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AUGMENTED REALITY FOR THE HERITAGE
Basilica SS. Medici in Alberobello, a case study

Ilaria Cavaliere

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ABSTRACT
This paper wants to delve into the use of augmented reality to support the architectural heritage, by describing a specific case study on the Basilica SS. Medici in Alberobello. The Basilica was never finished. Its dome at the crossing of the nave is missing, a flat slab is in its place. This also affects its external appearance, the absence of the tholobate makes the building appear incomplete, so much so that the community repeatedly tried to complete the project. Therefore, the creation of an Augmented Reality app (AM) was considered helpful to make the users see the sacred space as it was ideated by its designer, based on a reconstruction process recently developed by scholars and architects from Politecnico di Bari.

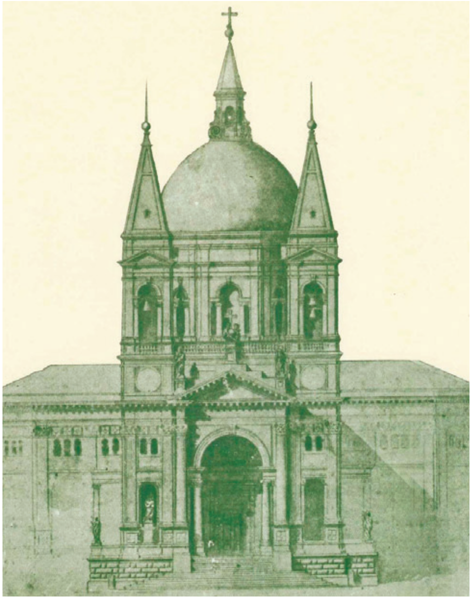
KEYWORDS
augmented reality, extended reality, architecture, heritage, virtual architecture

Ilaria Cavaliere, Architect, is a PhD Candidate at the DICAR department of Politecnico di Bari (Italy). She carries out research mainly in the field of 3D printing for the architecture, virtual reality and augmented reality. Mob. +39 366/42.21.735 | E-mail: ilaria.cavaliere@poliba.it

The digital revolution has radically changed the way we face many problems, first and foremost the relationship with reality. The arrival of tools such as augmented and virtual reality – generally called ‘extended reality’ or ‘XR’, a term that includes the full range of experiences involving the interaction between virtual and real elements – brings a wide range of possibilities in many contexts, including architecture, restoration and the conservation of historical assets, leading to frequently find newly coined terms such as ‘virtual architecture’ or ‘virtual heritage’. Digital reconstructions paired with extended reality, in all its forms, consent to pre-view – in a more or less immersive and interactive way – a designed space, to view historic reconstructions, interact with objects and artefacts without physically coming in contact with them and, hence, without creating damage, enjoying the monument in otherwise impossible ways and perspectives. All these possibilities make them appealing in the field of actual design, scientific investigation, valorisation and dissemination.

This paper focuses in particular on the case study of an AR app developed by the Author for the Basilica SS. Medici in Alberobello, currently unfinished, because it has no dome. Since this problem is felt by the community, the goal was to provide users (believers and tourists) with a way to fully embrace the sacred space simply and interactively, and also to stimulate a collective consideration and a subsequent debate on the possibility of a concrete architectural intervention. Therefore, this paper, after an introduction to the state of the art on XR research at the international level, will deal with the description of the above-mentioned case study and will describe the app and its development process, and finally will evaluate its innovative aspects and limits.

State of the Art | Augmented reality consists of the implementation of tangible reality with virtual elements, so that users can enjoy a more complex and richer dimension. Therefore, it is a sort of ‘integration’ of reality with added elements, such as texts, graphs, 3D models, audio, videos, etc. Over the years, the idea of the growing potential of extended reality has led to a substantial increase of the experimentation linked to it, allowing us to consider also the protection and enhancement of Historic Heritage sectors. On the international level, there are increasingly more studies aimed at the evaluation of the worth and effectiveness of extended reality tools (both VR and AR), which are considered a new opportunity to disseminate knowledge (Ibañez-Etxeberria et alii, 2020). Their effectiveness has often been tested and positively demonstrated by focused research and experiments, targeting visitors of historical assets and museums (Tsai, 2019; Trunfio et alii, 2021). This happened and still happens, because the applications of augmented reality are created to increase the curiosity of the users, thanks to a setting that makes them perceived as useful and at the same time fun to use. Basically, the principles of ‘gamification’ (Swacha, 2021) are put into practice, producing ‘serious games’, helping to transfer knowledge through a playful dimension that encourages more effective and stimulating user experiences (Mariotti, 2021; Ye, Wang and Zhao, 2021).



Together with the purely informative functions aimed at user involvement, the XR supported by other technologies, such as the laser scanner, can be useful tools for the 'virtual preservation' of buildings and historical heritage endangered by the devastating consequences of climate change. They would allow for virtually preserving aspects that could endure irreversible changes and damages, and for helping to create virtual archives for the transmission of stratified information to future generations (Reaver, 2019). The progressive establishment of augmented reality technologies was supported also by the constant evolution experienced in the last twenty years. Initially, the AR apps required bulky and impractical devices, that have gradually evolved up to becoming smartphones and portable devices, which are now accessible to everyone.

One of the first examples of AR application for the Heritage was created within the project Archeoguide (Augmented Reality-Based Cultural Heritage On-Site Guide), launched in 2001 (Vlahakis et alii, 2001; Vlahakis et alii, 2002). An app for Olimpia archaeological site was created, through which the visitors had the chance to see the geolocated reconstructions, correctly placed on the ruin site. Three different devices were available for visitors (laptop, pen-tablet and palmtop), but only the laptop could exploit all the software's functions. Since this technology is at its beginning, using the app complex equipment was necessary: the images were displayed with special glasses, and the laptop was carried by the tourist in a backpack together with batteries and a GPS receiver and other devices. It was necessary to wear a helmet on which a webcam and a digital compass were attached. Bulky and impractical equipment was the constant of the first AR apps developed between the late 1990s and early 2000s.

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Fig. 1 | Drawing by Antonio Curri for the project of the Alberobello Basilica (source: Pignatelli, 2019).

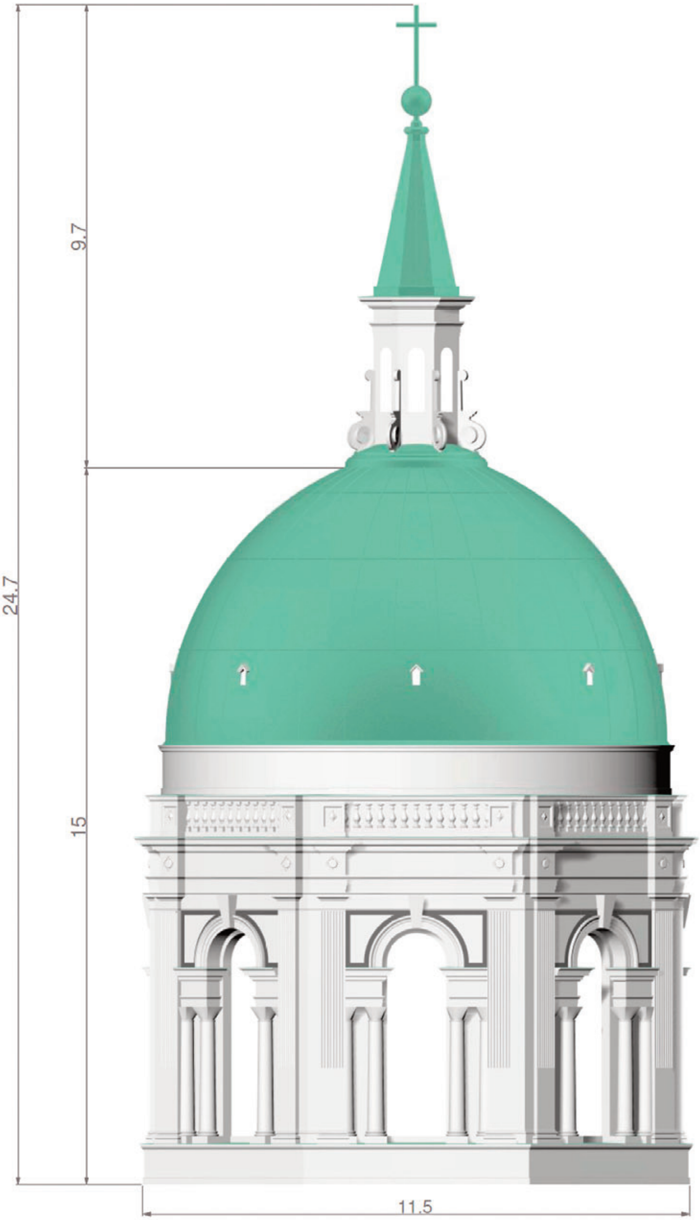
Fig. 2 | Photo of the flat slab at the crossing of the nave and the transept (credit: I. Cavaliere, 2021).

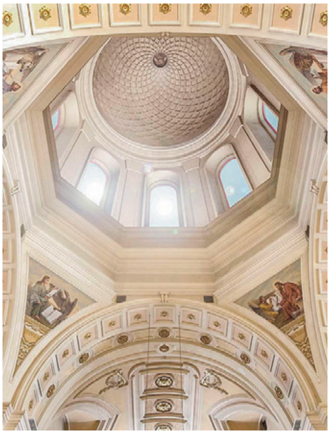
Fig. 3 | Photo of the façade of the Basilica, where the absence of the tholobate is striking (credit: I. Cavaliere, 2021).

Another example is the Augurscope project, developed in 2002 by the Mixed Reality Laboratory in collaboration with the University of Nottingham (Schnädelbach et alii, 2002). It is a dispositive prototype for AR applications, which was made up of a laptop and a webcam assembled together in a special case. The case was mounted on a tripod with wheels to ease the movement from one station to another. Although innovative, it was an impractical and not very versatile object.

With the arrival of smartphones, augmented reality has become a wildly widespread easy-to-use technology, allowing archaeological sites, museums and Municipalities to simplify the integration process of this technology in their Assets, replacing the bulky equipment of the past with apps that anyone can download on their mobile phone. A more recent example, from 2012, was CityViewAR, an app for Android developed after the Christchurch earthquake in 2010 (Lee et alii, 2012). This app was conceived to allow citizens and tourists to view many buildings as they were before the earthquake destroyed or damaged them, through 3D geolocated models, implemented, when needed, with historical photographs and informative texts. Another study, also carried out in 2012, in Norway concerned the use of an augmented reality app called The Historical Tour Guide. Its main purpose was to provide informative texts and historical photographs of cultural assets in Trondheim (Haugstvedt and Krogstie, 2012).

An even more recent example, from 2019, is a study carried out by the Polytechnic University of Milan, that has led to the development of a Mixed Reality (VR/AR) app for the Basilica di Sant'Ambrogio (Banfi, Brumana and Stanga, 2019). It is a complex and stratified work that originated from the study of historical documentation and then





Figg. 4, 5 | Façade and photo-insertion of the new dome (source: Pignatelli, 2019).

shifted to 2D drawings, 3D surveys and an HBIM database. All this knowledge was then moved to the virtual environment, to be viewed partially with a VR visor and partially through AR: reconstructions of the church from different periods, technical drawings, decay maps, etc.

These are just some examples of the countless experiments made on the use of augmented reality. They show the potential of this technology: it gives the chance to see geolocated historical constructions, to virtually preserve Assets that were irreversibly damaged, to simply and easily interact with landmarks and get information on them, to create digital archives containing complex and layered information on a given asset. In general, the common thread underlying these and other experiences is the transfer of knowledge in a new way, involving users more and stimulating their curiosity.

The case study: Basilica SS. Medici in Alberobello | This paper focuses on the Basilica SS. Medici in Alberobello, a monument particularly dear to the community to which it belongs. The cult of Saints Cosma and Damian, which started in Alberobello in the 18th century, has gained great importance over time, in fact, many remodelling and expansion projects of the original worship place were performed where now stands an imposing basilica designed by the architect Antonio Curri, inaugurated in 1885. However, when entering the church, there is a detail striking out: at the crossing between the nave and the transept, the dome was never built. It is present in the original drawings of the project (Fig. 1), but in its place, there is a flat slab (Fig. 2). This affects also the outside, where the tholobate is missing. It should be framed by the two tower bells in the façade (Fig. 3). This absence makes the whole building appear incomplete, so much so that, over the years, the community repeatedly tried to complete Curri's project, but never finished because of a series of static problems that have appeared over time.

Professor Giuseppe Fallacara, together with the Architect Micaela Pignatelli – within the Course of the School of Specialisation in Architectural and Landscape Heritage of the Politecnico di Bari – and the students of the CESAR Advanced Course of the Politecnico di Bari, studied the Basilica and the drawings by Antonio Curri and the design

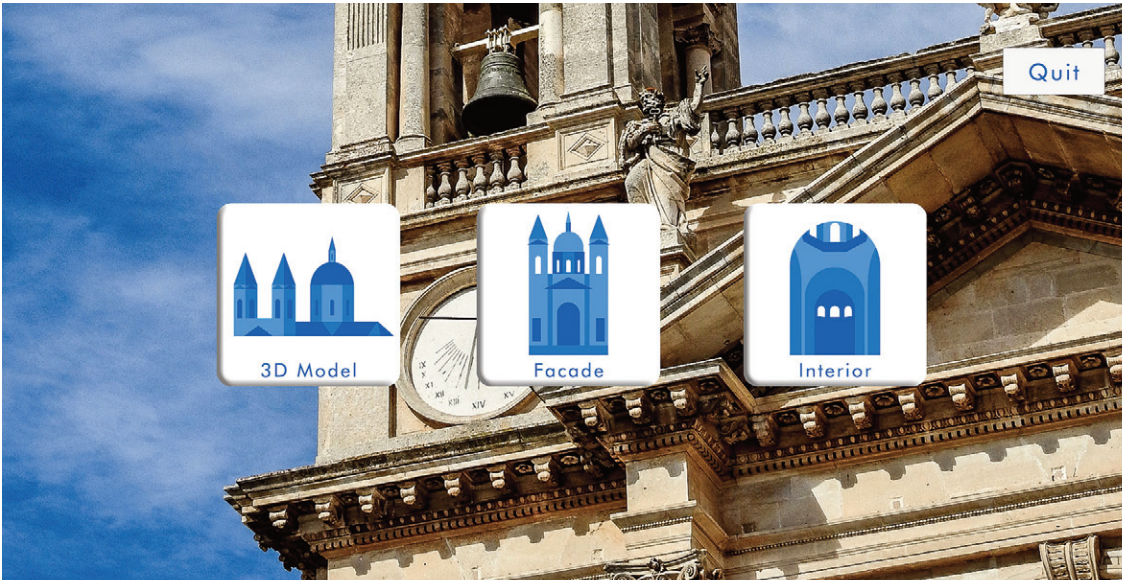


Fig. 6 | Screenshot of the home of the app (credit: I. Cavaliere, 2021).

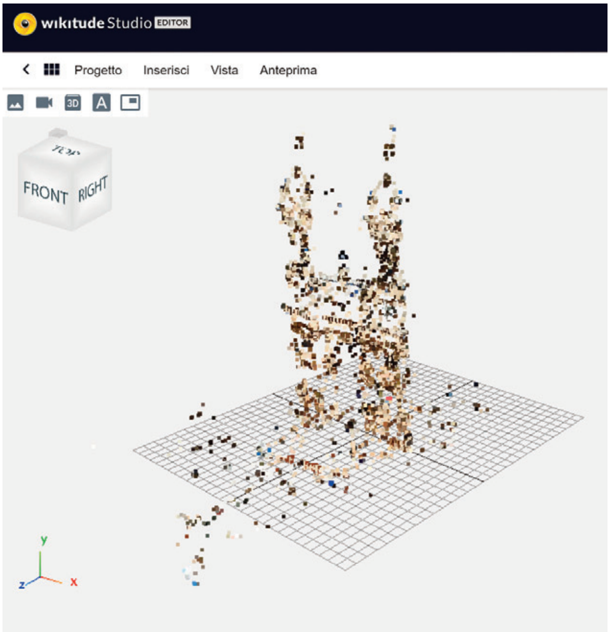


Fig. 7 | Point cloud created with Wikitude Studio (credit: I. Cavaliere, 2021).

of a new dome (Figg. 4, 5). It was created to be as accurate as possible to the original project, with minimal approximations only where the representations were incomplete or unclear – for example in the case of the decorations on the intrados (Pignatelli, 2019). Although the described project was not realised, the interest it generated has led the Author, in collaboration with professor Fallacara, to start thinking about the possibility to enhance its contents and make them available to the community of Alberobello through the potential of new visualisation and design technologies available to architects. In particular, among the extended reality technologies, we decided to use augmented reality because it is currently the most accessible and easy-to-use: to use AM all you need is a smartphone, while virtual reality needs a visor to be enjoyed.

The development of the app | Before starting with the veritable development of the augmented reality app, we thought about its precise aim – to better understand how to structure it – and also about the way to make it known and used by users. As for the first point, the aim is both to give the visitors the possibility to see the dome project on a global scale and to understand how it modifies the sacred space. Therefore, we aimed to obtain a three-dimensional visualisation tool that focuses on the ease of use and immediate communication, which translated into the design of an extremely simple and user-friendly interface, with a limited number of text boxes, photos or other media in order not to make it over-layered.

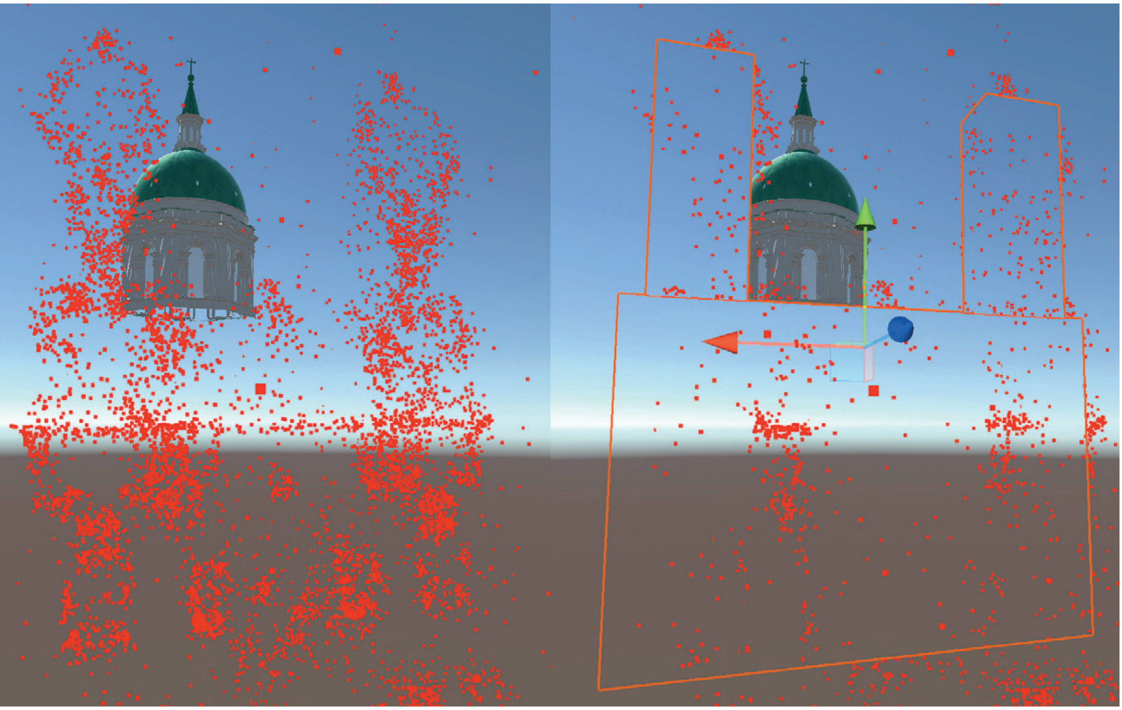
As for the second point, we planned to provide visitors with brochures briefly explaining the project and its context, promoting the app and supporting it. The app was developed for Android smartphones with the 2020 Unity3D graphics engine and the Wikitude plug-in. It was decided to separate the AR experience into three parts: the first consists of globally viewing the dome model, with the possibility to move and rotate it, while the other two parts enable it to be observed correctly positioned from the outside and from the inside, at the crossing of the nave and transept. For each of these possibilities, a 'serious game' level has been reserved, that can be selected in the home (Fig. 6).

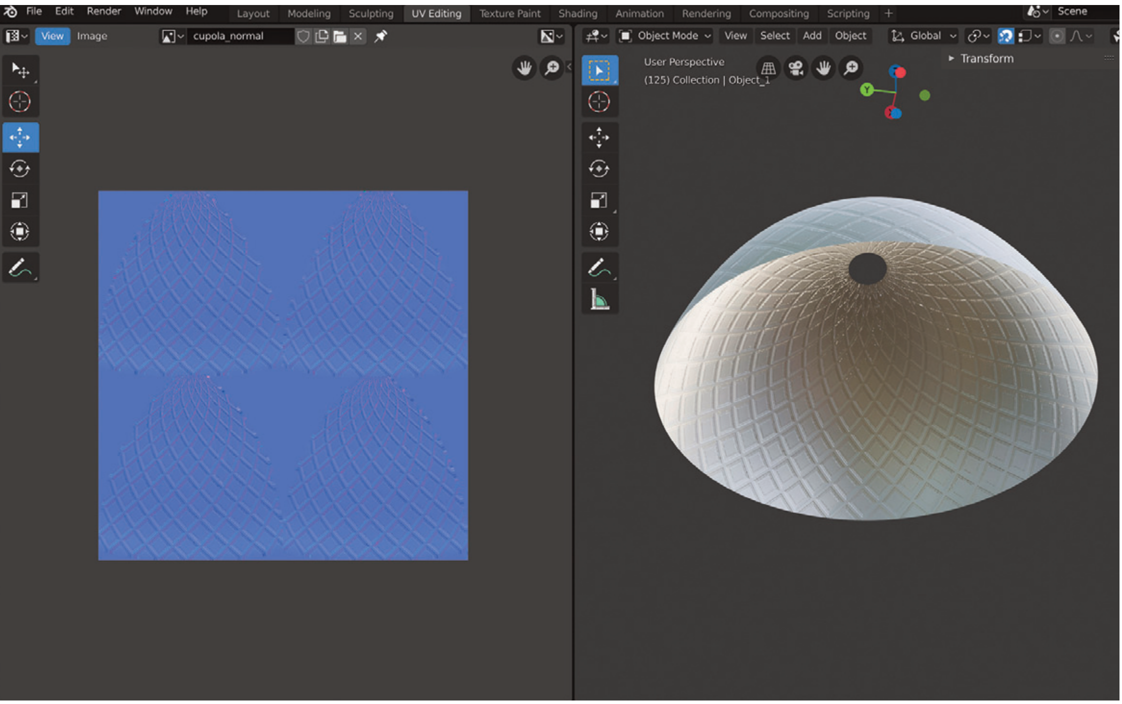
1st level: 3D Model | The development of the first level was based on image tracking, which is a system envisaging the interaction between AR and a 2D image: a photo or a drawing can be printed or viewed on another device, and if you scan them with your smartphone, they become the target for viewing a 3D model or other contents, which are linked to the target, thus following its movements. The image used in this case is the orthophoto of the Basilica, on which appears, correctly placed, the tridimensional reconstruction of the roofing with the insertion of the tholobate that can be studied at 360 degrees simply by moving, tilting and rotating the reference picture to one's preference.

The 3D model of the Basilica roofing used for this level of the app was created with drone photogrammetry. The photograms were processed with Agisoft Metashape and then the model was optimized through Blender. In this way, it was possible to eliminate the 'noise' typical of photogrammetric meshes, the number of polygons was drastically reduced and the topology changed. For the tholobate, it was used as a simplification of the model made with Rhinoceros. The starting 3D model was extremely detailed and included also structural elements that are not visible – for example, the wood load-bearing structure – and, to avoid the excessively large model from affecting the performance of the app, only the external visible parts were kept.

To make the level work properly, Wikitude Studio was used. Starting from the orthographic image of the Basilica, a target was obtained and then imported into Unity3D, where the image tracking was set. To make this level work, it is important having external support from the target image. That is why the above-mentioned brochure can be used. Besides including information on the project and the church, it could show the orthophoto of the Basilica and could encourage to use of the app.

2nd and 3rd Levels: External Façades and Interiors | The second and third levels, are based on object tracking technology, which allows obtaining the point cloud of an object starting from a series of photographs. The point cloud enables the graphic engine to recognize the volumes of the object that, when scanned with the smartphone, become the target for an AR interaction. In this case, it was employed the possibility given by Wikitude to use photos of interiors to convert the simple object tracking into scene tracking, so that the app can recognise the walls and architectural element volumes of the Basilica, in order to view the dome placed where it should be and understand how the perception of the church changes.

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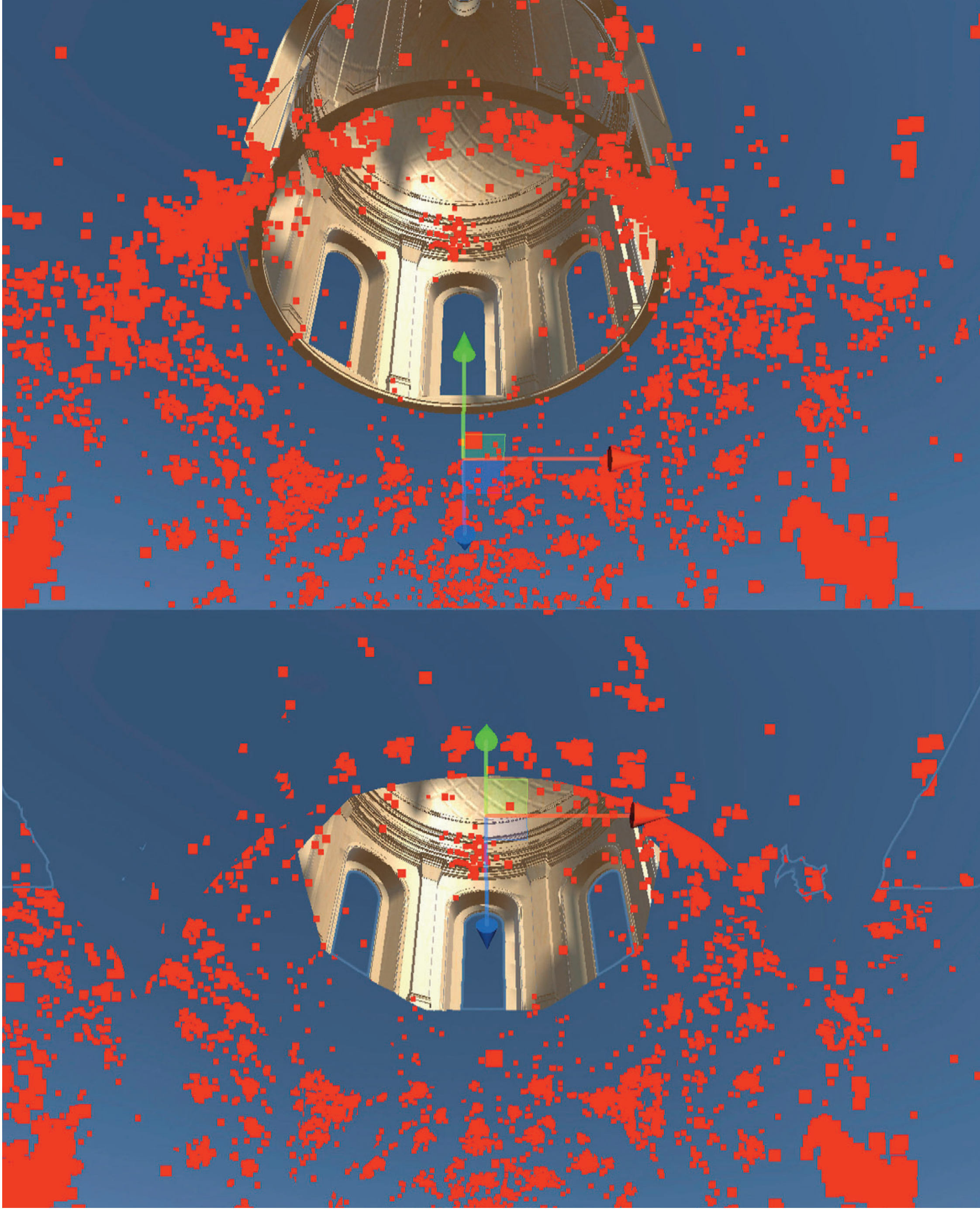

Fig. 10 | View the difference of the tholobate in Unity3D editor before and after adding one occluder before the vault (credit: I. Cavaliere, 2021).

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Fig. 8 | View the difference of the tholobate in Unity3D editor before and after adding occluders on the façade and bell towers (credit: I. Cavaliere, 2021).

Fig. 9 | View of the dome optimized through Blender thanks to the transformation of the surveys into a normal map (credit: I. Cavaliere, 2021).

Firstly, we dealt with the main façade, that is the south one. Fifty photos were taken – the maximum limit allowed by Wikitude – starting closer to the Basilica and moving on the west and east sides – to get close-up images from different points of view and allowing the software to obtain a three-dimensional reconstruction of the façade – and repeated the process, moving away progressively. Then, the images were processed through Wikitude Studio to obtain a point cloud (Fig. 7), imported as file tracking in Unity3D. In the graphic engine, the tholobate was scaled and correctly placed – the same model used for level 1 – and also the occluders were added before the façade and bell towers. An occluder is a geometry that is assigned a particular material and hides all objects positioned behind it, but is transparent (Fig. 8). The aim is to simulate the real volumes of the Basilica so that they show or hide the dome depending on the point of view.

A similar process was used for the inside: fifty photos were taken of the slab at the crossing of the nave and transept, a point cloud was created with Wikitude Studio and it was imported in Unity 3D. To simulate the dome we have always started from the Rhinoceros model, but this time only the visible parts of the intrados – the inner wood cladding – were kept. To make another simplification, instead of keeping each ceiling coffer, their embossments were turned into a normal map[1] projected on a simple spherical cap[2] (Fig. 9). The outline of the whole vault obtained by photogrammetry was used as an occluder. The 3D model obtained with Metashape was optimized with Blender as it was done for the outside and in Unity3D it was scaled and placed with the dome so that it adapted to the point cloud (Fig. 10). By accessing one of these levels and scanning the Basilica façade or the indoor area with the smartphone, the dome will be displayed at its correct place and it will be possible to overcome the current impression of incompleteness (Figg. 11, 12).

Conclusions | In conclusion, after a thorough analysis of past studies concerning augmented reality and cultural Heritage, it was attempted to give an answer to Alberobello citizens, restoring, at least virtually, their Basilica at its full, producing a creation very similar to the design conceived by architect Antonio Curri. The significant difference between this experience and others carried out in the same field is the final aim of the obtained application: most extended reality app for Cultural Assets aims to give the users objective information and reconstructions or to visually preserve artefacts. Therefore, they are responsible for a ‘knowledge transfer’ following different modalities from the conventional ones (written panels, audio guides, etc.).

The app described in this paper, conversely, does not aim to convey ‘what existed in the past’ but ‘what could have existed’, since the dome presented is not the reconstruction of a real space, but of an idea. Although meticulously based on architect Curri’s original design, in some cases, this reconstruction presents unavoidable changes due to the accuracy levels of the design drawings found. The aim is not only to show users a space similar to the one originally designed – partially reducing the sense of

Figg. 11, 12 | View of the dome correctly fitted on the façade and inside with the developed app (credits: I. Cavaliere, 2021).

incompleteness the visitors perceive observing the Basilica inside and outside – but also to start critical reasoning and, consequently, a debate involving the whole community of Alberobello and that concerns also the possibilities and consequences of an actual architectural project for the church. This might lead to considering augmented reality technologies as a tool to foster the involvement of citizens in the field of architectural and urban projects concerning their community. As stated above, the app developed can be easily used by anyone with a smartphone and the possibility to preview the project – without physically touching the artefact – and interact with it, makes it especially fit for purpose.

The limit of this application, however, is especially the type of information conveyed. To be more immediate and clearer for everyone, the information is mostly visual, linked to the need to create a suggestion in the viewer. Because of that, this app is suited to start a debate or, to foster it in the initial stages, because delving into it would require a greater stratification of information, according to models already considered within this paper (addition of photographic documentation, decay and issue maps, etc.). The hope for the future development of this research is to make the app available to the community and evaluate the feedback from the users, by direct observation and the help of purposely prepared forms. As a result, strategies to improve and stratify the app could be implemented, fostering the debate and considerations within experimentation that is not the work of one person only but a shared experience.

Acknowledgements

The survey of the external and internal vault of the church was carried out by the Geologist Gianluca Fallacara. For the first case, a drone was used, and for the second a stereo camera.

Notes

1) A normal map is a colour texture that provides information about the textures of a surface in all three directions of space.

2) For this project, Blender was used, by baking a normal map. It is an operation commonly used to obtain low-poly 3D models – suited for AR, VR applications or in general for real-time rendering – starting from 3D detailed models. The detailed model (called 'high-poly') and the simplified one (called 'low-poly') are superimposed and the textures of the first are 'projected' on the second as a normal map. By implementing this texture to the lowpoly, the embossments will only be displayed as a visual effect, allowing the use of a light model, that does not affect the performance of the project.

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