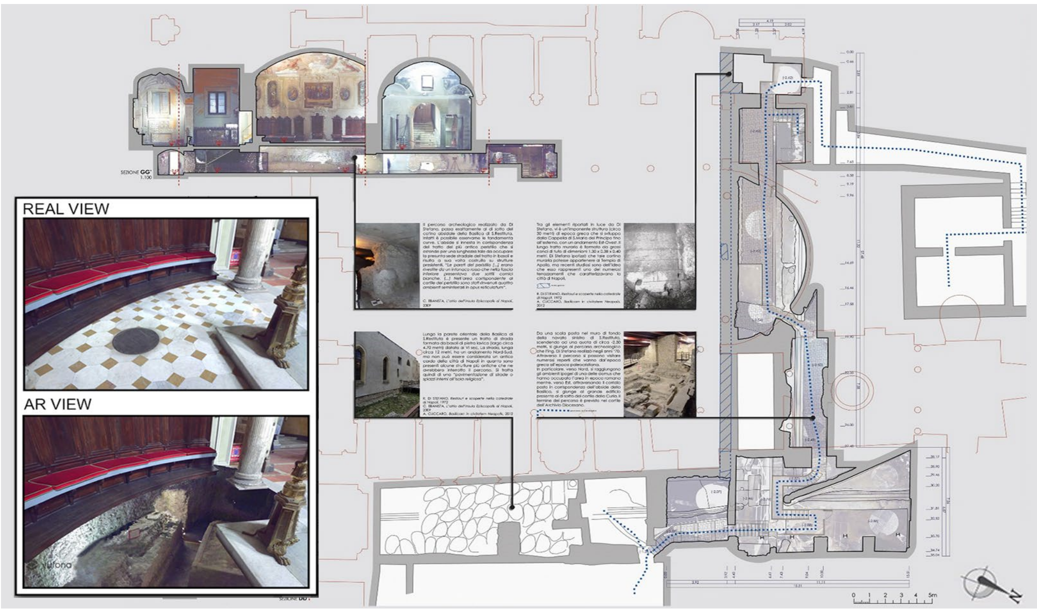
AR to Enhance and Raise Awareness of Inaccessible Archaeological Areas

Margherita Pulcrano
Simona Scandurra

Abstract

This paper shows a research experience interested in exploring the potential of XR systems for the use and dissemination of knowledge about the architectural Heritage and, in particular, about those areas that are currently inaccessible. Specifically, the methodological approach adopted employs AR as a user friendly tool that, through the involvement of the user in experiences implemented by multimedia content, allows to highlight unexplored aspects of the Heritage.
The experimentation carried out involved part of the *Insula Episcopalis* of Naples, investigating the relationship between the Basilica of Santa Restituta and the archaeological area below. To this end, the instrumental surveys carried out to understand the relationships that exist between the different parts of the *Insula*, were of support for the construction of the communication project, constituting in fact the reference model on which the tracking of the scene and the anchoring of the different information was based.

Keywords
AR, reality-based model, archaeological area, architectural survey, information XR model.



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The AR Project Idea for the Accessibility of the Area

The whole process of knowledge and presentation of the architectural Heritage is nowadays permeated by the use of digital technologies which, if in part are already consolidated, in other part are assuming an increasingly relevant role in valorisation and dissemination activities [di Luggo et al. 2019]. This is especially true for those sites whose actual physical accessibility is strongly conditioned by one or more aspects, be they related to the specific conformation of the sites, to unsafe conditions or to specific safeguarding protocols [Quattrini et al. 2016; Spallone 2020]. However, the possibility of accessing the cultural contents conveyed by the historical-artistic heritage remains a fundamental requirement, and for architecture, which by its very nature is intrinsically characterised by multiple potential modes of fruition, technology becomes an extremely useful means to ensure adequate enjoyment.

In addition to this, the unexpected limitations induced by the recent pandemic situation have further increased the inconveniences related to the possibility of physically enjoying even generally available spaces. The need to renew processes alongside traditional ones in order to achieve extended forms of communication is therefore increasingly evident. This would bring us closer to and broaden our knowledge and appreciation of the assets in our territory. Designing digital access modes does not necessarily mean replacing real experience. Rather, it would guarantee an opening towards new readings capable of highlighting different aspects, sometimes hidden or not immediately perceptible.

The application of ICT, together with the various forms of eXtended-Reality communication, does not distort but renews the traditional relationship with the artefact, generating new relationships between the real and virtual environment, conforming fruitions that make the user an active spectator in the interaction with the added information content.

The various augmented reality (AR) and virtual reality (VR) projects are pushing towards alternative ways of accessing knowledge, through systems that hybridise the two worlds or propose a total digital simulation of them [Jung 2019]. Recent suggestions on the possibility of generating a Metaverse capable of merging the perception of everyday physical reality with digital worlds that can be totally superimposed on it, underline once again the international interest in the search for increasingly immersive and connective technologies.

The research presented in this contribution focuses precisely on the possibility of using an AR project to enjoy an otherwise inaccessible space, while maintaining a certain degree of relationship with physical reality. By creating an App for mobile devices, the experimentation conducted proposes a possible application approach that transmits and anchors digital content on reality-based three-dimensional acquisitions (Fig. 1). The study is part of a broader research work [Scandurra 2016] inherent in the identification of appropriate methods of dissemination of different aspects (historical, morphological, metric, artistic, etc..) characterizing the *Insula* of the Cathedral of Naples – and in particular the Basilica of Santa Restituta –, for an audience of visitors that includes from tourists to experts.

The *Insula*, in its current conformation, is the result of a mixture of architectural styles and artistic events that have taken place over the centuries and have written its rich history [Ebanista 2019]. Among the many events that have made it a protagonist, the work carried out by R. Di Stefano between 1969 and 1983 brought to light the remote memory of the

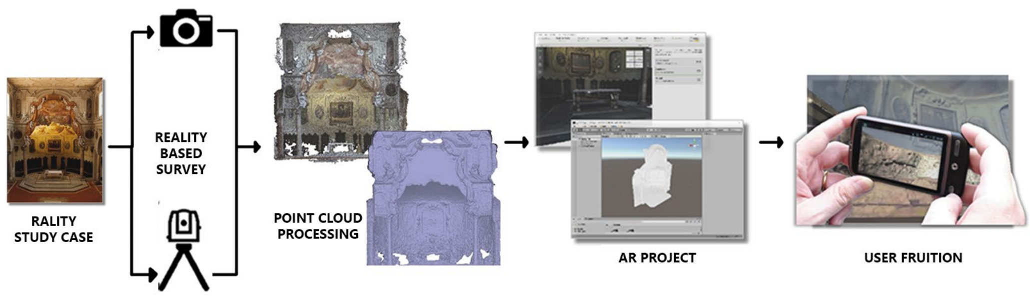

Fig. 1. Workflow from real data to augmented reality project.

Fig. 2. Underground archaeological area at the *Insula Episcopalis* in Naples.

place through the discovery of a vast archaeological area from the Greco-Roman period (Fig. 2). The area, concealed beneath the floor of the Basilica of Santa Restituta and part of the inner courtyard of the *Insula Episcopalis*, is currently inaccessible to the public and therefore little known.
The research aims to bring the archaeological site back to light – albeit indirectly – through the targeted use of tools made available by digital technologies, making the site observable in its morphological characteristics and communicating its undoubted historical value. Alongside this, a multilevel reading was proposed that, by breaking down the physical (real) reality, directly connected the above and below, reinforcing the perception of their reciprocal relations. Digital content superimposed on physical reality is thus a disruptor of physical reality itself, as it allows the vision of what it conceals.
Specifically, the AR project hinges on these objectives, and the results achieved are the result of reflections on both the correct overlap between real and digital, and the graphic coding in the representation of the various contents implemented, as well as the methods of accessing them. The choice of the technical solutions and software applications to be used was therefore made so that the AR App would meet the prefixed aims and not be influenced by the constraints imposed by the site. This last aspect was important in the design and execution of the AR itself because it affected, in particular, the dynamic mapping of the real environment and the correct display of the digital contents superimposed on it, which, as is well known, are linked to the decoding of the position and orientation of the user – or of the mobile device used.
From a methodological point of view, digital 3D models representing the state of the sites were first built. For this phase, it was decided to use reality-based surveys and data fusion processes of the relative point clouds. The sites were acquired using laser scanners with phase modulation technology and digital terrestrial photogrammetry procedures so that, through the well-known processes of data processing and manipulation, it was possible to obtain mimetic models of reality, recording in a digital environment the spatial configuration of the various environments that make up the Basilica and the archaeological area below (Fig. 3).
As with any architectural and archaeological survey, the choices made in resolving the models took into account a number of aspects. In this specific case, attention was paid to the level of accuracy necessary for the data to be usable virtually and to photorealistic rendering.

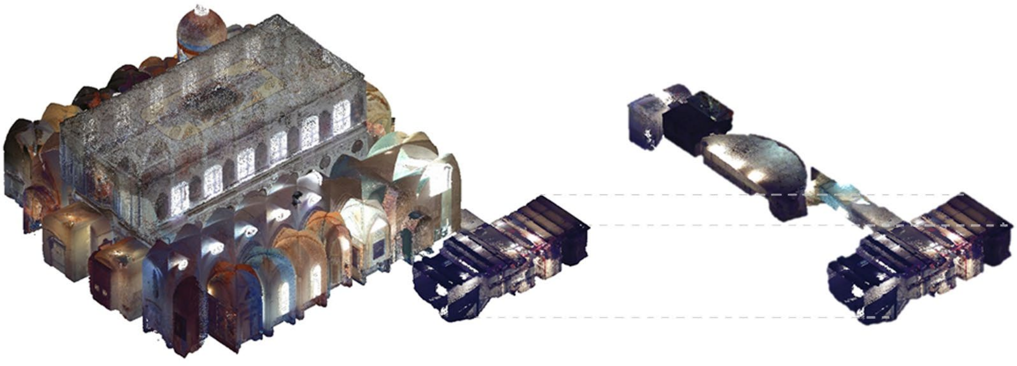

Fig. 3. Point cloud of the Basilica of Santa Restituta and the archaeological area.

These data, in fact, in addition to providing the necessary information for a metrically accurate and up-to-date documentation of the site, were of support for the construction of the augmented user experience: the point cloud returned by reality-based acquisitions was considered the foundation of the AR App. A part of it was used to build the digital content; another part, instead, was used to calibrate the well-known tracking phase of the scene for the alignment of the data used through the mobile device in situ. This operational choice was dictated by the desire to make the environment of the Basilica free from the presence of any fiduciary markers and the impossibility of using location-based systems due to the lack of GPS signal. The solution undertaken, therefore, bases the orientation of the device and the visualisation of the increased content on the optical recognition of the geometric and colorimetric characteristics of the real elements, framed by the camera integrated in the device used.
The operations described were managed through the *Unity 3D* game engine software and the *Vuforia Engine* and *Model Target Generator* tools. The association of the different applications, if on the one hand it has allowed a high degree of personalisation in the construction of the user experience and the achievement of the pre-established objectives, on the other hand, as we will see later, it has imposed specific solutions in the structuring of the digital data, especially in the manipulation of the point model.

Built Reality as a Reference for AR App

The archaeological area that underlies the Basilica of Santa Restituta passes mainly under the apsidal area.
This portion of the church and the archaeological finds were considered to be the most interesting areas for the construction of the spatial relations necessary to relate the digital content with the physical reality in the context of the AR project. The area of the apse was extrapolated from the overall cloud of the Basilica and was considered the digital homologue of the natural target, i.e. the reference on which to set the construction of the App. The archaeological area, on the other hand, was elaborated so that it could generate the main digital content usable by the users of the App. The experimentation, therefore, began by structuring the survey data in a specific way in order to make it suitable for the purposes (Fig. 4).
The portion of the point cloud relative to the apse was transformed into a continuous model made up of surfaces. The numerical consistency of the polygons that could be obtained from the meshing process for an accurate restitution of the plasticity in the architectural forms, clashed with the limitations of the maximum number of triangular surfaces that could be imported by the *Model Target Generator.* This required further editing phases of the survey

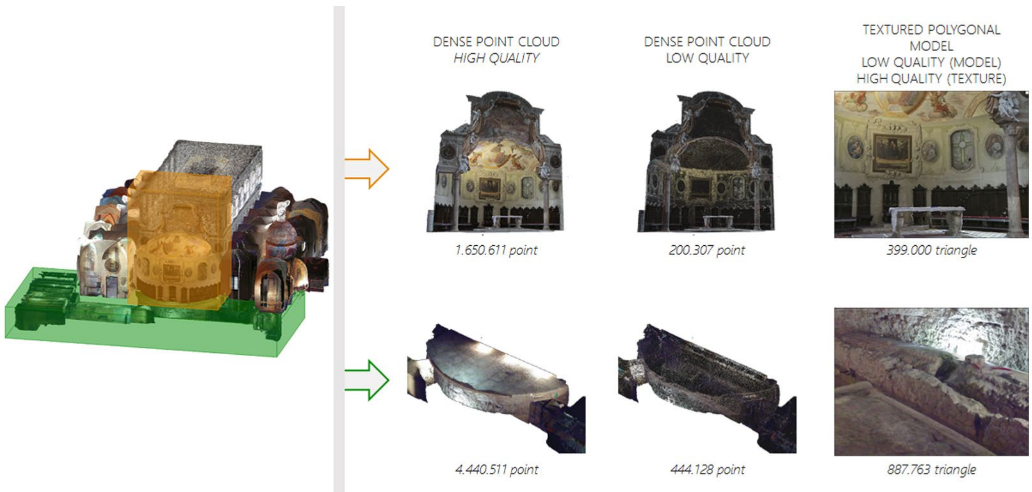

Fig. 4. Management of the point cloud for texturisation.

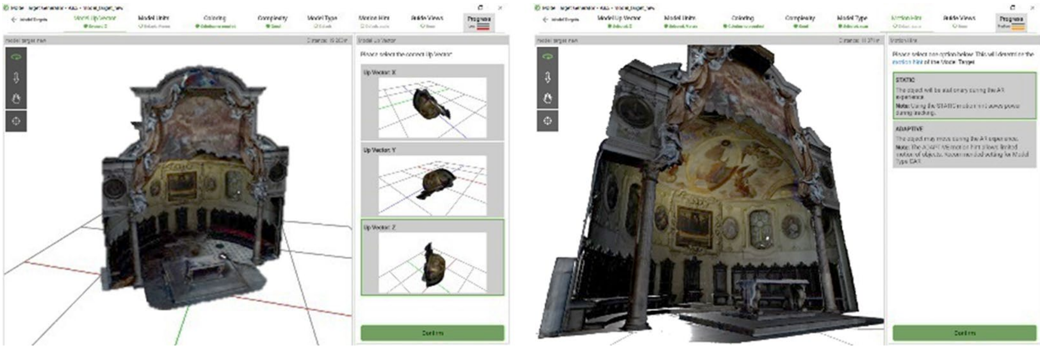

Fig. 5. The link between reality and digital content is made through the correspondence between the model and the constructed reality.

data in order to simplify it without excessively altering its morphological and topological characteristics. The complexity of the mesh was then decimated, through the execution of edge collapse algorithms and the definition of the maximum limit of polygons to be returned. Subsequently, the mesh was textured, in order to obtain complete information: the geometric data was integrated with the colorimetric data and the resulting 3D model, although simplified, presents a level of detail that allows a correct reading of the specific properties and the identification of those characteristics necessary for the univocal recognition of the reference elements to be used for tracking.
The textured mesh of the apse, thus constructed, after the appropriate refinements and export in *.fbx* format, was converted into a *Vuforia Engine* database by means of the *Model Target Generator* application (Fig. 5). Here, having read the morphological and dimensional characteristics, the orientation and the colour information of the 3D model, the application identified the elements (planes, lines, edges and other discontinuities) to be used as a reference during the tracking of the scene. In practice, by means of the device's camera, the AR App was able to detect the correspondences between the constructed reality and the digital model loaded in its database. Through this correspondence, the App updates in real time what the user sees on the screen of his smartphone or tablet, recognising his position and relative orientation.
Through the various operational sequences of the application, the information associated with the reality-based model has been used to extract the data useful to configure the digital content with reference to a specific point of view – and therefore to the relative shots – necessary to start the process of fruition. From the 3D model, the application elaborates a

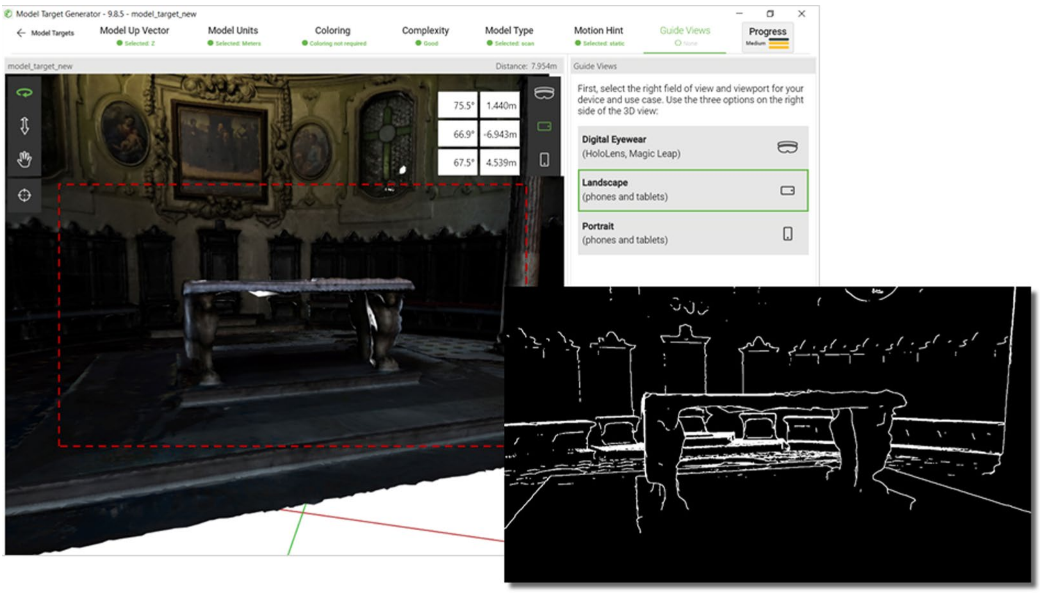

Fig. 6. Identification of the altar in the *Model Target Generator* for the use of digital content.

simplified 2D representation, where lines, edges and planes are highlighted in the creation of a real guiding image (Fig. 6).
In the specific case of the Basilica of Santa Restituta, in the AR App it was decided to identify the altar mensa as the start point; the user, therefore, only has to frame this part of the architecture with his mobile device in order to start the execution of the fruition project and, therefore, the visualization of the contents added to it.
What comes out of the *Model Target Generator,* in fact, is a 3D model cleaned of superfluous information, but accompanied by the 2D guide view and converted into a *Unity Engine* package which, together with the *Vuforia Engine* tool, implements the development environment of the gaming engine software with functionalities closely linked to AR. Among the technical solutions used in the programming of the App, it was chosen to make visible, on the screen of the mobile device, the references of the start point, supporting, in this way, the user in the correct alignment between the latter and the real object.

The Use of Digital Informations

Once the *Unity 3D* environment was prepared with the added component *Vuforia Engine* and the *.unitypackage* database exported from the *Model Target Generator*, the applicative experimentation of the research continued with the actual structuring of the AR App, inserting the different contents to be communicated to the user and programming the executable actions. First of all, the model target of the apse and the *AR camera* for the rendering of the scene were placed in the three-dimensional space of the *scene view.* The first one is clearly essential in the construction and execution of the AR; nevertheless, the fruition is not influenced by its presence since, in fact, it is displayed only in the App development phase and, consequently, it does not interfere neither with the digital contents nor with the real space. The *AR camera*, on the other hand, replaces the traditional *main camera* – present by default in *Unity 3D* projects – with specific scripts and components. These relate the target model to the real environment on the basis of previously identified references and, at the same time, allow the overlay visualisation of the digital contents. In fact, the *AR camera* emulates the behaviour of the mobile device's camera and orients the information in real time in relation to the user's movements.
The scene view was then implemented with the different information the user can access, made *GameObjects*, to respond to the logic of the gaming engine software.
For the specific project of the *Insuala Episcopalis* – as anticipated –, it was decided to make the archaeological area below the apse of the Basilica of Santa Restituta usable, transforming, therefore, into *GameObjects* the polygonal model of the path that characterises it, with the set of wall and floor finds that make it of considerable cultural interest. The meshing and texturing process followed elaborations similar to those previously carried out for the apse, but differed in the degree of simplification implemented. Here, in fact, reflections on

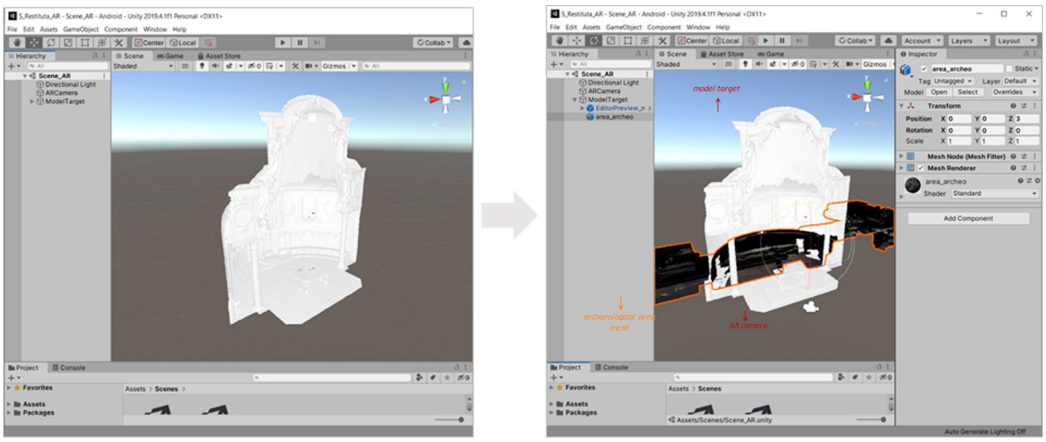

Fig. 7. Setting the overlap between target and *GameObject* in *Unity 3D*.

the typology of the 3D object and its rendering in real time, have led to the choice of a greater geometric discretization, this time not linked to a predetermined numerical value. This expedient – not applicable for the apsidal zone so as not to affect the determination of the reference elements, the generation of the model target and, consequently, tracking – was useful for obtaining a highly optimised model, but one that still has a high degree of correspondence with reality in its photographic rendering. This has made it possible to reduce the conversion time of the 3D data into a 2D image and to limit lag or inconsistencies with what is displayed in AR, facilitating, as is well known, the rendering process and restoring fluidity to the execution of the fruition.
The user who frames the apsidal area, therefore, opens a sort of digital window that breaks through the physical limit of the pavement he is walking on and allows him to observe the archaeology it conceals. To this end, the positioning of the mesh in the digital space of the *Unity 3D scene view* clearly took place in relation to the model target, simulating the visualization prefigured in real space. And, therefore, it was necessary to translate – along the vertical direction – the relative *GameObjects* in order to induce the sensation of being inside the archaeological area and, at the same time, to perceive the existing relationship with the Basilica of Santa Restituta just through the overlapping visualization between the real and the digital environment (Fig. 7).
In addition to the 3D model of the archaeological site, other elements have been included in the *scene view* to further implement the information conveyed to the user through structured data in different formats: short texts describe what is being observed, photographs allow the user to dwell on specific portions of the underlying path, two-dimensional graphics highlight the dimensional relationships and textures of the constructive apparatus found in the archaeological excavation. Access to the various contents takes place through the *UI Button* and *UI Toggle* of the *canvas*, i.e. activation buttons represented by graphic symbols that anticipate the type of data to which they are related. The user can then interact with the App and choose in full autonomy what and how much to look at, according to his personal interest (Fig. 8).
Finally, each *GameObjects* positioned in the digital space has been connected to the target model by means of *parent-child* relationships, i.e. they have been incorporated and made integral with it in their behaviour. This, in addition to conforming a single hierarchical data system, is necessary for AR visualization and to allow the AR camera to return them correctly during the execution of the App.

Conclusion

In conclusion, the aim of the presented research project was to make usable, at least digitally, an area that is hidden and not known to the majority of visitors who access the Cathedral of Naples and the Basilica of Santa Restituta due to inaccessibility for security reasons. The use of consolidated technologies for the creation of an app for mobile devices allows for easy

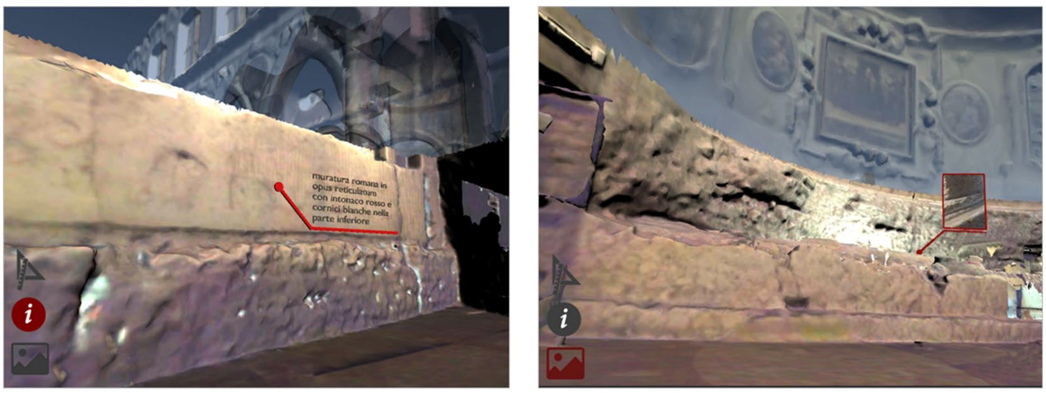

Fig. 8. Insertion and use of added information content: text, images and 3D model.

dissemination among users and a virtual visit that does not neglect the need to be physically on site and therefore reinforces the visit of the permitted areas. The project clearly hopes for the dissemination of knowledge about the archaeological area, but also for the possibility that in the near future the user will be encouraged to return to observe and experience the area for himself.

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Authors
Margherita Pulcrano, Dept. of Architecture, University of Naples Federico II, margherita.pulcrano@unina.it
Simona Scandurra, Dept. of Architecture, University of Naples Federico II, simona.scandurra@unina.it

 Isbn 9788835141945