Mixed Reality Experiences for the Historical Storytelling of Cultural Heritage

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Abstract The aim of the research is the realization of Mixed Reality experiences to narrate the history of architectural heritage. This work is related to the INCIPICT Project and to 5G experimentations conducted by L'Aquila University for the supporting of scientific research and productive activities through the realization of a smart city. In particular, the work roots on the 3D reconstruction of the no-more existing Baroque configuration of the Basilica of Collemaggio in L'Aquila (IT), made according to the analysis of archival documents and the surveying of the current building, with the integration of laser scanning and photogrammetry by drone pictures. The Baroque system was demolished in the Seventies for a stylistic restoration. ICT allows the ubiquitous visualization of real time renderings of the old historical phase on people's personal devices, coherently superimposed to the surrounded reality framed by the users. The 3D model's visualizations have an educational purpose, but also configure as visual-computing tool for historical-critical study and enhancement of architectural heritage.

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C. Bolognesi and D. Villa (eds.), *From Building Information Modelling to Mixed Reality*, Springer Tracts in Civil Engineering,
https://doi.org/10.1007/978-3-030-49278-6_3

Keywords Mixed reality · Architectural heritage · Architectural survey · 3D modeling

1 Introduction: The INCIPICT Project and 5G Experimentation for Architectural Heritage Enhancement in L'Aquila City

The study roots in the INCIPICT Project (Innovating City Planning through Information and Communications Technology) of L'Aquila University (http://incipict.univaq.it), financed by the CIPE (Interministerial Committee for Economic Planning) of the Italian Government, after the earthquake of 2009 that has severely hit the city of L'Aquila (Italy), and caused several collapses of buildings and more than 300 victims.

The INCIPICT Project integrates with the 5G experimentation, in progress in L'Aquila city in collaboration with Wind and ZTE. INCIPICT + 5G studies aim to support the scientific research and productive activities in L'Aquila through the use of ICTs. Therefore, one of the main outcomes is the realization of a smart city, where the technological opportunities merge and match with cultural issues. In this way, the L'Aquila city itself configures as a living laboratory: the city is intended as a complex organism of tangible and intangible aspects, including the historical buildings, the cultural and social context, the economic system, the network of infrastructures and services (Brusaporci et al. 2018a).

With specific reference to the theme of cultural heritage enhancement, the research unit is working on the use of augmented reality to narrate the history of architectural heritage and places, through the visualization of no more existing past configurations (Brusaporci et al. 2017, 2018b, 2019).

We present an experimentation on the virtual reconstruction of the Baroque configuration of Collemaggio Basilica in L'Aquila. At the beginning of the Seventies, a stylistic restoration destroyed the Baroque apparatus to bring the church back to a presumed medieval guise, according to preexistences discovered into the masonries and under the stuccoes. Moving from the digital surveying, through the study of historical graphical and photographical documents, a 3D photorealistic model of the no more existing baroque church has been realized, aiming to digital in site visualization for the storytelling of a particular phase of the history of the Basilica (Cavazza and Donikian 2007; Clini et al. 2017) (Fig. 1).

2 The History of Collemaggio Basilica

The Collemaggio Basilica in L'Aquila was founded in 1287, probably completed in its first configuration in 1294, when Pietro del Morrone was here crowned Pope with the name Celestino V.

Fig. 1 Basilica of Collemaggio, L'Aquila: the facade

By the end of the fourteenth century, many transformations—also consequently the earthquakes of 1316 and 1349—have led to the current settlement with three-naves, transept in line with the fabric, flat terminated apses. The current rectangular facade can be traced back to the fifteenth century (Gavini 1980; Giardini et al. 2006).

As a result of the damages caused by an earthquake in the mid-fifteenth century, important works began; but it is above all by the 17th century that the baroque interior reconfiguration takes place, with an overall re-configuration completed in 1669 for the main hall (Moretti 1971; Antonini 1999).

On the baroque configuration and decoration, some authors underline the local influences (Colapietra II 1158), other Central European ones (Moretti 1972a), but more likely the most important influences are correlated with southern cultural flows related to other important Celestinian centers (Antonini, 201).

The earthquake of 1703 seriously damaged the apses and the transept, and to the subsequent interventions of the XVIII century are attributable the decorations and the altars of the apses and of the transept, and the vaults on the side aisles (Antonini 1999; Colapietra 1978) (Figs. 2 and 3).

Between 1970 and 1972 the Superintendent Mario Moretti realized a stylistic restoration, aimed to the "re-discovering" of the medieval building, hypothetically preserved under the surface of the baroque "superfetations". The approach is based on a prejudice of stylistic value towards artistic and cultural expressions chronologically more recent than the ancient one, and on the mistaken belief that baroque interventions were simple overlaps that had not affected the medieval "support". From this cultural line, numerous stylistic restoration have been realized in Abruzzo

Fig. 2 View of the main nave of the Basilica of Collemaggio

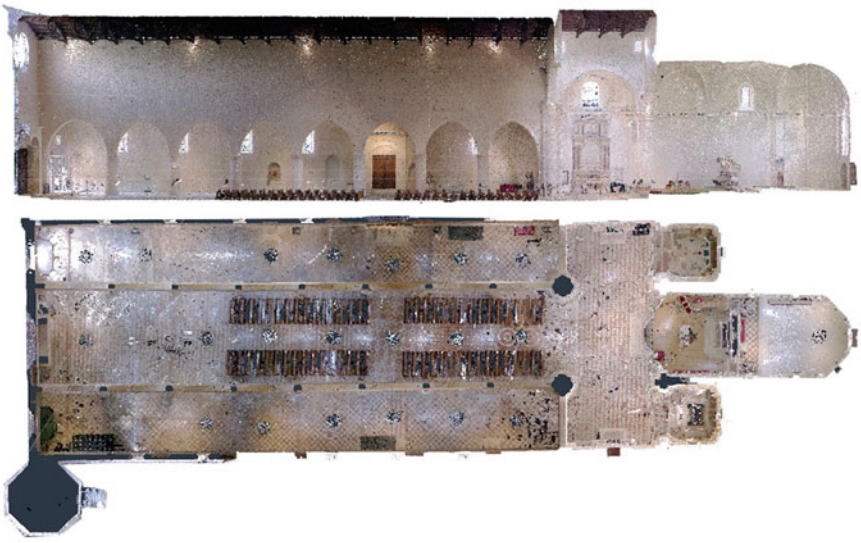

Fig. 3 The survey of the basilica: plant and longitudinal section of the point cloud

(Torlontano 2010). Practically, the Moretti intervention of restoration is operationally based on the "research" of pre-existing medieval elements through demolitions, with the removal of "modern" walls and baroque elements (plasters, stucco, altars, cornices, false ceilings). Once he discovered partial surviving medieval elements, an overall redesign of the configuration of the building followed. The restoration of Collemaggio had a wide media impact, nourishing a bitter discussion, with critical interventions also of well-known figures as Bruno Zevi (Moretti 1972b).

Only the eighteenth-century configuration of the apses and the transept of the Baroque apparatus survives to the restoration of Moretti.

Finally, the 2009 earthquake once again caused serious damage to the basilica, particularly in the area of the transept and apses, even with major collapses. This was followed by a critical conservative restoration intervention; the Basilica was re-opened in 2017.

3 The Virtual Reconstruction of the Baroque Main Nave: Surveying, Methodology, and Outcomes

The research moves from the surveying of the current configuration of the church, intended as the only architectural document really experienceable, and from the study of the old documents, in particular the graphical surveying of the church before the stylistic restoration (plant, longitudinal and cross sections), and the old photos taken before and during the works. The old drawings present a low level of detail, and the baroque decorations are identically repeated; many particulars are different from the photographic ones. Moreover, the old photos have a low resolution; many times is difficult to define the exact element framed by the camera—also because they are non-more existing. Aiming to define the baroque particulars, inverse prospective restitutions (made in a graphical way or using digital photogrammetry inverse camera procedures, such as in forensic applications) are of little or no use (Figs. 4 and 5).

A specific issue is related to the definition of the colours of the baroque plaster, stuccos, decorations, also of the wooden false ceiling; only a coloured picture exists, probably recoloured, but at the same time as when it was taken, probably in the Sixties: therefore, it is a very important document. All the historical documents are saved in the historical archives of Abruzzo Superintendence, and many of these are published (Moretti 1972a).

The architectural surveying of the Basilica was realized with the integration of Leica BLK360 laser scanner and digital photogrammetry applied to pictures taken by a DJI Phantom 4 drone. UAV technology have been necessary to realize the point cloud of the external parts of the building that cannot be measured by the terrestrial scanner, in particular the roofs, the façade and the related architectural particulars.

Using the drone, a dataset of 159 images of the exterior, 86 images of the so-called Holy Entrance, 219 of the main façade, and 25 of the main rose window have been registered. According to Structure from Motion technology, images have

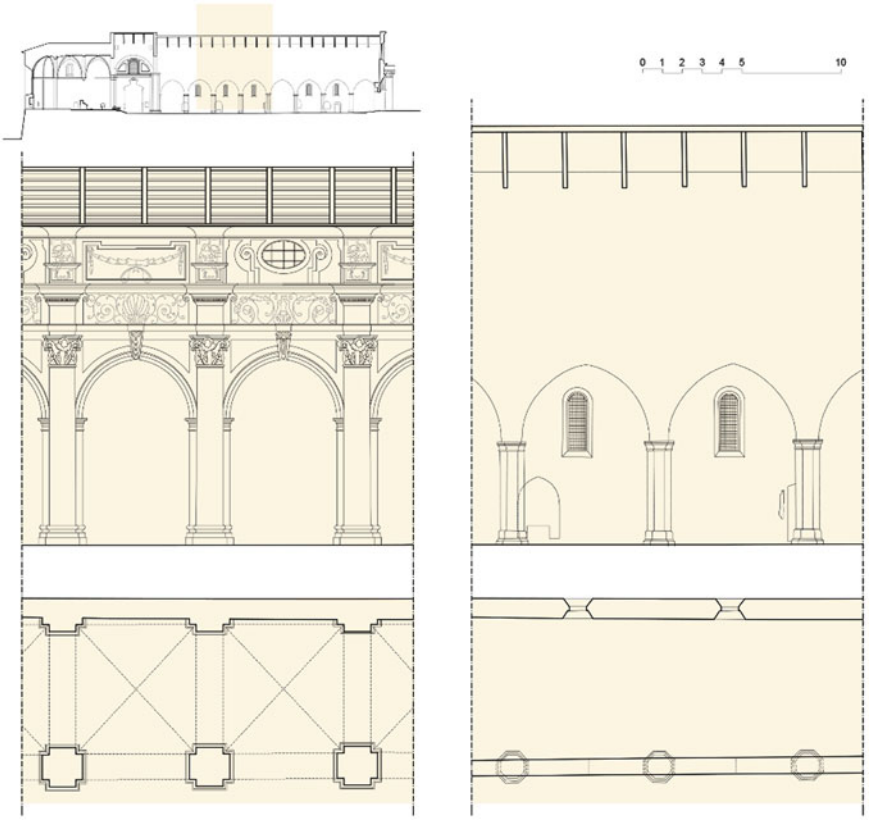

Fig. 4 Comparison between the re-drawing of the baroque configuration and the survey of the current state

been elaborated with the Agisoft PhotoScan software, realizing a point cloud and a textured mesh. The laser scanning campaign was realized with 37 station points into the church and 13 outside. The instrumental resolution between two points at 10 m is of 20 mm. The 50 scans have been recorded with Autodesk ReCap software. The terrestrial laser scanner point cloud and the aerial UAV point cloud have been registered with Cloud Compare software. The whole cloud, imported in Autodesk Autocad, has been used to draw current bi-dimensional restitution of the Basilica, such as plants, sections, and elevations (Bianchini 2014).

According to this archival information, the baroque configuration has been critically re-designed in relation to the existing building, first in bi-dimensional graphics, then in the three-dimensional space, with the use of point clouds and 3D models. The three-dimensional model of the Baroque church has been realized with Rhinoceros software (Fig. 6).

Fig. 5 Digital reconstruction of the baroque configuration: view of the main nave

This spatial work favors a "visual computing" processes of understanding: it is a critical and iterative process, where the modeler, observing and re-drawing the documents, creates his own ideal concept; then he elaborates his idea and refines it though the modeling; consequently, he compares it back to the documents, and the process restarts, evolving toward the final critical interpretation. Therefore, the 3D restitutive model configures as a new critical contribution of knowledge (Brusaporci 2015; Apollonio 2012; Maiezza 2019) (Fig. 7).

This 3D modeling workflow is based on an interpretative reflection and reconstruction, without automatic processes: the baroque elements have been shaped in analogy and proportion to the ones represented in the by old documents: it is an artisan approach and attention, even if conducted in the digital space and with advanced modeling tool. This works roots on a digital molding skill—similar to that of the artisans who worked in the ateliers and in the pre-modern construction sites—that require the knowledge of the past design rules and technologies by the contemporary digital "handicrafts" worker (Guidi et al. 2014).

The aim of the research is not the apologia of the disappeared baroque configuration, but a study based on an historical-critical methodology, the understanding of historical and aesthetical values rises from the reconstruction of the history.

Therefore, the study aims to reconstruct and narrate the physical transformations, that is a phase of the history of the Basilica of Collemaggio, which derives the current configuration of the church, important both from a historical and cultural point of view.

Fig. 6 Rendered view of the baroque configuration

The model also favors the description and valorization of the current church: it is an educational purpose and it presupposes an active participation of users in developing a personal critical reflection, based on the new cognitive outcome offered by the visualization of the 3D model in relation to the physical church (Luigini 2017, 2019).

Fig. 7 Detail view of the baroque apparatus reconstructed in the 3D model

4 Mixed Reality Application

Mobile augmented reality falls within the boundaries of augmented reality (AR) re-search. The initial description of what AR is can comes from Sutherland's 1965 essay (Sutherland 1965) A more technical definition for AR is provided by Azuma (1997). This definition is a basis for discussing AR in precise terms and it defines the following three properties for AR:

It should combine the real and the virtual.
The augmentations should be interactive in real time.
They should be registered in three dimensions.

In contrast to virtual reality (VR), AR does not replace the real world with a simulated world (Steuer 1992). Rather, it seeks to combine the real with the virtual, with the virtual (augmentations) being interactive in real time and in three dimensions.

With the recent proliferation of mobile devices incorporating more processing power and features, including GPS, accelerometers, gyroscopes, and advanced computer vision algorithms, AR has become both feasible and affordable, leading to its widespread adoption.

The fundamental difference between Augmented and Virtual Reality consists in the concept of simulation used. Virtual reality leads us, through a more or less immersive system, to think of living a certain reality deceiving our senses; this reality is completely computer-generated. So, the VR stands between us and the real world,

breaking at several levels sensory communication with it and replacing it entirely with a fictional environment.

Augmented reality, on the contrary, takes advantage of the real world as the basis on which to add information layers. "Augmented" refers to the feeling of "enhancement" of perception, understood as an expansion of the information that we would normally perceive using our senses. This technology is achieved in each case creating virtual content which, exactly as in virtual reality, aims at providing visual, auditory and even olfactory and tactile data, integrating them in the commonly perceived real space.

The 3D contents related to Collemaggio Basilica in L'Aquila are used to extend the tourist experience by exploiting the potential AR solutions. Since the main purpose for AR is to enhance the reality with virtual content, it is important to make sure that virtual objects are correctly registered to the real scene. This can help users view the virtual content as part of the real world. Correct registration can be obtained by estimating the pose of the camera (for video see-through) or user's viewpoint (for optical see-through). The registration process usually consists of two parts. In the first part, fiducial markers or feature points are detected, using marker-based methods or marker-less methods (Huang et al. 2013) Then the second part estimates the pose and maps 3D virtual objects through proper projective geometry. The maker-less method is the one chosen for the experimentation. It helps the AR system detects the scene in a more natural way. In the feature extraction step, the goal is to find areas of interest in the input image that can be served as unique and reliable markers. There are lots of feature detection and extraction algorithms based on different single or combination of features, such as edges, corners, blobs, ridges (Deriche and Giraudon 1993).

The implementation of an AR system required the development of a computer vision system that is able to recognize objects, places or details allowing the user to interact with them or gather information. Concerning the development of the solution for the experimentation, the focus is toward mobile devices, such as tablets and smartphones, in order for the users to exploit their own devices. Nevertheless, AR glasses have also taken into account (Fig. 8).

5 Conclusion

This interdisciplinary study rises from the collaboration of computer science, ICT, and cultural heritage scholars. The outcome is the realization of a mixed reality cultural experience. From a methodological point of view, the work moves from the concept that reality is the result of processes of transformation and modification during time, and that the 'narration' of these processes favors the understanding of the 'reasons' and 'values' of buildings and places. On the History for the Architecture, Spagnesi (1984, p. 7) wrote: "If doing the 'history' is always equivalent to knowing, the History of Architecture can only be the knowledge of the physical space built by man, that is to say the current reality. Therefore, wishing to pose the problem of

Fig. 8 Mixed reality with the overlapping of the old Baroque configuration on the current view

'knowing' today the 'reality', we only have to analyze the occurrence of the essential reasons that produced it in a temporal succession, as they occur, and with respect to which homogeneous time periods in the history of human communities".

At the same time, the digital multimedia 'artifact' have the status of cultural expression of human doing (UNESCO 2003), and together with the reality to which they are referred, it is a new kind of cultural heritage. In fact, digital heritage from

real contents—in particular in mixed reality applications—is not something opposed to the "real", but it is a further manifestation related to the tangible, which can play an important role in processes of interpretation, communication, conservation and enhancement of cultural heritage (Brusaporci and Maiezza 2018; Trizio et al. 2019; Russo et al. 2019; Luigini et al. 2019).

In particular, the 5G technology allows managing a large number of mobile devices, connected with a low latency, i.e. with an extremely reliable and fast response speed, allowing a ubiquitous massive flow of data. In the cultural heritage field, this favors virtual and augmented reality applications in real time. In this way, it is possible to see on the screen of the smartphone—or other kind of devices, renderings of complex informative models in such a short time to allow the coherent superimposition of these images to those of the buildings or places observed and framed by the user (Lackey and Shumaker 2014; Dragoni et al. 2018). Therefore, people are free to move in the space that surrounds them, synchronically observing both the reality and the information that is visually superimposed. In this way, we have an effective advanced Internet of Things system, but realized with an overall respect of the historical "matter" of the works of art, where the interaction between technological applications and heritage physicality occurs only in the dimension of the digital image.

Acknowledgements The research has received funding from the Italian Government under Cipe resolution n. 135 (Dec. 21, 2012), project INnovating City Planning through Information and Communication Technologies (INCIPICT).

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