What Images Say/What Users See. Exploring Mobile Augmented Reality for Visual History-Telling of Architectural Heritage

Pamela Maiezza(✉), Fabio Franchi, Alessandra Tata, Fabio Graziosi, and Stefano Brusaporci

University of L'Aquila, L'Aquila, Italy
pamela.maiezza@univaq.it

Abstract. Aim of the paper is the study of the potentialities offered by augmented reality visualizations of 3D models to communicate the history of architectural heritage, also for its valorization. The case study is the Basilica of Collemaggio in L'Aquila (IT). The church was the subject of a stylistic restoration that returned the building to an ideal former medieval appearance. Based on the digital survey of the current church, a 3D model of the baroque structure of the main nave, which no longer exists, is created by studying the graphic and photographic documentation of the period. An augmented reality application is developed at the University of L'Aquila, and used with the aim of visualising the 3D model to tell the story of the Basilica, so that superimposed information can be displayed dynamically and in real time. Young people aged around 20 years were asked to navigate the visualisations and then to answer a form with questions in order to evaluate the effect of computer based visualisations. The answers are analysed, and in particular it can be seen that while there is not a high level of explicit awareness of digital tools and techniques, there is clearly a habit of frequenting digital environments. Visualizations in augmented reality arouse particular interest.

Keywords: Architectural Heritage · Computer based Visualization · Mixed Reality · Visual Communication · Public History

1 Introduction

With reference to the city of L'Aquila and its buildings, considering the processes of modification and stratification characteristic of the architectural heritage and historic cities, the 2009 earthquake represented a moment of evident importance: still today there are many buildings with a limited access, and the restoration led to significant interventions, often technologically advanced, to be appropriately documented.

In this post-earthquake context, there are further problems of fruition accentuated by the COVID, which limits participation in events and the visits to specifically valuable buildings. In particular, we would like to mention the recognition in 2019 of the "Perdonanza Celestiniana" as an intangible heritage of Humanity by UNESCO. It is manifested through rituals that take place in the Basilica of Collemaggio in L'Aquila. According

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to this context, the digital technologies offer significant methodologies and instruments for heritage study, understanding and valorisation [1–3].

The paper presents a study that roots on the virtual reconstruction of the baroque configuration – no longer existing – of the Basilica of Collemaggio in L'Aquila, carried out with the aim of visualising it in order to tell the story of the church, using an augmented reality application. It allows the visualization of information displayed dynamically and in real time through a mobile device. This experience is based on the use of an augmented reality application, developed by the University of L'Aquila [4–7].

The aim of the study is to evaluate the potential of mobile augmented reality to tell the story of architectural heritage and to valorise it [8, 9]. Therefore, people of about 20 years of age were asked to navigate the visualisations and then to answer a form with questions, in order to evaluate the effects of the visualisations.

This research is part of the INCIPICT project (Innovating City Planning through Information and Communications Technology) of L'Aquila University (http://incipict.univaq.it), financed by CIPE (Comitato Interministeriale per la Programma-zione Economica), and it aims to develop its outcomes and evaluate them according to their public effect and potentialities for heritage valorisation.

Fig. 1. AR App by L'Aquila University, used to navigate and visualize the destroyed baroque configuration superimposed on the views of the current building.

2 UnivAQ Mobile AR

Mobile augmented reality (Mobile AR) is gaining increasing attention from both academia and industry. Hardware-based Mobile AR and App-based Mobile AR are the two dominant platforms for Mobile AR applications. However, hardware-based Mobile AR implementation is known to be costly and lacks flexibility, while the App-based

one requires additional downloading and installation in advance and is inconvenient for cross-platform deployment. However, with the improved communication and computation capabilities provided by 5G technologies, a combination of both technologies is growing up in order to support tourists and cultural applications: (i) virtual, augmented or mixed reality (VR/AR/MR) applications enriching their sight-seeing activities; (ii) integrated transport, accommodation, and entertainment services; (iii) and new social-networking based ways to communicate with other tourists. Consequently, visitors (users) will be targeting for an advanced, combined physical and virtual touristic experience [10–13].

Furthermore, the emergence of 5G mobile communication networks has the potential to enhance the communication efficiency of Mobile AR dense computing in the MEC – Mobile Edge Computing – approach. In particular, MEC, formerly mobile edge computing, refers to the enabling technologies that provide computing capabilities and service environment at the edge of the network (European Telecommunications Standards Institute (ETSI) White Paper).

In recent years, the advances in the following three technologies have further fueled the research and development of AR: the emergence of dedicated AR devices (e.g., Google Glass, Microsoft Hololens and Magic Leap) and powerful development kits (e.g., ARCore and ARKit), the improvements in the performance of mobile devices and sensor integration, and advances in computer vision (CV) technologies.

To achieve better performance, Mobile AR applications usually take advantage of a way to off-load computation (e.g., cloud computing) to accelerate the process. However, computation offloading may introduce an additional communication delay, which will impact the user experience and limit its application under the current mobile networks.

The good news is that several technological advances have started to enter the landscape of Mobile AR. First, the upcoming 5G networks [14] bring new opportunities for Mobile AR. They provide higher bandwidth (0.1–1 Gb/s) and lower network delay (1–10 ms), which improves the data transmission on mobile networks. Second, the introduction of new characteristics, such as MEC, device-to-device (D2D) communication, and network slicing, provides an adaptive and scalable communication mechanism that further provides efficient infrastructures for the deployment and promotion of Mobile AR. The soon-to-be-available 5G networks and the rapid performance improvement of mobile devices, therefore, have laid a solid foundation for the practical deployment and application of Mobile AR on a large scale.

Within the INCIPICT project a MEC based demonstration testbed has been setup. The system exploits the platform available at the MEC LAB of the University of L'Aquila in order to validate the capabilities of the MEC architecture to support applications dedicated to AR services. The MEC LAB provides a complete and customizable network environment and consists of 3 nodes distributed in the city of Aquila: one in the Coppito campus of the University, one in the historic city center inside Palazzo Camponeschi, seat of the rectorate of the University, and the last one hosted in the "Tecnopolo D'Abruzzo" site. In the Coppito hub, more than 15 physical servers are available and interconnected using optical and wireless technologies to provide heterogeneous connectivity between nodes up to 10 Gbps per network segment. The laboratory hosts also

a 5G radio access network and a core network to implement network slicing with guaranteed performance on a common physical infrastructure and it is used to perform edge computing experiments. The availability of distributed computing infrastructures in the city allows the experimentation of the orchestration of virtual services in metropolitan networks required by the AR services.

Moreover, a mobile app based on Apple's ARKit has been developed in order to evaluate service. In order to exploit the system some 3D models were created in different sizes. AR was made by the developed application available for 5G smartphones. All 3D models were stored into the MEC platform and accessed by the 5G network minimizing the latency and with a very high throughput in order to provide the best user experience. Once available within the app a user can browse the 3D model using the device camera.

3 Augmented Visual History-Telling

The baroque configuration of the Basilica of Collemaggio in L'Aquila has been virtually reconstructed. It was removed in the early 1970s by a stylistic restoration, aimed at restoring the church to a supposed medieval appearance. Based on the digital survey of the current church, a 3D model of the no longer existing baroque structure of the main nave is created, according to the studying of the graphic and photographic documentation of the period [15].

The aim is its visualisation and evaluation for the telling of the history of the Basilica, through an augmented reality application, which makes it possible to display dynamically and in real time information related to what has been framed by a mobile device [16–18]. Therefore, young people aged around 20 years were asked to navigate the augmented reality images and then answer a form with questions in order to evaluate the effect of the visualizations. In order to study the communicative capacity of augmented reality images, there was deliberately no introductory seminar on the history of the church; the only information given to users was that the 3D views would show no longer existing baroque decorations (Figs. 1, 2, 3).

Users were given a link to access the visualizations and asked to answer questions by filling in a Google form. The form has been organised in three main parts: first one with general questions about the users' background on digital heritage and their experiences with it; the second one with general questions about the impression and judgement regarding the specific AR and VR experience of the Basilica of Collemaggio; the third with specific questions on the contents of the visualisations, in order to understand the degree of effectiveness of the visualisations in telling the story of the basilica, also in relation to the level of attention of the users and their cultural background. Finally, some concluding cultural questions.

Follows the questions and the answers with their percentage. Not all users answered all questions, and some questions gave the possibility to provide multiple answers.

We had the response of 21 participants (12 females, 9 males).

Fig. 2. Views from the AR app: the present naves; the present church with the AR vision of the old baroque false ceiling; the virtual reconstruction of the whole church before the restoration.

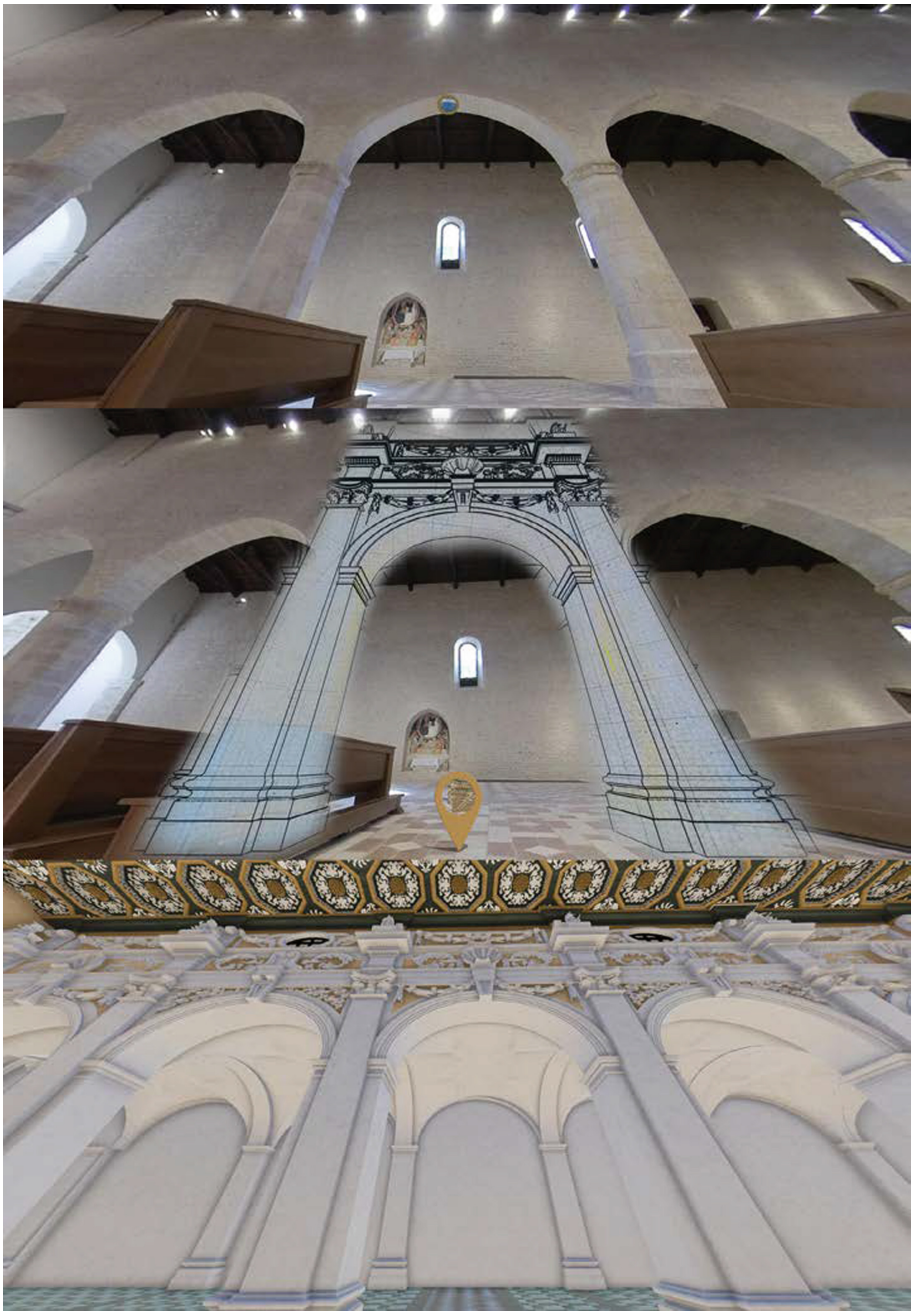

Fig. 3. Views from the AR app: a span of the church; the AR view of the destroyed apparatus; the VR of the baroque configuration.

Part 1: Previous Experiences.

1.1) Do you know the difference between Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)? Yes: 14,3%; No: 71,1%; I cannot answer: 14,3%.
1.2) Have you ever experienced VR, AR, MR applications applied to cultural heritage? Yes: 33,3%; No: 57,1%; I cannot answer: 9,5%.
1.3) With regard to cultural heritage, what kind of experience have you had? Rendering images (not interactive): 52,4%; VR video (not interactive): 57,1%; Touch screen panels in cultural sites: 28,6%; Real time VR with 3D viewers such as "Oculus": 9,5%; AR of digital content displayed superimposed in real time on the in-frame reality of your mobile phone, tablet, etc. 14,3%; Multimedia website: 52,4%; Social network pages: 47,6%; Other kind of experiences: 9,5%.

Part 2: This Experience.

2.1) How would you rate the experience? Amazing: 19%; Interesting: 81%; Of some interest: 0%; Of low interest: 0%; Trivial: 0%; Obsolete: 0%.
2.2) Which of the following topics interested you most? The spectacularness: 33,3%; The historical narrative: 28,6%; The IT side: 33,3%; Other: 4,8%; It did not interest me: 0%.
2.3) With regard to the visualisations of the church, which aspect do you find most interesting? Spatial visualisations of the current church: 4,8%; 3D visualisations of the reconstruction of the baroque apparatus: 42,9%; Visualisations of the baroque configuration superimposed on the present church: 81%.
2.4) Do you think the experience is useful for understanding the history of the church? Yes: 90,5%; No: 0%; Little: 4,8%; I don't know: 4,8%.
2.5) Do you think the experience is useful for understanding the current spatiality of the church? Yes: 81%; No: 0%; Little: 14,3%; I don't know: 4,8%.
2.6) To describe the baroque configuration of the church, which of the following representations do you consider most appropriate? Traditional drawings: 9,5%; Rendering of 3D models: 52,4%; Video: 19%; Real time 3D apps: 38,1; I don't know: 28,6%.
2.7) Would you recommend the experience to a friend? Yes: 100%; No: 0%; Perhaps: 0%.

Part 3: The Historical Contents.

3.1) The 3D reconstruction of the Baroque configuration relates to: The interior of the entire church: 28,6%; The interior of the church up to the transept: 33,3; The central nave only (correct answer): 28,6%; I don't know: 9,5%.
3.2) The height of the Baroque ceiling was: Higher than the current roof: 19%; Same as current roof: 23,8%; Lower than the current roof (correct answer): 42,9%; I don't know: 14,3%
3.3) Before the restoration, the side aisles were covered with: Trusses: 0%; Barrel vaults: 9,5%; Crossed vaults (correct answer): 52,4%; Wooden false ceiling: 9,5%; I don't know: 28,6%.

3.4) After having this AR experience, do you think that a visit to the current church could be: Less necessary: 0%; More interesting: 100%; I don't know: 0%.
3.5) To answer the previous questions, was it enough for you to just navigate AR one time or did you do further viewing? Only one view: 57,1; More views: 42,9%.

Closing Questions.

4.1) After this AR experience, assuming that the wooden ceiling of the main nave is still existing, you think that should be: Interesting to put it back on site to cover the nave of the present church: 57,1%; It is not appropriate to relocate it on site to cover the nave of the present church: 4,8%; Useful to show it on site, e.g. in a neighbouring room: 38,1%; AR visualisations make it less useful to expose the remains of the ceiling: 0%.
4.2) As a result of the experience, which of the following aspects would you like to explore further? Church history: 50%; The 3D modelling process of the disappeared baroque configuration: 85%; How to visit the church: 5%; Other: 0%.
4.3) Did you know that the Basilica houses the remains of Pope Celestinus V and it is part of the Perdonanza Heritage recognised by UNESCO in 2019? Yes: 52,4%; No: 14,3%; Perhaps: 0%; I only knew about the Pope's remains: 33,3%; I only knew that the Perdonanza was a UNESCO heritage: 0%.

4 Conclusions

From the answers, it can be observed that while there is not a high level of explicit awareness of digital tools and techniques (questions 1.1, 1.2), a habit of frequenting digital environments is evident (1.3). In fact, significant is the fact that when asked "How would you rate the experience?" (2.1), the 81% of users answered "Interesting", and only 19% "Amazing". Regarding which aspect interested them, users were equally divided between "the spectacularness", "the historical narrative", and "the IT side", that is they have been equally attracted by the visual experience, the cultural aspects, the technological issues (2.2). Anyway they are aware that the experience is focused on history (2.3, 2.4, 2.5). About question 2.6, considering the answer in the Part 1, we are not certain if they know the difference between static renderings and real time apps. Anyway, answer 2.7 certifies their interest.

The Part 3 focuses on the use of digital reconstruction to tell the history of the church, and here only one of the answers is correct. The questions aim to understand how accurate is the attention of the users or the ability of visualisations to communicate. The percentage of correct answers varies between approximately 30% and 50%, but please remember that the experience was deliberately not preceded by a seminar on the history of the church in order to better evaluate the AR's communication capacity. Therefore, we think that these percentages are acceptable, because this is a study, and if AR will be used to valorise the building, it must be accompanied by other information. Question 3.4 highlights that AR do not favour the substitution of a real visit in presence. The fact that the answers to 3.5 ("just navigate AR one time or did you do further viewing") are almost equally divided at 50% certainly deserves further consideration.

The "closing questions" open to cultural considerations, influenced by the knowledge and previous studies and experiences of each person. Certainly, they have not a background in architectural restoration history and theory. So their answers may represent a common feeling, mirroring the society and the thinking of young people of that age. These answers have a particular value according to the local discussion involving civil society after the earthquake of 2009 that hit the city. Of particular interest the question 4.2 (users can give multiple answers): the fact that half of the user are interested in visiting the church after the AR experience is very interesting.

In conclusion, the control questions relating to the contents demonstrate the validity of the visual methodology for the communication and enhancement of architectural heritage. The experimentation represents a first experience, and in the future the AR views will be enriched with multimedia contents; moreover, the experience will be extended to different kind of users, in particular to include people of different ages and cultural backgrounds, to repeat the test before and after seminars of presentation. In addition, to deepen the analysis of the responses in collaboration with an interdisciplinary team.

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