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, *ARtifact* , 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.

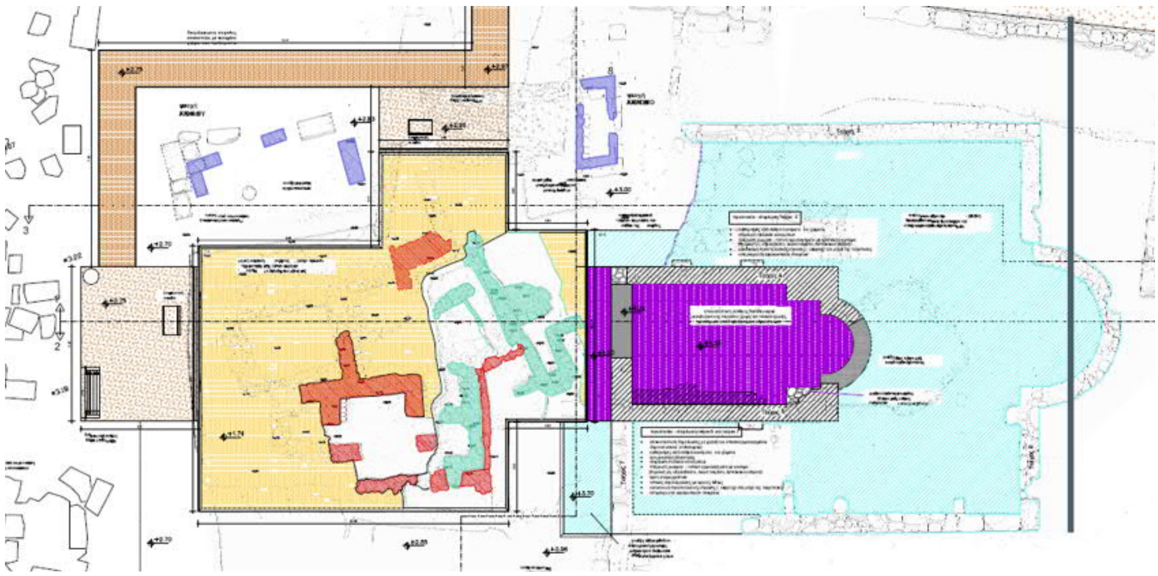

Fig. 2. The partial back-filling of the Neolithic settlement in the archaeological site of Halai in Lokris (© J.Coleman, G. Kakavas, K.Siountri, and E. Pavlidis)

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.

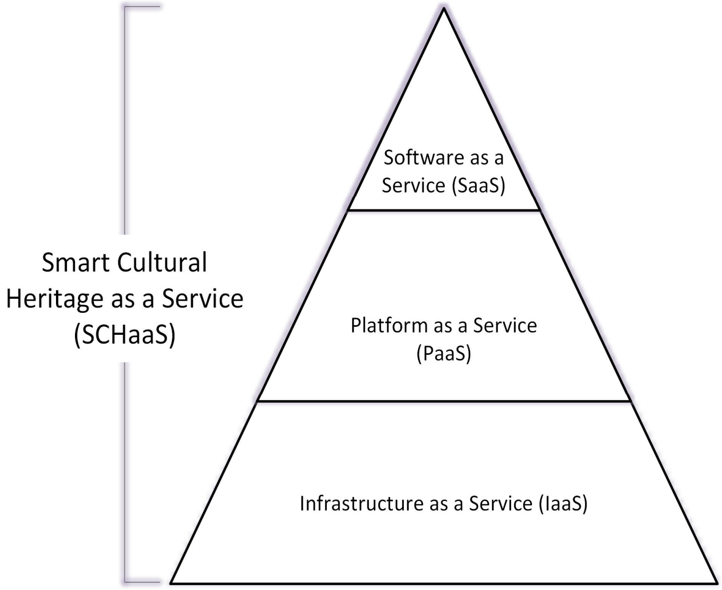

Fig. 3. The Smart Cultural Heritage as a Service (SCHaaS) delivery model

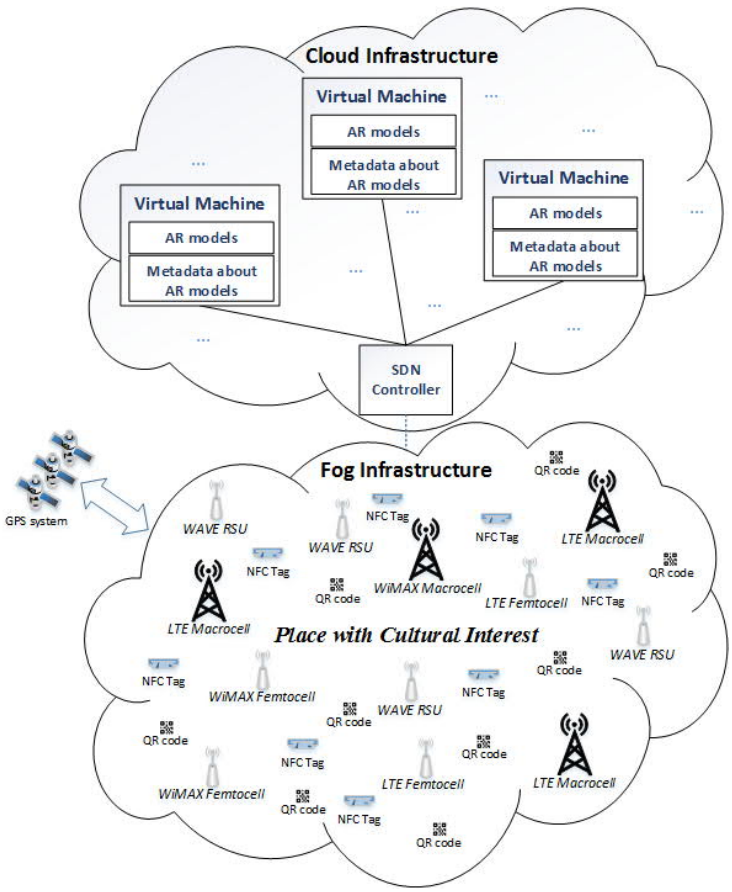

Fig.4. The proposed system architecture

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.

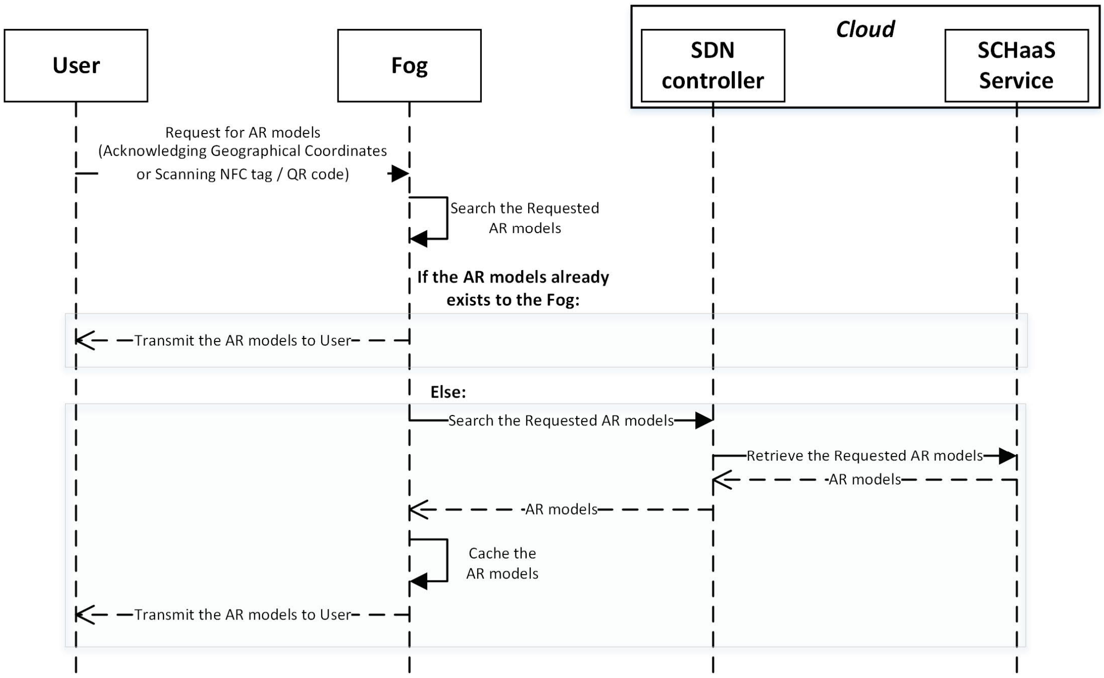

Fig. 5. The sequence diagram that describes the functionality of the proposed system

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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