presented in such ITVE, and to contextualise them in the period of their realisation. Thus, the contextualisation process is crucial in the project: the design of the ArkaeVision experience is focused at facilitating those steps in the learning process that are usually complex to activate when one observes something that belongs to the Past. Specifically, we talk about abstraction: that moment in which the user faces a fragmentary, decontextualised historical-archaeological find and must reconstruct in his mind what this form refers to, what was the its original appearance, what it was used for, etc.

With the use of multimedia and virtual technologies this step is clearly supported. Even more if the archaeological find is represented in its original context, as in ArkaeVision, inserted in a lively life scenario, with warm colours and described at the time of its use. Everything becomes clearer, more concrete, more alive or, better, "credible" or "acceptable" to the human mind. Thus "real" in the Virtual. Multimedia can symbolically help recreating the "sphere" of life of cultural objects, increasing awareness and understanding of history. The latter will no longer be so distant, foreign, but will become part of our present with its voices and colours. This is the role of narration and evocation for the ArkaeVision project: objects and places of Culture become "opportunities" to create a dramaturgy around the object, naturally based on correct historical and artistic contents verified by the experts.

ArkaeVision therefore introduces a new communication paradigm, realised through the generation of various levels of historical and archaeological information, according to two experiential modalities which use the immersive

Virtual Reality (VR) and the Augmented Reality (AR). More in detail, ArkaeVision allows users to live inclusive and customisable experiences. The inclusiveness consists in various levels of sensorial experience's integrations, as it may happen during the observation of an artwork (real or virtualised), by means of contextualised information, audio, tactile feedback, digital actors and so on. The customisation, instead, rely upon the possibility for users to select and follow their own storyline or pathway inside the virtual exploration, as it may happen with the visit to an ancient greek temple, walking around in the central corridor or sneaking around the columns.

The strategy of user involvement and stimulation upon which ArkaeVision is set, rely upon a user-centric interactive approach, taking also advantage from "gamification" and "rewarding" techniques. The proposed solution, typically used in *serious-game applications*, involves the users in a progressive discovery, where the experience takes place following a reward mechanism linked to users actions and interaction within the environment and with the characters.

The interaction is achieved through the combination of an advanced interface and a real-time engine. The interface allows an intuitive interaction, replacing the traditional IT systems of pointing and selection with a gesture-based recognition and a cybernetic glove, suitable to operate in cyberspace, as in VR. The integrated real-time engine allows interaction between the visitor and the virtual environment through the interface. In order to make the response of the adaptive system not only to the way in which the user interacts with it, but also to its cultural and age characteristics, access to the augmented contents, as well as their nature, is mediated by a capacity user profiling implemented in the system, which allows to calibrate the provision of the experience according to a previously acquired user profile. Moreover, the proposed system supports an innovative multi-user modality, enabling multiple users to share the immersive VR experience, by recording the key aspects of the experience made by a given user and allow sharing it with other users.

In ArkaeVision, the storyline and the interaction methods follow exactly this type of learning: the audio, composed of an evocative soundscape and the voice of one of the virtual characters, accompanies the user along the experiential path, helping him in his choices and understanding cultural content; the highly photorealistic and romantic taste 3D visualisation, enjoyed thanks to the immersive viewer, is the background to the events and allows the recognition of places and actions; the motility required during virtual exploration, through the joystick, allows the user to learn while performing gestures or perform tasks, according to the doctrine of learn-by-doing (also called *experiential learning*)

2. Related works

Cultural contexts, and particularly museums and archaeological sites, during the last years tended to overcome the traditional hierarchy on exposition space, contents and visitors, fostering new, more involving immersive and multi-sensorial approaches, to allow a direct way to the knowledge through a ludic and spectacular dimension. As museums cannot expose all their collections and pieces at the same time, due to space and resources, VR applications may broaden in time and space the physical museum dimension. AR allows indeed users to look at real spaces - through mobile devices - thanks to infinite possible information layers [Schavemaker M., 2011]. Thus, the visitors' experience is empowered, allowing users to respect their own times and ways to approach the cultural good - no forced by guides or predefined visit path . The whole museum environment may become an interactive place, reducing paper-based information in favour of a more personal, intimate and customisable exploration, to be recalled whenever users decide to.

The ArkaeVision experience has been designed starting from three analytic levels:

1. Identification of the main potential application domains - Cultural Heritage and Tourism;
2. Identification of different ways and typologies of platforms - AR and VR [COM(2009) 512].;
3. Identification of different kind of users and their needs, according to the experience.

The application domain of ArkaeVision stands between Cultural Heritage sites and monuments, and touristic attractions. In Italy these fields are often overlapped one to another. A particular relevance has been reached in the last years by digital applications in such fields. This is due to different reasons: AR, in particular, seems to have a strong potential in boosting cultural tourism as the generic idea of a technology offering partial contents whose complete exploitation implies to reach specific locations, is a powerful incentive to visit a place. Generally speaking, the relationship between Cultural Heritage and Tourism has ever been a specific link of proportionality between the increase on the incoming visitors and the museum public, at least in Italy in the last decades [Palombini A., 2015]. In such a situation it seems reasonable to consider Cultural Heritage and Tourism as two terms of an integrated system in which any action to boost one of the elements, sets a proportional effect on the other: increasing the general number of tourists makes the museum public grow, as boosting the efficacy of CH (also through digital devices) increases the number of incoming travellers, both at national and local level.

The use of the Virtual in such scenario become more and more constant and crucial because of some intrinsic characteristics of the tourist product: it is indeed composed of a set of different services that range from transport, accommodation, food, leisure, culture and entertainment. So it is a "multi-layered" product where the exchange of information is extremely important at every stage of cultural heritage and touristic experience. For such a reason, allowing people to benefit from a virtual tool or service that allow them to quickly access reliable and accurate information, to feel even more reassured, it provides a higher tourist satisfaction [Neuhofer B., 2014; Ferreira F. et al., 2014; Salerno A., 2017].

With the term Virtual Reality (VR) we mean a synthetically generated reality within which the visual, acoustic and possibly even tactile *stimuli*, generated electronically, become preponderant until deceiving the senses, convincing the user to be "immersed" in a world, completely rebuilt on the computer. At first, VR is conceived as to replicate the reality as carefully as possible, in order to act in the virtual space overcoming physical economic, safety limits. It represents an involving and alternative reality which may result in a knowledge improvement. This, it is an ideal tool for teaching and communication activities [Hew K.F., Cheung W.S., 2010; Merchant Z. et al., 2014]. The use of VR for CH implies various strategies, allowing the enhancement of partially preserved items, as well as reconstruction (partial or complete) of whatever is no more visible in its original historical context. It is possible as well to allow visitors virtual walks in contexts very far (in space and time).

Similarly, the Augmented Reality (AR) is based on the possibility of adding further information and dimensions to the reality that surrounds us, allowing the display of virtual data overlapping a real object simply by framing it. For AR as well, many kinds of CH applications are available, such as visualisation of graphs and text close to the material objects, the superimposition of digital restoration, the virtual presence of characters in real contexts, and so on.

Technological-mediated fruition can therefore assume a complementary role in the direct experience of cultural good, and does not replace the direct one. Access to Cultural Heritage through the Virtual should always maintain an integrative, introductory, introductory character. However, we can not forget that the indirect experience of Cultural Heritage, in many cases, is the only solution to the impossibility of a direct experience, for reasons of restoration, lack of exhibition space, uniqueness of cultural heritage, unavailability to fruition because of loan, distance from the context of discovery, closure of the museum structure and so on. One example can be the Pompeii chalk moulds, which have always been requested for exhibitions all over the world and thus have been worn and damaged: they have been recently substituted with 3D printed copies (https://all3dp.com). Another example pertains the fruition, through virtual reproduction, of underwater archaeological contexts or deep and hardly reachable caves, like in the iMareCulture project [Philbin-Briscoe O. et al., 2017; Bruno F. et al.; 2017].

Technologically-mediated fruition can also strengthen the experience of the assets and places of national heritage, through the creation of virtual itineraries, interactive guides, animated reconstructions of scenes of life in the past or relating to a place or to a monument no longer existing or far in space. All this offers the opportunity for the public to have various levels of culture reading: the Virtual is not a substitute of the way of how was normally pursued cultural knowledge until now - through written texts, images, oral tales and experience in the field - but it is an addition, a further mean of knowledge, complementary to others, an augmentation of the educational potential inherent in communication products. Specific examples in this sense are applications like "The Revealing Flashlight" [Ridel B. et al., 2014], presented at the Imperial Fora Museum of Rome, in 2014, and the Santa Maria Antiqua's multimedia application of Rome, open-end to the public in 2016 (https://www.katatexilux.com).

Starting from these needs, ArkaeVision addresses its activities towards multidisciplinary, experimental and inclusive field of work: multidisciplinary, in order to guarantee the treatment of historical-cultural themes from different points of view and through different faces and voices; experimental, both in technologies and in communication techniques (and storytelling), in order to produce engaging, coherent and sustainable solutions from an economic point of view and cut to the final target; inclusive, both in terms of active public participation at the time of use, and in terms of interaction and usability of the proposed technology.

Moreover, ArkaeVision takes advantage of user profiling to design an effective and fruitful the experience of visitors. With user profiling we mean the study and analysis of the specific user that will visit and enjoy the cultural site and the technology usable in it. Such study is not only preparatory to the development and preparation of the space that will be accessible to the public, but it is also carried out after the final setup, in order to verify, confirm or refute the design assumptions. The contribution that the user profiling can give to ArkaeVision is therefore the personalisation or, better, customisation. Digital technologies, in this sense, help to dress cultural content more and more on the individual attitude, on personal interests and needs. However, profiling is not only aimed at segmenting users, but also at establishing connections, common experiential paths and social networks that are not always evident but sure existing between groups of people when visit a cultural venue. Several examples can be counted in this respect: for the "Keys to Rome" exhibition a preliminary study on users visiting the hosting museum helped researchers to better address the interactive modalities of the virtual installations that would have been placed [Pagano A. et al., 2015]. Such study has been compared with user experience data collected after the visitors fruition, providing researchers more insights on the design experience, the efficacy of the application and its usability [Graf H. et al. 2015; Fanini B. et al. 2015; Pagano A.,

Cerato I., 2015]. The "Etruscanning 3D" natural interaction application followed the same workflow [Pietroni E., Rufa C., 2012; Pietroni E. et al., 2012; Pagano A., Pietroni E., Rufa C., 2013]. The EU project "CEMEC" took advantages of preliminary user profiling for the design and development of the holographic installations for the partner museums [Pietroni E. et al, 2017; Pagano A. et al., 2018; Pietroni E. et al., 2019]; in this case, evaluations on different user targets, made venue after venue, helped researchers to enhance the installations, both on a content perspective and usability.

2.1 The state-of-the-art: Virtual Reality in museum applications

Museums are strong public attractors, thanks to their masterpieces and exhibitions, but they are not scalable. Whereas, the Digital and the Virtual domains are highly scalable, and the cost for shaping and presenting new content to visitors is actually zero. In VR we never lack about space, and combining real objects with their digital replica, it is possible to allow millions of people, physically placed everywhere, to feel themselves into an "alternative museum", which grant a dynamic and customisable cultural and entertaining experience.

Moreover, as the storytelling of museum objects is the main goal of an exposition, VR helps very much such an activity, making very simple the superimposition of an infinite number of thematic layers, featuring history, arts, culture through simulations, reconstructions, and object restoration. VR also allows to access sites and monuments which are hard to physically be reached because of their maintenance, logistics or safety. Finally, VR may support a valid restoration activity, allowing virtual *anastylosis* without object alteration [Ferdani D. et al., 2016].

Many institutions, in the last years, developed and provided users with some interesting VR installations:

- *The Museum of Pure Form (Pisa, Italy, 2001):* a VR system is usable by visitors in order to interact with digital models of some sculptures through touching senses [Bergamasco M. et al. 2001];
- *Museo virtuale della Certosa di Bologna (Bologna, Italy, 2001):* it is focussed on the two World Wars and the last century's history of the city, while enhancing the monuments to the War dead [Felicori M., 2008];
- *Virtual Moregine (Pompeii, Italy, 2005):* a particular focus in the VR application has been addressed to highly realistic avatars, thanks to advanced shading techniques for the skin and particle-based hair simulations [Abate A., Nappi M., Ricciardi S., 2004; 2005];
- *Museo virtuale della Vita Quotidiana (Virtual Museum of everyday life: Bologna, Italy, 2001):* the MuVi Project attempts to a careful reconstruction of common people life and environment in the last two centuries through immersive VR solution [Bonfigli M.E. et al. 2004; Liguori M., 2008];
- *Museo Virtuale della Via Flaminia Antica (Rome, Italy, 2007)*: the VR system is used allowing four people at the same time to move simultaneously and independently in the Livia's Villa, in its current archaeological conditions and in the original ones [Forte M., 2006; 2007];
- *Franklin Institute (Philadelphia, U.S.A., 2015)* developed a system ables to enhance the museum experience using both Oculus Rift and HTC Vive [https://www.fi.edu/virtual-reality];
- *L'Ara com'era (Ara Pacis Museum, Rome, 2016):* A multimedial tale in which history and technology come together to create a fully immersive and multi-sensorial experience of the Ara Pacis. People, gestures, divinities and animals are turned into 3D animations that, with the addition of color, tell the story of the origins of Rome and the Emperor Augustus' family with AR technology (http://www.arapacis.it);
- *Domus Aurea VR (Archaeological Park of the Colosseum, Rome, 2017)*: inside some of the spaces of the Domus Aurea in Rome, an immersive VR application like a video-story allow to present in a new way the palace of Nero. A high-tech Oculus visor pushes visitors into an immersive and unprecedented experience of the reconstructed rooms of the Domus, with the virtually "restored" light inside the monument (www.colosseo.beniculturali.it);
- *A night in the Forum (EU project, 2019)*: a video-game for Sony Playstation VR, realised within REVEAL European project. An Educational Environmental Narrative Game that uses real resources and written dialogues, validated by archaeologists, to create an experience, based on the narrative that is engaging and can communicate the complexity of the history of the Roman Empire under Augustus, telling the daily life at the time of the Roman Empire (https://revealvr.eu/).

- *Santa Maria Antiqua multimedia application (Rome, 2016)*: a series of multimedia workstations is dedicated to the frescoes of the Basilica, including video-mapping on highly effective architectural structures, aimed at simplifying the understanding of wall paintings. The project aims to guide the visitor in reading the history of the building and its paintings in an emotional and scientifically reliable way. Through the video mapping, the missing parts of the frescoes of the two chapels on the sides of the presbytery were returned in an immersive manner (https://www.katatexilux.com).

As shown the list above, Cultural Heritage applications are based on different technologies ranging from Head Mounted Display (HMD) to the monitor (smartphone or desktop) as well as projections. Examples show different way of presenting cultural content with the common purpose of obtaining an always greater integration between real and

virtual. These case studies presented useful tools for a better understanding of the cultural heritage and, for this reason, users are pushed to try the technology, at least in an initial phase of the experience, moved by curiosity or by emulation; in some cases, the innovativeness offered by the Virtual in the presentation of the cultural good pushes the users to persist in using the applications and, above all, they support friends and relatives in this activity. Also storytelling is a key element of such applications: it is of great appreciation by users because it allows them to be the protagonist at the center of a story. Of course also the efficiency of VR devices in the visualisation of cultural contents is a motivation to use them; these aspects also encourage the less literate to take advantage of such tools - as they make the technology ready for use and responsive. Finally, the multi-dimensionality and scalability of VR applications are also highlighted by some users, especially experts in the field.

The balance between immersion in the Virtual and awareness and perception of the Real is the key to produce devices capable of overcoming the current physical and digital barriers of the current technology at disposal. The main objectives of the latest experimentations in the Cultural Heritage field are two: (a) to extend the range of supported input devices, such as voice and gestures, to allow users a truly concrete and effective experience of the Past; (b) create a solid technical foundation for the development of new interactive experiences, allowing content creators to integrate real-world media with contextual 3D overlays. Beyond these theorised directions of development, it is foreseeable that where the potentialities of tracking and calculation would be significantly greater than the current ones, a probable development will certainly be in the direction of simulating the human presence of more individuals/avatars, so that each of them can see the other or their perceived space. At the same time, we can also imagine forms of applications that are able to produce (via scanner or photogrammetry) real-time models of the surrounding space which, like frames of a video, follow each other in perception.

2.2 The state-of-the-art: Augmented Reality in museum applications

AR technology started to be presented in museums since mid 2000s, and changed the museum visit giving the chance of interaction, contextualisation and sharing the experience with others. The Trendwatch Report [American Alliance of Museums, 2015], reports that the most of museums uses only new generation mobile devices to involve customise, and "democratise" cultural experience. Some of the reasons for using AR based applications are:

- Helping people in visiting the museum and making easy the museum visit path thanks to adjacent and superimposable information;
- Integrating existing information, multimedia materials and real objects, making faster the acquisition and elaboration of knowledge, directly on the site of fruition;
- Giving access to materials which are not visible because of logistics, maintenance or safety;
- Reconstructing with the help virtuality and digital, in general, cultural objects which has been damaged, partially or completely, by time;
- Giving opportunity to present more emotional and involving insights about the story of cultural objects, allowing visitors to see "beyond" the materiality, breaking a long term tradition of museum "subjective" experience.

Some examples of AR applications in museums are:

- *Archeoguide (Olympia, Greece, 2001):* it allowed visitors to walk along the ancient city looking at its original buildings beside archaeological remains [Vlahakis V. et al., 2001];
- *Marq (Mobile Augmented Reality Quest, Alicante, Spain, 2005):* it targeted mainly on 12-16 year old people and it connected a game to an educational application on museum contents [http://www.marqalicante.com];
- *Carnuntum App (Austria, 2011)*: it is an AR mobile for the enhancement of the archaeological park of Carnuntum (Austria). The AR app acts as a support for guided tours in the park, providing visitors with information that is directly updated on the site. The AR solution intends to provide users a journey through time (1700 years ago) to relive the Roman military camp of Carnuntum, a walk-through in the 3D reconstruction of the city directly on the site, and create a new interactive experience, even for the little ones.
- *Jumigies App (France, 2012)*: it allows you to explore the Abbey of Jumièges on the site or at a distance and by AR metaphor, as it was before its partial destruction. Five different eras have been reconstructed, from the 9th to the 18th century.
- *Museum of Celtic Heritage (Hallein, Austria, 2016)*: the visitor can use the app as an interactive guide in the museum. The avatar of a Celtic warrior appears in the windows after scanning a target positioned near the artifacts. The avatar tells about the way of life, the personal stories and details about the artifacts. The added value of the narrative is the fact that the story is told from a personal, emotional point of view.
- *Lumin (Detroit, U.S.A., 2017):* it is based on the Google technology for Simultaneous Location and Mapping (SLAM - Project Tango); it allows to explore some museum contents, such as a mummy X-ray analysis or the restored Ishtar mosaic [https://www.dia.org/lumin];
- *Maua (Museum of Augmented Urban Art, Milan, Italy, 2017):* it is an open-space gallery, in the city of Milan, consisting in over 50 urban artworks, visible together with virtual contents [www.mauamuseum.com];

- *KeyARt* (*Europe, 2018*): it is the free app that uses AR and image recognition and gives the opportunity to visit a museum, gallery or exhibition. KeyARt is already available for the most visited museums in the world such as the Louvre, the Metropolitan, the Art Institute of Chicago, the Getty Center, the Vatican Museums, the Guggenheim, the LACMA, the Peggy Guggenheim collection of Venice, the Tate Modern and the National Gallery [https://www.keyartapp.com/];
- *The Speaking Celt (Museum of Celtic Heritage, Salzburg, 2018)*: with the use of AR, an animated avatar guides visitors through the museum and tells stories related to objects. This creates a very personal, interactive experience in which the person can recognise himself [https://heritageinmotion.eu];
- *Terracotta Warriors AR (The Franklin Institute, Philadelphia, U.S.A., 2018):* visitors can take advantage of the institution's application to see the mystery of the Terracotta Army in augmented reality in order to better understand it. The enhanced performance in AR includes the representation of how the sculptures, weapons and artefacts appeared more than 2000 years ago [https://www.wikitude.com].

There are many examples of AR in the field of Cultural Heritage. As the list above showed, in some cases these are pioneering and research applications, as in the case of *Olimpia*, but already quite complete at the concept level; in other cases, they are products developed mainly for tourism and commercial purposes. The AR has been applied in multi-scale, from small contexts such as objects and museum display cases (*Museum of Celtic Heritage, Marq, Speaking Celts* and *Maua*) to architectural contexts (*Jumièges, Lumin, KeyARt, Terracotta Warriors AR*) and territorial (*Olimpia, Carnuntum*). The type of 3D models involved, as well as the frameworks used, are closely linked to the technology available at the time of creating the AR product. The strengths of the various use cases in the visualisation field are the high-quality of rendering and real-time view, the fidelity with concrete structures and artefacts as well as the reliability of the reconstructed historical context. An interesting aspect of usability is the fact that they are considered as simple and immediate to use. This aspect support the communicative efficacy and intuitiveness inherent in the metaphor of AR, especially when applied to mobile devices such as tablets.

3. ArkaeVision project: contents and functions

ArkaeVision is a platform able to enrich, support and increase the experience done by the visitors using a solution based on new multi-layered and narrative modalities. The full platform includes three subsystems:

1. A Web portal
2. An application in Virtual Reality (*ArkaeVision Archeo*)
3. An application in Augmented Reality (*ArkaeVision Art)*

ArkaeVision is deployed starting from two contexts of references, applying two different technologies. The two demonstrators are:

- *ArkaeVision Archeo*, an experience made with a dedicated HMD related to the Temple of Hera II of Paestum as main subject; it uses the VR, where the actual scenario overlaps and integrates itself with the 3D reconstruction of the archaeological site;
- *ArkaeVision Art*, an experience in Augmented Reality (AR) made by using a mobile or a tablet, related to the Tomb of the diver of Paestum as main subject; the AR is used to animate the scenes represented in the various slabs of the tomb, as well as the characters, who speak to the user directly from their fixed position.

The archaeological site of Paestum has been selected because of its modern persistence of ruins and museum, one close to the other: the archaeological area is quite well preserved and did not collapsed in the urbanisation of the modern city; whereas, the National Archaeological Museum collects and shows the pieces coming from the site and its few steps from the ruins, on foot. Also the good state of conservation convinced the team to work on this subject, as well as the possibility to tell a plausibile but still not concrete story, given some historical and archaeological issues not yet resolved on this site - i.e. the colours of the architectures, the the elevations of some temples (gable, frieze and rooftop unknown) number of structures in the site at its period of maxim splendour, the type of inhabitants (how they were dressed, which were their main activities…). Moreover, no works in this direction existed for the Paestum area: with the support of the museum staff and direction, the team was finally able to reconstruct and virtually restore the Hera II Temple, the altars and the *donari* area.

The starting point of the VR application was the creation of the three-dimensional model of the environmental context and the monument, in order to navigate inside and facilitate the reading and understanding of users. The AR application was instead based on the possibility of adding further information and dimensions to the reality that surrounds us, allowing the display of virtual data overlapping the real artefact, simply by framing it. To do so, a photographic campaign was done, as well as 3D reconstruction and partial virtual restoration of the slab.

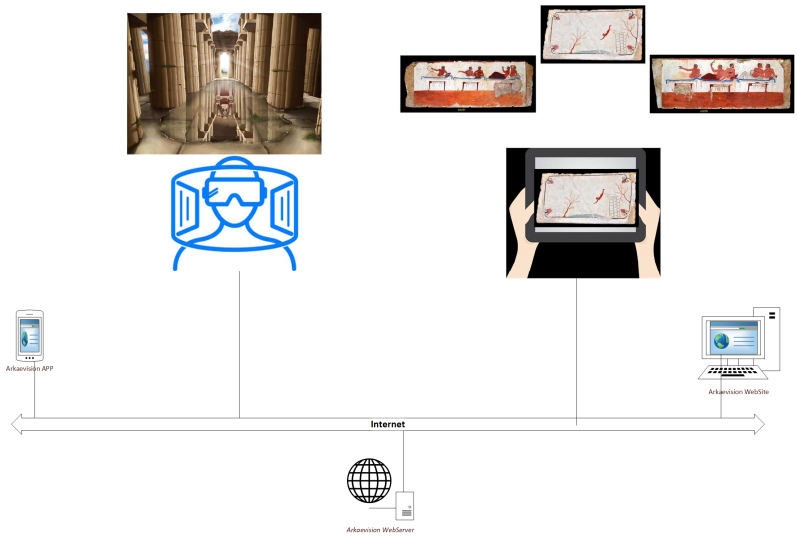

Fig. 1 - An overall view of the ArkaeVision framework including both VR (Archeo) and AR (Art) visual paradigms.

The main target of ArkaeVision is not unique but varied and interconnected. The platform addresses its experiences and services to:

- Italian and foreign tourists, in form of organised groups, families or individuals wishing to visit the cultural site and the technological application available to it, not as experts but as passionate or curious; this first target is certainly intercepted during holiday periods, short and temporary stay in the cultural place, probably included in tours or directed by word-of-mouth.

- Children and adolescents, through schools, summer groups, associations and families; this second target is intercepted through activities organised *ad hoc* and cut to the needs, interests and abilities of young users; the scholastic and aggregative context certainly influences the experience of visiting the museum and the multimedia application that must necessarily be designed for a type of participatory and inclusive cultural fruition.

- People with various disabilities (above all motor skills); in developing the most suitable technological solution for the enhancement and use of the subject of ArkaeVision, i.e. historical-archaeological heritage, an inclusive approach is applied, thus elaborating a multimedia application usable by a widespread usage.

- Experts, professionals, amateurs who, with various capacities, reach the museum independently, moved by an interest and curiosity related to the profession, the academic field, etc. For them, the museum experience is quite focused even if perceptual *stimuli* and in-depth material are also necessary for the purpose of a better understanding and reading of cultural contents; for this reason, the multimedia application for this target is an integrative and reinforcing answer to the knowledge already in their possession.

The platform collect all the profiled data, put in connection information from several inputs, update and modify the user profile, granting visitors a personalised and intimate experience before, during and after the visit at the cultural heritage site with the ArkaeVision technology. The user profiling involve indeed individuals in three distinct but not separate moments, which have an impact on the effectiveness and usability of the two ArkaeVision applications. These moments are:

- Prior to the use of the multimedia application, where the users face the subject of the virtual experience, becoming familiar with it through the web and the project portal, Arkaevision.com. In this phase users act spontaneously and autonomously address their interest, curiosity and stimulation towards the experiences proposed. A first profiling step can now be performed by the user through the compilation of a questionnaire, which occurs after the registration on the Arkaevision website.

- During the interactive experience, in the cultural venue; the user can enjoy the multimedia exploration composed of two parts: (1) an interactive visit more emotional and narrative, where his attention is focused on the evolution of events and the story that brings him back to the past; in this phase the user can not choose what to do and where to go but is guided in the experiential path directly from the system; (2) a more free and didactic exploration, where the user can deliberately deepen cultural information, accessing specific points of interest of which this second part is composed (which is optional and not mandatory). The user's profiling

takes shape in this second moment through the recording of the choices made by him, access to additional information and to the time dedicated to him for the whole virtual exploration.

- One last moment is characterised by the user's consultation of the profile registered on the ArkaeVision portal, which gives him information about the virtual experience just ended. In this phase, he can participate in further cognitive actions of the subject of the application, through mini-games, classifications and challenges.

Hence, the ArkaeVision platform allows to parallel input-output modalities: the former controlled by users, who physically insert their data on the portal, consult them and share them; the latter, instead, controlled by the system, updated during the users' experience and influenced by the gamification algorithm - which put in connection user's selections and choices in the virtual environment with rewards and points.

3.1 ArkaeVision experience design

The ArkaeVision experience is circular and iterative. It starts with a direct interest of users in the moment when they access the ArkaeVision web portal, continue with the use of technology in the place they decided to visit and finish with rewards and extra activities they want to. The results of these activities characterise the users profile, updating their status continuously and automatically. The algorithm which lays behind the whole system allow the user experience to be adapted to the users' needs and interests, while suggesting them new content, an alternative storyline and giving access to extra virtual environment.

The experience that the users make on the portal is not measurable in terms of timing and quality; nevertheless, the virtual experience on the cultural venue is limited to 5 minutes (*Art*) and 15 minutes (*Archeo*) and users can freely decide to leave the storytelling whenever they want, even if the sense immersion and the engaging storytelling push visitors to arrive at the end of the exploration.

The ArkaeVision experience can be made one person a time, for what concerns the immersive VR moment of *Archeo*, and can only be done on the real site, as well as the profiling and the awards section present on the web portal. Differently, the AR moment of *Art*, can be experienced alone or together with others, depending on the support people are using (smartphone or tablet).

The technical features of AR and VR greatly empowered the ArkaeVision user experience, because of (a) the fidelity of the immersive visualisation related to the archaeological site of Paestum, with respect to the Temple of Hera II. Fidelity is not only physical-sensorial (visual, acoustic, tactile), but also includes other types, including the functional one (level in which the system replicates the actual functioning of the instrumentation) and psychological (degree in which the digital contents succeed to reproduce the psychological factors that would live in real experience). Also (b) the usability of the system is influenced by the technological features: the graphical interface - the shapes, the style, the colours and the general atmosphere - as well as the interaction modalities - way of moving inside the virtual environment - are planned to grant in immersive and fully-grounded experience. In this respect, (c) the sense of presence (and immersion) is digitally shifted and re-proposed. This aspect is often used as a quality issue to evaluate, develop and optimise the virtual contents.

But why use the enabling technologies of AR and VR? What is the added value of their use? Various studies have shown that these influence positively [Zara J., 2004; Forte M. et al., 2006; Fassi F. et al., 2007; Navvab M. Et al., 2013; Forte M., Danelon N., 2015; Fassi F. et al., 2016; Teyssier Y., 2016] (a) the acquisition of knowledge (understanding and learning), (b) the acquisition of certain skills (experience), (c) conservation of knowledge for medium to long periods (storage and processing).

In ArkaeVision we want to study and demonstrate these trends through an initial evaluation so as to understand if the *demo* version of the project is really effective and efficient from a technological and content points of view. These data may indicate that users tend to acquire more information, learn to apply them in a concrete way and above all tend to remember them in a more lasting way over time. In addition, the playful aspects may allow the user to live a rewarding experience, a source of positive emotions such as interest, curiosity, exploration, the sense of challenge and self-efficacy. The same emotions exert a strong influence both on attention and on the ability to memorise and remember information concerning what is being done [Anderson A.K., Phelps E.A., 2001]. Moreover, the positive emotions of the users learning process bring to the strengthening of the memory, making it more defined and persistent over time [Bernstein, 2002].

The experience design of ArkaeVision become even more relevant in relation to the fact that it has been decided to use the *serious-game* model as a tool for visiting the archaeological area of Paestum and its antiquities. The game mechanics has been identified as the most suitable to enhance the user's involvement, through targeted motivational drives, so as to induce the public to use the ArkaeVision demonstrator and to achieve a significant pedagogical impact. Thus *gamification* techniques are the background to the storyline and highly emotional and plausible visualisation.

3.2 ArkaeVision architecture: interconnected layers

The architecture of ArkaeVision platform is organised in five layers (fig.2):

- *User layer: it refers to all possible addresses of the platform that are common user, system administrator, local operator;*
- *Hardware layer*: it includes all the hardware devices used by the platform;
- *Interface layer* (or low level layer): it represents the drivers to communicate with the hardware;
- *Manager layer* (or medium level layer): it consists of all the modules dedicated to the management;
- *Decision Making layer* (or high level layer): it is really depending by the specific application and includes the application logic and the Artificial Intelligence library.

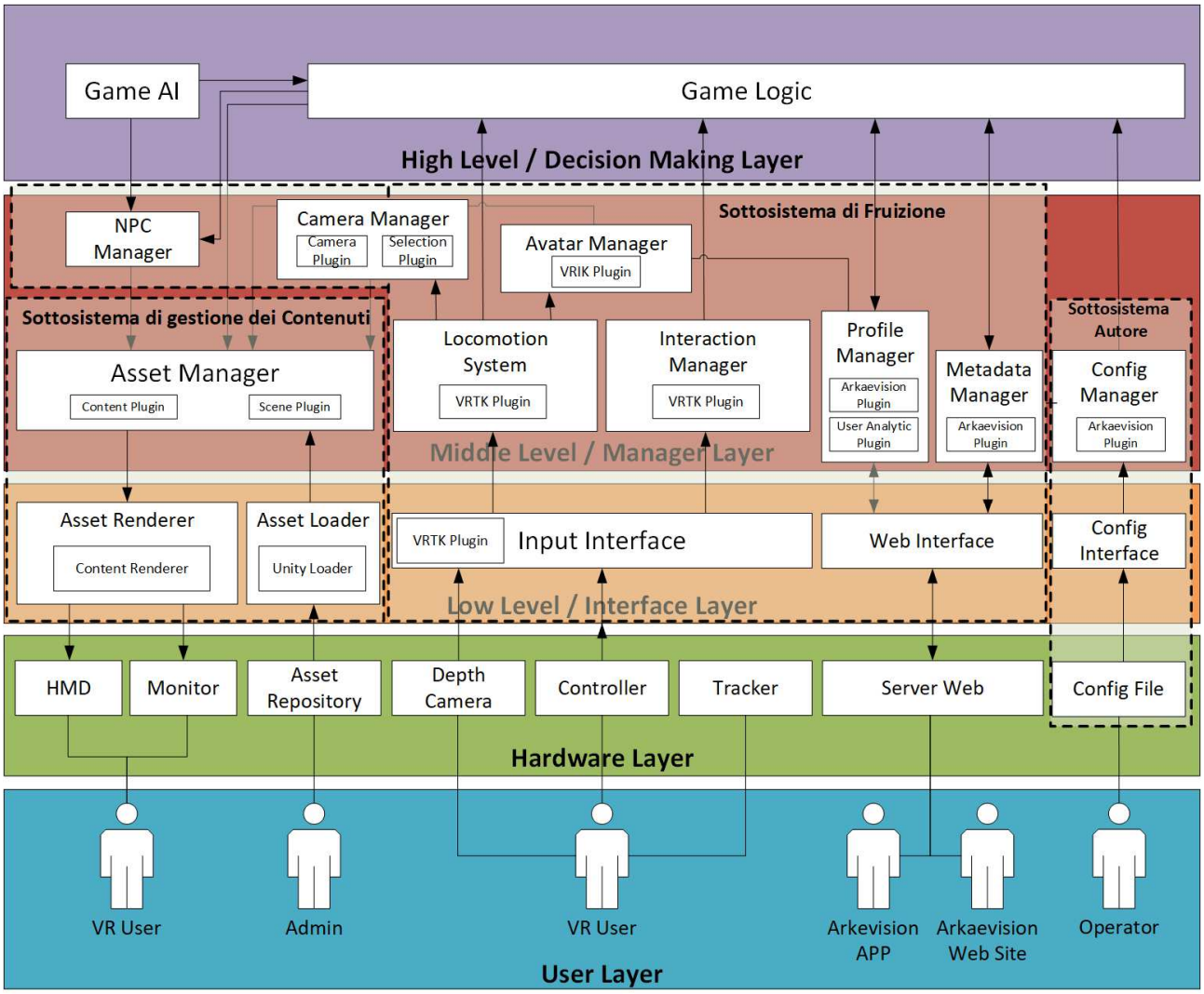

Fig. 2 - Functional diagram of ArkaeVision layered architecture.

Each layer includes one or more modules that can communicate with others using an event-based system. This means that every action, gesture and decision made by the end-user it will be tracked and put in relation with the game logic and the narrative. Technically, each module can be performed by one or more plug-in and it provides at least one service. One or more modules that provides a full functionality are organised in packages so, at the end, starting from low level to high level, we have the following hierarchy: Plugins, Modules and Packages.

The virtual and augmented experiences are organised in nodes. Each node has an (a) Entrypoint, a (b) Do action and a (c) Exit point.This means that for each user's action there will be a start moment, where that action has been recalled, a factual moment, where the user is accomplishing a task and an ending moment, where he/she closes the action and passes to the following activity or event. Indeed, the (a) includes the node "identifier" of incoming node and additional parameters to use in the current state to decide the action to do and eventually the Exit point. The (b) is the main part of node, where a decision is taken and the logic of the experience is performed. This part depends on the values of the parameters.The (c) or exit condition, has all the information about the next node where to go at the end of do action. The exit condition depends by the Entrypoint parameters and the result of do action.

3.1.1 Interface layer

As said above, the main aim of the *ArkaeVision Archeo* is the realisation of an immersive experience able to communicate information on several levels to the user, creating the perfect atmosphere which is both compelling and instructive, exploiting the human desire to live the impossible. To this regard, the possible lines of communication with the user are:

1. *Environmental.* The first level of information is represented by everything the user learns as a simple consequence of immersion in the virtual environment. Immediate considerations concerning the environment in a place or a time that differ from the one in which the user exists, such as the state of nature or human artefacts, or the weather conditions at the moment represented, reach the user without the need to be made explicit through direct communication.
2. *Experiential.* The second channel is represented by the information absorbed as a direct experience of the events he/she is living within the Virtual Reality. Being approached by someone who relates to the user as if he/she is present within the scene, interactively participating to a personal or collective action, as well as witnessing the occurrence of a given event, are all modalities and sensations that allow the user to learn new concepts in a modern and engaging way.
3. *Educational.* The third channel are information too structured or out of the historical context of the experience, which will be learned in a more conventional way through written texts and / or read by a voice recorded within the Virtual Reality environment. It is undeniable that some topics can be treated only traditionally, however, the skimming of the latter through the two previous channels leaves only a small amount of information to be communicated directly, without unnecessarily overloading or annoying the user.

The *ArkaeVision Archeo* experience is structured in such a way to allow the user to face both an immersive gaming-oriented journey, where everything is focused on the captivating experience of diving in a distant past 2,500 years, and a more classic experience, in which information delivered to the user are of historical scientific relevance as the construction of the Hera temple and its other peculiarities. The user can choose whether to live the immersive experience (2) or the educational one (3), by selecting one of the two virtual paths (fig.3).

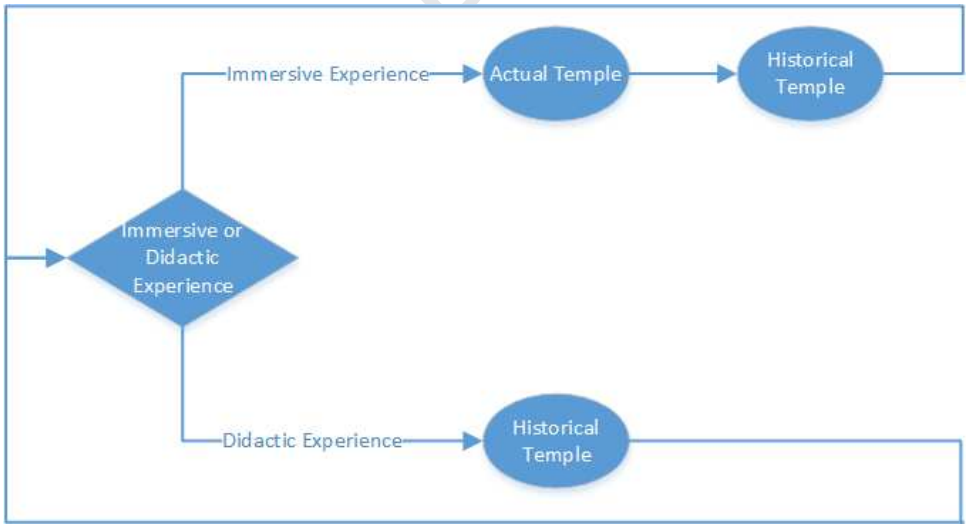

Fig. 3 - Different kinds of experience related to virtual path selection.

The (2) is strongly characterised by the narrative component. The user is guided to visit the Hera temple in its current conditions, and later in the historical reality of the 500 BC, when that site was in function. The Priestess Ariadne guides the user during the exploration, making him/her a participant in the cult of the Goddess Hera and in the practices of that century. The (3) only concerns the reality of 500 BC, where there is be no narrative to follow. The user has at his/her disposal information panels through which he/she can learn scientific historical notions of a higher level regarding the Hera temple - notions impossible to insert during the previous experience without irreparably weakening the sense of immersion.

The user can choose to play both experiences in sequence, or to live only one. This peculiarity can be either configured before the experience starts by the museum operator or automatically, via the profile information previously provided by the user.

The user's avatar is basically identified in himself, lucky participant of a time travel in 500 BC in which he can experience the way of life and customs of Hera II temple in Paestum. The avatar's body is never be visible to the user, as experienced in other VR applications: the auto-verifiability seems to increase the realism but ends with the worsening of the sense of immersion given the asynchrony between the user's movements and the absence of character's

answer to the game. The only exception is represented by the HTC VIVE controllers, useful to manage the movements within the scene and interaction into the virtual environment.

The only non-playable character within (2) and (3) is represented by the Priestess Ariadne. The Priestess herself is represented as an animated photorealistic character, dressed in a philologically correct manner for the time. As the only "animated" link to the player, this has to appear to the user extremely vivid and credible, favouring the establishment of an emotional connection with her. This end is achieved thanks to reactivity (the character must appear alive and responsive and not following a predetermined script in a too obvious way) and attraction (the character should behave in a natural, intriguing and engaging way, in order to tickle the user's curiosity. It is followed by him/her while speaking, and she interacts with the player in a verbal and gestural way that stimulates empathy to the utmost).

From a more technical point of view, to achieve the aforementioned goals, a state-of-the-art approach to modelling, texturing, rigging and animation has been adopted. More in detail, the digital character creation process started from a large number of artistic sketches based on the references collected. These pre-visualization samples led to model a first approximated 3D mesh followed by a high-detail version suited to be progressively refined through interactive 3D sculpting and, then, topologically optimised for efficient and visually convincing mesh deformation at joints. The use of a human model to be captured through 3D scanning techniques, such as structured light or laser scanners, has also been considered and then discarded due to the very high number of topologically unoptimised polygons typically resulting from this approach, which require to retarget the acquired mesh on a “generic” optimised mesh [Abate A. et al., 2004]. The technique chosen enabled a greater level of control on mapping coordinates application which turned out to be valuable on the most critical joints of the character's body. A hybrid physics+skinning based approach to real-time character’s cloth deformation complemented the body animation to further improve Ariadne’s realism and credibility [Abate A. et al., 2005].

To fulfil the requirements of a believable animation of body and face, a sophisticated motion capture set has been set up. 36 Vicom high speed capture cameras and related led array IR illuminators has been carefully positioned within a 300 mq facility to achieve an optimal acquisition area of about 15 mt x 10 mt. A separated set featuring 4 close range Vicom capture cameras has been configured for facial expressions acquisition during a specific session of “face-only” dubbing of the previously captured body acting. In both mocap sessions an actress playing Ariadne had to "worn" IR-reflective markers (positioned on a special suit for the body capture and directly sticked on her face for facial capture) to make the co-registration of character rig to the actress body and face possible. An important aspect of this mocap procedure, is that most complex motions have been break down into basic "atomic" motions, which are then concatenated and blended in real-time by the animation engine [Abate A. et al., 2011]. This approach make re-using and re-arranging the original capture samples possible within an adaptive method based on user behaviour during the interaction with the character.

3.1.2 Manager layer

This layer of ArkaeVision platform includes two important functionalities: (a) the management of metadata and (b) the management of the user profiling. Indeed, all the objects represented in VR or AR can be associated to metadata. They stand as additional information that are possible to be exploited during the educational experience. Such information are called metadata and they can be of different type:

1. TXT: it is a text file including a description to be visualised (a metadata includes always a description while all the other types are optional);
2. IMG: it is a set of images that can be visualised in the virtual environment;
3. AUDIO: it is an audio file that can explain an archaeological find or to tell an history;
4. VIDEO: it is a video file;
5. GATE: it is a virtual scene that can transport the visitor into another place or into another time span;
6. ALT_VIEWS: it stands as an “alternative view” and allows user to appreciate the same item on different perspectives. It is practically a set of pairs {“epoch”; “3D Object”} where the visitor can select an epoch and see the associated 3D object in the scene. Changing the epoch the 3D Object will change accordingly giving a final effect of a time-flow.
7. TRIGGER: it stands as an event-based information where the user can react according to “on_interact” mode (the icon representing the presence of a metadata is activated only if the visitor interacts with the object referenced by the metadata); “on_look” mode (the icon representing the presence of a metadata is activated only if the visitor looks for a defined number of seconds, the object referenced by the metadata);or “on_proximity” (the icon representing the presence of a metadata is activated only if the visitor is close to the the object referenced by the metadata).

The ArkaeVision platform allows thus to study and customise the *user experience*. The user is profiled analysing all the interactions that he/she has with the web platform and with all the interactions happened within the VR and AR experience. Each action performed by the user is considered as relevant information to know better our audience. The platform foresees an initial registration of the user where the first information are collected to generate

the initial basic profile. During the navigation on the web portal (that is considered a "pre-experience" phase), the user enriches its profile. In a similar way, all the user's actions and choices made in the web portal (and its related community, i.e. likes, comments, clicks, etc.) are analysed and used to update his/her profile. Such data are further represented using an ontological model with a graph in which each node is a "concept" and each arc is a "relation" between the concepts. The graph is used in combination with a machine learning system that is able to recognise a "preference", a "pleasure" and it is able to characterise the user profile.

3.1.3 Decision Making layer

The decision making layer is one of the main parts of the architecture of ArkaeVision platform. This layer is based on (a) a finite state machine (FSM) and (b) a behaviour tree. All the application's logic is controlled by (a) which is mainly based on the nodes represented in the fig.4:

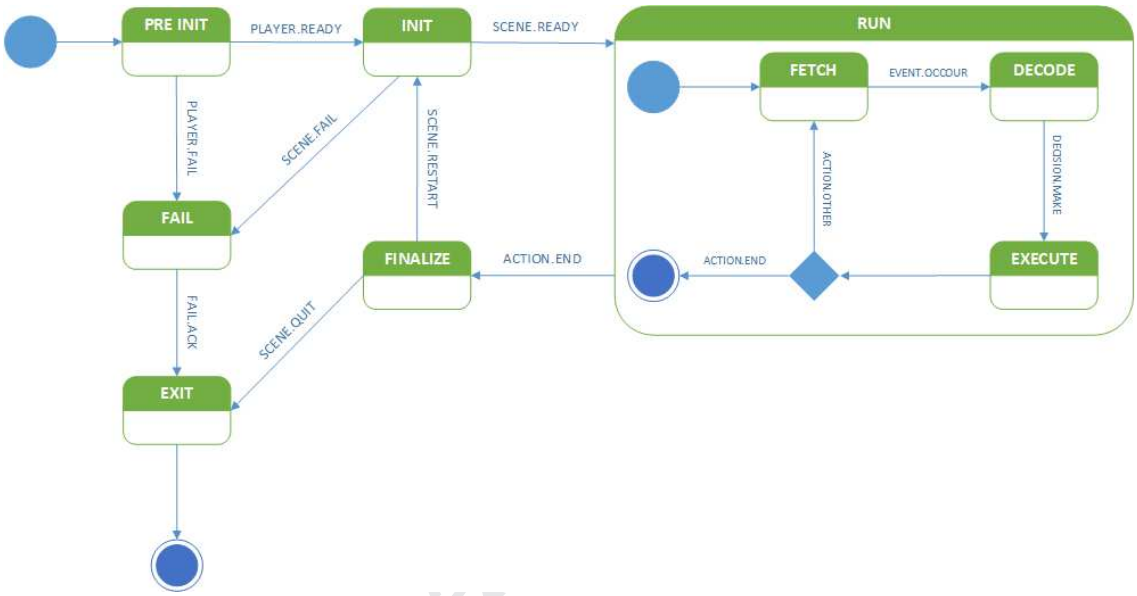

Fig. 4 - ArkaeVision's AI approach based on behavior-tree and Finite State Machines.

There are some states that are used during the initialisation and the finalisation of the experience; in case of failure, the main state named "RUN" works in the same way of a processor and it has three sub-states:

- *Fetch:* acquire the incoming commands or events
- *Decode:* decode the events or the received commands
- *Execute:* execute the action associated to the event or to the command

The (b), instead, is in charge to process the information coming from the virtual environment and to generate the related actions, behaviours or events depending by the selected experience and by the user profile. The decision process can be considered as an Artificial Intelligence process which sees as an extension of the control structure "Sense-Think-Act". The "sense" step captures all the relevant information in the environment starting from a list of events and entities defined "important"; all the other aren't considered; the "Think" step generates a set of conditions used by the logic to decide the action to do; moreover, it evaluates the state of the each condition and of each action to in order to decide the gesture to perform; finally, the "Act" step performs the selected action and changes the state of the system.

3.3 Deployment: storyline and game mechanic

The ArkaeVision storyline allows users to listen to a guided voice, personified by a digital character, and to follow her along the path of exploration; furthermore, users may have access to additional and supplementary information, by superimposing them in the immersive visualisation or by deciding independently to access them by clicking on a simple button. The information is also diversified by type of users, therefore understandable at various levels of cognitive intensity, and by narrative style. In ArkaeVision *Archeo*, the story is profound, evocative and intriguing; in ArkaeVision *Art*, however, the story is more didascalic, minimalistic yet full of curiosities (fig.5).

ArkaeVision *Archeo* consists in an immersive virtual exploration into the reconstructed Temple of Hera II, beside the character of the priestess Ariadne, to discover the secret of the Hera cult. Visitors were not allowed to enter the temple, at that time (we are in the V sec BC), as the priestess tells at the very beginning of the story. She scolds the users to get out of the central cella where the Goddess Hera statue is placed; she also invites to visit the garden and architectures outside of the sacred area, to visit the *donari* room and make there an offer to Hera. Along this exploratory

journey, users hear stories and insights of the priestess life and believes as well as information on the ancient times of Paestum.
ArkaeVision *Art* instead allow users to look, through a mobile device, at the painted slabs of the Swimmer's Tomb and see the animation of the painted characters, learning about the ancient greek funeral ritual. Faces, vases, water, chairs and musical instruments starts moving one after the other, favoured by a punctual soundscape like the breaking of pottery, the wind blowing among the foliage, the falling of the water and the splash of the see, as well as the notes coming from the picking and strumming of the musical ropes.

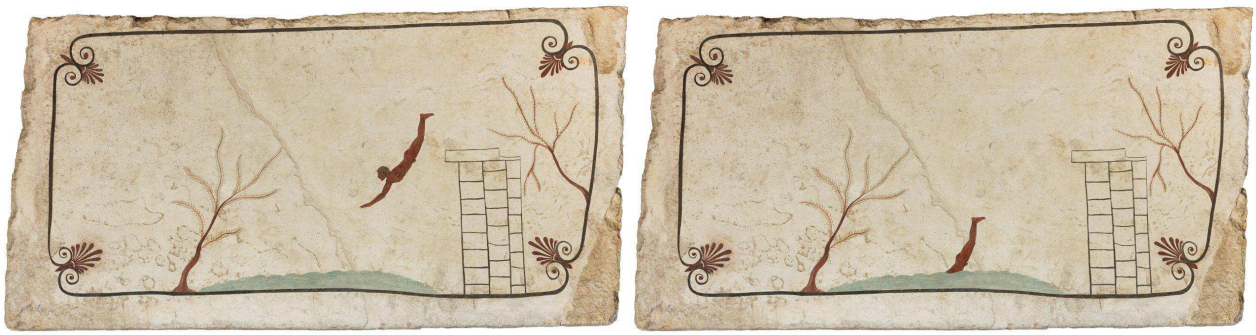

Fig. 5 - Screenshots from ArkaeVison Art showing: (left) The current Top panel of the tomb; (right) A subframe from the animated sequence visible in AR.

The virtual exploration of ArkaeVision contemplates a series of game strategies that allow users to start the experience and to complete it thanks to a story that takes place in a dynamic way, depending on the choices of the user, but still univocal (the end is the same for all users). The time of exploration, the choices made, the paths undertaken and the overcome mini-games are translated into the profiling section of the platform, in order to collect scores useful for the *post*-visit phase.

In ArkaeVision, the exploratory experience allows the user to follow the narrative divided into “chapters” or, better, nodes. Such information can be accessed, in some cases, through small games/challenges where the user has to find the correct answer to a question, or by listening to the guide voice and continuing the story following the directions just received. However, the goal is to reach the end of the story, so as to live a global experience that brings the user back to the initial visualisation - a sign of the end of the exploration. Clearly, the time between the beginning of the experience and the end allows users to be included in a ranking scale, through the portal of ArkaeVision, which identifies the position and, in a sense, the explorative capacity of users (he was good/agile/fast/he answered correctly the questions of the game).

ArkaeVision's game logic relies fundamentally on three principles: moving (in a controlled way) the user along a pre-established experiential line, which leads him from the entrance of the Temple of Hera II (fig.6a), for example, to the portico in front of the entrance and then at its entrance to the altar of the Goddess (figs.6b-6c). During this virtual exploration, users must make choices that lead them to collect some scores; these are clearly symbolic at the moment of fruition, but they translate into material and social benefits as soon as the experience is over and users have accessed the ArkaeVision portal. They can indeed migrate the accumulated score to a digital wallet, useful for buying future immersive experiences in other places of culture, or share them with other users registered on the portal, etc.

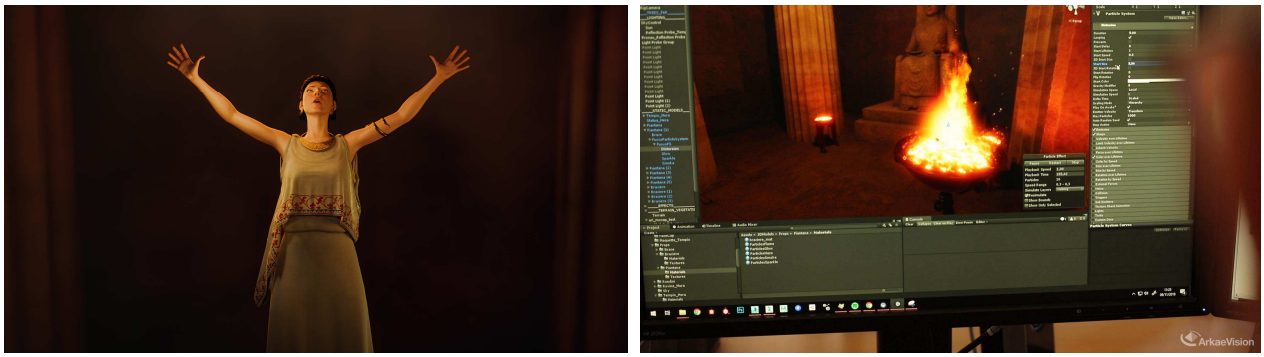

Fig. 6 - Screenshots from ArkaeVison Archeo showing: a) The current Hera temple exterior (in Paestum); b-c) Ariadne, the Hera's priestess, praying the goddess in the naos*; d) Particle systems setup during the authoring of the experience.*

ArkaeVision uses various tools and learning strategies; these are located throughout the virtual exploratory experience and are referable to graphic expedients (360 panoramas, pictorial style of 3D modelling, influence of nineteenth-century romanticism, etc.), elements of advanced animation (rigging and motion capture for movements) of the virtual guide character so that it seems likely in the gestures), informative units with a particular language, fables in some cases, and intriguing for all the public.

On a cognitive level, attention, memorisation and processing are studied and analysed. In detail, the receptiveness of each user, that stands as the ability to perceive and pay attention to *stimuli* (visual input, verbal suggestions, etc.) localised throughout the virtual exploration are investigated. Also the user's emotional response, that is the ability to react to a *stimulus* coming from the surrounding environment (in our case virtual environment) and the predisposition to respond in a condescending or spontaneous way to such *stimuli* are studied.
Then, at psychomotor level, the basic movements that the users perform (locomotives, manipulative and related to an activity) are considered as significant the fundamental, like the dexterity movements - which is the ability to adapt to a virtual scenario or alternative to reality with different rules and dynamics - and the usability of tools.

The whole ArkaeVision platform (both *Archeo* and *Art*) has been designed to be as generic as possible, thus providing a collection of tools, functions and programming assets which enable the authoring of similar experiences in any other historical and/or artistic scenario. This is particularly true for some key-component of this framework, such as the character-user interaction engine, the animation-handler, the user-controlled navigation handler, the user profiling and reward engine. Moreover, either the immersive VR or the Augmented Reality visualisation modalities and the underlying code have been designed and implemented considering abstraction as one of the main aims.

That said, at this moment, a general authoring environment, meaning an integrated software enabling the creation from scratch of a new virtual world and the complete management of a story in terms of interactive user-experience, is still a objective to be reached. There are, indeed, a number of challenges in achieving this goal which include the definition of a comprehensive formal representation of environment's hot spots, character's behavioural patterns, objects properties, game logic, storyline management, which would require a huge effort both in term of system design and of software engineering.

Nevertheless, the current architecture already allows the experience designers and creators to re-use or simply edit a good number of components of ArkaeVision "Paestum" for another scenario, reducing the need for re-starting from scratch and greatly shortening the timeframe required to produce a new interactive experience.

4. User Experience Evaluation

For ArkaeVision it was necessary to set up a working methodology that would place, at various points in the creation and development chain of the multimedia application, a study of the requirements before implementation as well as intermediate efficiency tests during the development; finally, usability and cognitive impact surveys at the time of their public exposition.

Although the *user experience* - the "discipline" that investigates the intimate relationships that exist between the design features of a product and the emotional and cognitive feedbacks of the user to whom this product is subject [www.nngroup.com] - is recently used in the Cultural Heritage domain, it still finds obstacles for the structuring of a univocal procedural taxonomy to carry out the evaluation activities. It is obvious that there is no a unique investigation methodology, given that each survey refers to a specific multimedia project, often very complex and ambitious, which foresee interaction modalities and contents highly cut on the technological support selected and on the final destination.

Moreover, one of the difficulties in conducting such evaluations lies in the multidisciplinary nature of the investigative activity.

Nevertheless, a preliminary evaluation was planned for ArkaeVision during the Archeovirtual exhibition, held in Paestum, in November 2018. The goal was to understand the general appreciation of public while using the VR solution, ArkaeVision *Archeo,* the type and time of fruition, and the usability of the system. Before presenting the results, it is relevant to note down that:

- the application was presented at Paestum in its *demo* format, so a reduced version; it was not possible to verify step-by-step all the usability and learning indexes contained in the ISO framework [ISO FDIS 9241-210:2009];
- the multi-partitioned analysis generally used (observation/questionnaire/guided scenario) in this occasion could not be applied [Pagano A., Pietroni E., Poli C., 2016];
- at the level of *gamification*, it was possible to probe very little given that the user did not really make "challenges" during the exploration.

At that time it was not possibile to evaluate either the AR solution, Arkaevision *Art*, due to development issues.

User eXperience (UX) evaluation took place at the Archaeological Museum of Paestum. DCM and CNR researchers followed the evaluation using a multi-method approach, which best answered our needs. The evaluation plan foresaw three different moments of investigation (and related activities):

1. A general analysis, at a time prior to the main UX survey, on the general museum environment. This was important in order to study the context of fruition and the exhibition availabilities, how the visitors usually approached the space and the objects exposed.
2. The UX survey on public, during the museum visit at the VR application, by means of observations, to verify and analyse the practicability of this expositive solution, the related effectiveness compared to traditional cultural panels and its relationship with the permanent collection on display.
3. After the VR experience, by means of paper-based questionnaires, to verify the users' feedback in respect to certain notions acquired or not when interacting with the installation, the usability and the interface design.

Observations and questionnaires were made along the day, covering all the time slots of the opening hour of the Museum. This was necessary in order to grant the most democratic users' selection, avoiding specific target groups - which would have badly influenced the final result of the evaluations. Users were chosen randomly according to their entrance at the exhibition and to their availability in participating at the evaluation. Participating to the survey was on voluntary basis and anonymous.

Users arrived at the multimedia installation freely. Once expressed their will to play with ArkaeVision *Archeo*, UX operator explained users the goal of the research, the conduction and the timing. If users accepted, then the immersive experience started. When they were wearing the HMD users followed the story having the technical operator aside, in order to recall his attention in case of necessity. In the meantime, UX operator observed them while filling a pre-defined form, in order to annotate relevant information about usability, appreciation and general comments. After the experience, users stopped a while at the desk of the installation to answer to the questions deferrable to the storytelling and the overall usability. In the majority fo the case, users filled the questionnaire template autonomously; in few cases, when the users were retired people, UX operator questioned them orally while writing down their answers. The UX evaluation documentation was unique for each user and the observation protocol was named progressively with a code, in order to match it with the correct questionnaire.

70 observations have been collected on ArkaeVision *Archeo*. The same applies to questionnaires. In general, users positively reacted to the evaluation: some of them wanted to give their own contribution at the research spontaneously approaching the operators; others, at direct request, kindly answered to join the study; very few visitors refused to participate. Even if some differences occurred in the users' attitude towards such kind of activities (due to the cultural predisposition, the background education, etc.) almost all of them fully compiled the questionnaire - leaving no unanswered questions.

The user groups for the evaluation were mainly composed by women (60% out of the global users). The medium age registered was around 30 years old, coming from Italy, nearby Paestum. They came from school (high schools and universities) and their technological vocation was more addressed to smartphones (26% out of the global users) and PCs (20% out of the global users). Game *console* and HMD were not fully experienced before.

4.1 UX results

As a matter of fact, UX evaluation confirmed a great interest toward the new narrative approach and the VR system designed for "visiting" the temple of Hera II (figs.7a, 7b). In all cases, a marked sense of curiosity toward such multimedia installation has been recorded. People staying in row, waited a lot of time in front of the application to test

it, together with friends, parents and relatives. Questionnaires and observations supported such considerations by registering a high percentage of users approaching the interactive area autonomously and remaining there for all the duration of the experience (89% out of the global users). The global vote for the VR application at the end was 9.

Fig. 7 - User experience of ArkaeVision at Archeovirtual exhibition: a) the guide helps the user to interact with the device; b) detail of a user with the HMD and the pointer in her hand.

Out of observations, it resulted that all users interacted with the system with not special help by the staff (14% made it completely alone and 50% with very small help by operators). The remaining 36% asked for help but specifically about the very beginning of the experience or the end (to wear the HMD and to take it off). Interaction was considered natural in its paradigm of exploration (88% out of the global users), intuitive to be used by means of HMD and hands devices (84% out of the global users), as well as practical in the handling of such devices and in the body movements (87% out of the global users).

From an emotional point of view, virtual scenarios and characters' features helped users to feel immersed into the temple of Hera II, as it may would have appeared in the V century BC. Indeed, 98% of the users affirmed to be emotionally involved in the ancient world and in the story; thus, a profound sense of inclusion and "virtual" presence was felt (100% out of the global users). Open comments also underlined such sensation like "I was quite embarrassed to meet the Priestess; she seemed she was really looking at me", "The lights and the warmness of the lamps inside the ancient temple were vivid and realistic".

What was mostly preferred to users were indeed the sense of immersion and the perceptive sensation of projection into another world (almost 25% out of the global users); then the global atmosphere recreated through colours, sounds and style of the virtual scenes (17,5% out of the global users); more, the scenography, with its particular setting and forms (almost 22% out of the global users) (fig.8).

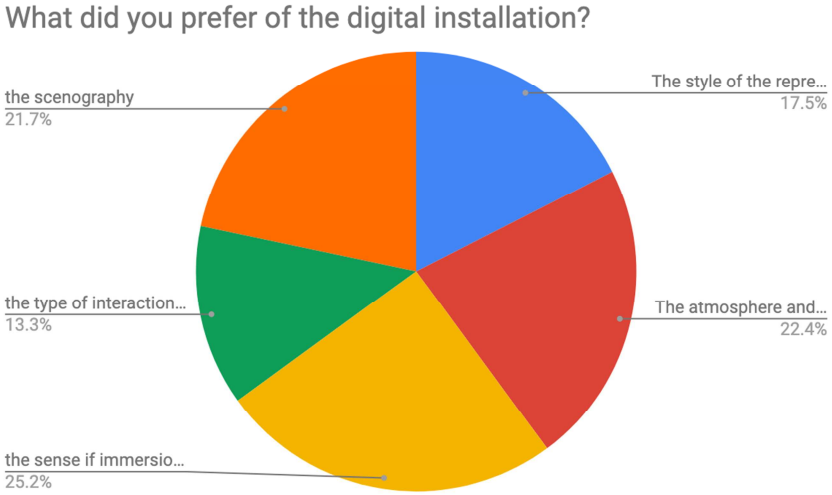

Fig. 8 - Preferences out of 70 answers to the question "What did you prefer of the digital installation?".

When directly asked, users confirmed that they were impressed by the realism of the scenes and the characters, the quality of the reconstructions and the general "taste" of the whole experience, just to mention few comments (fig. 9a).

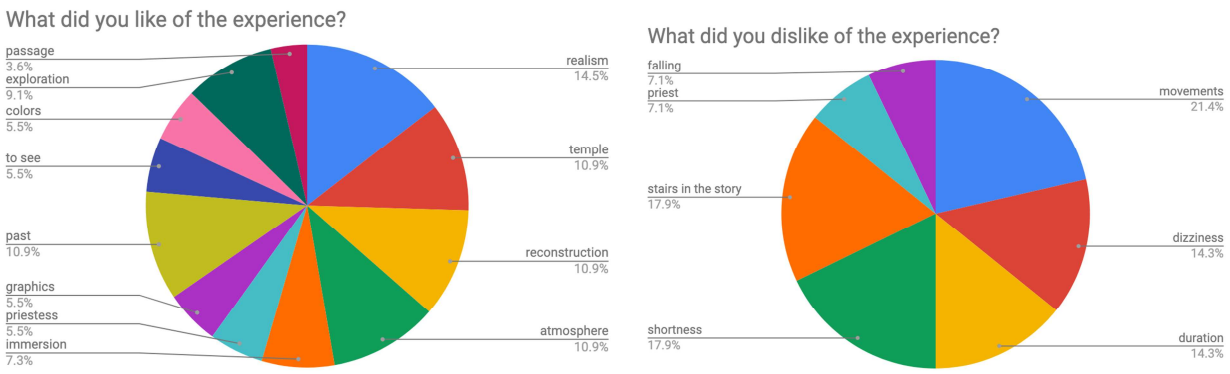

Fig. 9 - Preferences out of 70 answers to the questions a) "What did you like the most of this experience?" and b) "What did you dislike about this experience?".

They also underlined some issues to be improved such as the locomotion and the motion sickness, which might badly affect the general interaction; another point was the short version of the demo: people wanted to explore more and listen to the story of the Goddess Hera (fig. 9b). Surely, this last comments plays in our favour, given that at that time the application was not ended but now it will be. Whereas, about the sense of dizziness and a wave of nausea that someone felt, they are referable to technical constraints which are still under development. We envision to push foreword this problem by the end of the project.

5. Conclusions

ArkaeVision represents the earliest attempt of building a complete digital environment which can lead the public in a deep cultural experience through different moments of life, involving on-site gaming, edutainment and online supports and activities to the concrete museum visit; it is customisable to different user profiles and scalable for any monument, museum or archaeological site. The storytelling structure, VR and AR elements are combined together in order to achieve a system featuring high level performances both for the 3D graphic and the cultural contents. The capability of a careful user profiling and user evaluation may be the basis for the spreading of a new market environment for culture products.

As the preliminary inquiry pointed out, interaction influences the overall experience of the audience but still the major aspect to take into account it is the sense of immersion and presence into virtual world. This can be achieved by the use of VR and, more AR technologies which allow a deep involvement of the user on an emotional basis, together with a higher level of attention to what he/she is doing within the 3D environment. Details and logic narrative units are discovered and remembered thanks to the realism, referring to the general scenes' construction, the atmosphere and the perception of movements.

Some technical limitations have still to be addressed and studied, like the motion sickness produced by the system and the feasibility of such platform in terms of operators and guides (at home and at the museum). We will work on these aspects in the last part of the project where a second evaluation will be conducted at TourismA Expo, at the end in February in Florence. This supplementary evaluation will be conducted also for the *Art* version of the ArkaeVision platform, in order to test its usability, readability and informative potential.

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