SCIRES it
SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 12, Issue 2 (2022), 55-68
e-ISSN 2239-4303, DOI 10.2423/i22394303v12n2p55

CASPUR-CIBER Publishing, http://www.sciresit.it

FROM 3D SCANNING TO VIRTUAL TOURS FOR THE FRUITION OF ARCHITECTURAL HERITAGE. THE CHURCH OF SANTA MARIA DELLA PURITÀ

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Abstract

The present report deals with the research area concerning the use of ICT for the fruition of inaccessible heritage. To overcome this condition, the application of cognitive surveys through integrated and expeditious surveying techniques has proved to be very useful. In particular, the application presented here concerns the church of Santa Maria della Purità in Giugliano in Campania, a valuable example of Baroque sacred architecture built on the projects of the famous Neapolitan architect Domenico Antonio Vaccaro, closed to the public for 27 years due to deteriorating conditions. The survey made use of different technologies and had different purposes: the documentation of the geometry of the building, a first analysis of the deteriorating conditions of the structure, and finally the creation of a virtual tour to realize a new form of accessibility with innovative perceptive and informative modes.

Keywords

Inaccessible architecture, digital survey, 3D models, virtual tour.

1. *Introduction*

In recent years, the development of networks and the widespread diffusion of Internet accessibility, in parallel with the development of low-cost technologies for data acquisition and the production of digital three-dimensional models with lightweight and easy-to-use tools, led to a strong increase in experimentation on ICT (Information and Communication Technologies) for the fruition, enhancement and promotion of cultural heritage (Addison & Gaiani, 2000). The impossibility of visiting museums and cultural institutions in the pandemic years then led to a further acceleration in remote fruition strategies. Traditional modes of interaction between museum and visitor have been rethinked, freeing them from spatial and temporal boundaries (Gambino, 2021). Digital networks have been transformed from methods of promotion into tools of knowledge, through a wide range of digitized collections, workshops, educational activities, and digital guided tours (Montagud et al., 2020). Since the use of ICTs for the enjoyment of cultural heritage has mainly been aimed at tourism, most applications concern museums or archaeological sites. The architectural heritage in its intrinsic value, and not as a mere container of artworks, has also been object of interesting applications (Bekele et al., 2018). Virtual tours concerning religious architecture, such as the one presented in this article, are also mostly aimed at tourism, and thus mainly concern the destinations of pilgrimages and religious events. The use of ICT in this field includes applications for the knowledge of religious buildings to communicate an often very relevant heritage from an architectural and cultural point of view to users with different backgrounds and interests, using a simple language and focusing on the emotional aspects for the knowledge of the heritage (Ramos & Mafé-García, 2019).

The case study presented here fits into the field of research related to the use of ICT for the fruition of inaccessible places (Nicolas et al., 2015). Inaccessibility of architectural heritage is a condition that is quite widespread in our territory for several reasons: catastrophic events; material degradation with consequent danger to the safety of visitors; presence of provisional works for maintenance or restoration; regulations that prevent fruition; lack of surveillance personnel. To overcome this condition, the application of surveys through integrated and expeditious surveying techniques has proved very useful. Such tecniques ensure an adequate flow of information

collection even in contexts that are totally or partially physically inaccessible, with a level of data accuracy consistent with the formulation of subsequent recovery interventions. At the same time, they are useful for understanding and interpreting the cultural practices that generated the heritage (Fassi & Perfetti, 2019). The issue is part of the broader debate about inclusion, accessibility and innovation as cornerstones for the sustainable development of the future city. Cultural heritage should be a priority pole of interest for stimulating processes of knowledge, appreciation and active citizen participation (Kosmas et al, 2020). Accessibility should be interpreted not only as the possibility of physically visiting the buildings, but also as the ability to remove non-physical but informational barriers to the access. The feeling of cultural inadequacy of visitors in the face of objects or sites can be removed structuring the cultural route to amplify the potential of attraction to audiences less receptive to traditional types of cultural proposals (Prentice, 1994). Improving informational accessibility, in the sense of making paths suitable for those who feel potentially interested but culturally inadequate to understand the content as it is traditionally displayed and presented, can bring enormous benefits in terms of educational contribution made by cultural heritage to the community. In this sense, ICTs have proven to be highly engaging, interactive and customizable tools for differentiated access according to the interests of the individual user (Medri & Canonici, 2010). Applications in virtual reality, augmented reality, and digital simulations make it possible to overcome the spatial barriers determined by the works' container. Virtual or mixed environments can communicate information related to the artwork or allow to navigate it through spectacular and engaging spatial and temporal simulations (Kabassi et al, 2019). Their potential is proving to be of great interest for the interpretation, fruition, and enhancement of architectural heritage as well as the applications for museums (Spallone & Palma, 2021).

2. *The church of Santa Maria della Purità*

The research presented here concerns the church of Santa Maria della Purità in Giugliano in Campania, a fine example of Baroque sacred architecture built on the designs of the famous Neapolitan architect Domenico Antonio Vaccaro. The church has been closed to the public for 27 years due to the danger of falling parts of stucco and plaster, damaged by copious water infiltration, and has lesions on the intrados of the dome. The survey, carried out with expeditious techniques for safety reasons, had different purposes: the documentation of the geometry of the building, a first analysis of the deteriorating conditions of the structure and the cladding, and finally the creation of a virtual tour to make accessible at least virtually an important testimony of Baroque sacred architecture, while waiting for a desirable restoration that could also physically return it to the collective fruition.

2.1 Historical background and present conditions

The church of Santa Maria della Purità, also known as church of the Souls in Purgatory, stands in Giugliano in Campania, with its façade facing north on Corso Campano. Priest Fabio Sebastiano Santoro, in his book "Scola di canto fermo..." of 1715, in which he also provides news about the churches and convents of Giugliano, traces the church's origin to the habit of the faithful of praying to Our Lady of Purgatory at a votive aedicule on the site where the church now stands (Santoro, 1715). At the foot of the shrine were a multitude of souls in Purgatory, hence the church's double name. This was erected thanks to donations collected from the faithful, based on a project by Domenico Antonio Vaccaro. He was one of the best-known architects of the Neapolitan eighteenth century and also designed the interior stuccoes and the covering of the extrados of the dome. The foundation stone was laid in 1700, while the completion and inauguration of the church are dated to 1747 (Basile, 1800). Later, in 1765, the bell tower was erected, and the façade completed to the drawings of engineer Domenico Gaetano Barba. He also authored the historical plan that illustrates the church's interior and surrounding rooms and is a valuable testimony of the geometry of the church at the date of 1763.

The church is in a state of deterioration caused by an absolute lack of ordinary maintenance, for which it was closed by order of the Fire Department in 2005 due to the danger of falling parts of stucco and plaster, and to this day access is still prohibited. Inside, key lesions can be seen on the intrados of the segments of the dome, due to the weakening of the masonry by copious water infiltration at the impost. It is evident that the masonry is impregnated with water in large portions. This phenomenon, combined with the

presence of copious vegetation, results in the crumbling and detachment of large portions of plaster and stucco, particularly during the rainy season and the subsequent drying phase of the masonry in the dry season. The lesions present on the surfaces of the segments of the dome, arranged along the meridians, are probably caused by the cyclical settling of the tuff masonry, which is subject to alternating water infiltration and drying. It is greatly affected by the physiological alternating movement of swelling and retraction. On the extrados of the dome, on the other hand, the absence of portions of majolica tiles replaced by cladding and the considerable presence of vegetation are noticeable. The facade also presents a high rate of degradation due to the corrosive power of atmospheric agents and smog from cars on the main street of Giugliano, resulting in the creation of moisture stains, gaps, chromatic alterations, deficiencies, and superficial deposits (fig 1-2).

Fig. 1: Degrade conditions of the façade of the church of Santa Maria della Purità. Photography by Mario Ronca.

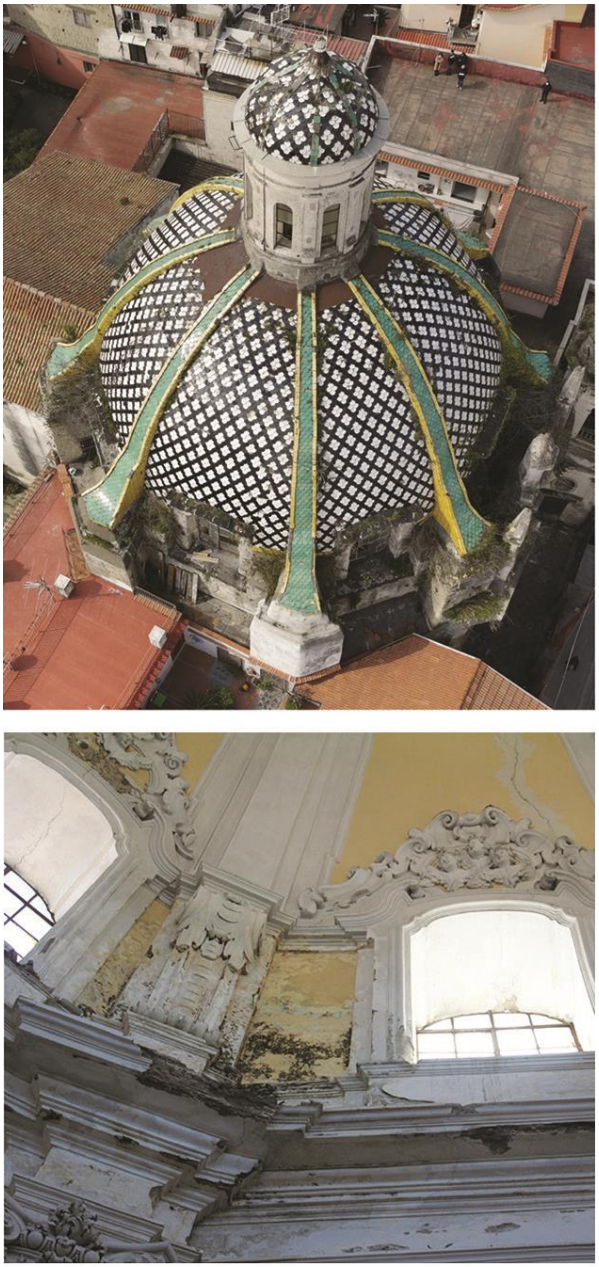

Fig. 2: Degrade conditions of the extrados and intrados of the dome. Photography by Mario Ronca.

3. Methodology

Due to the unsafe conditions limiting the stay inside the church, the use of expeditious data acquisition procedures was opted for (Reznicek & Pavelka, 2008). The survey was carried out through the integration of two instrumentations: the drone survey of the exterior, which was mainly useful for documenting the extrados of the dome, the bell tower, and the façade; and the terrestrial laser scanner survey for acquiring data about the interior of the church. In both cases, state-of-the-art instrumentation was used, with easy operation,

good accuracy and short time frames. These instrumentations, which were useful for the documentation phase of the building's geometric characteristics and conservation status, were then joined by another three-dimensional scanning activity using image-based technology to create the virtual tour of the church (Manferdini & Remondino 2012).

On the operative side, the survey was first achieved to the acquisition of external data through the drone survey, and then to the data related to the interior of the church. The first task

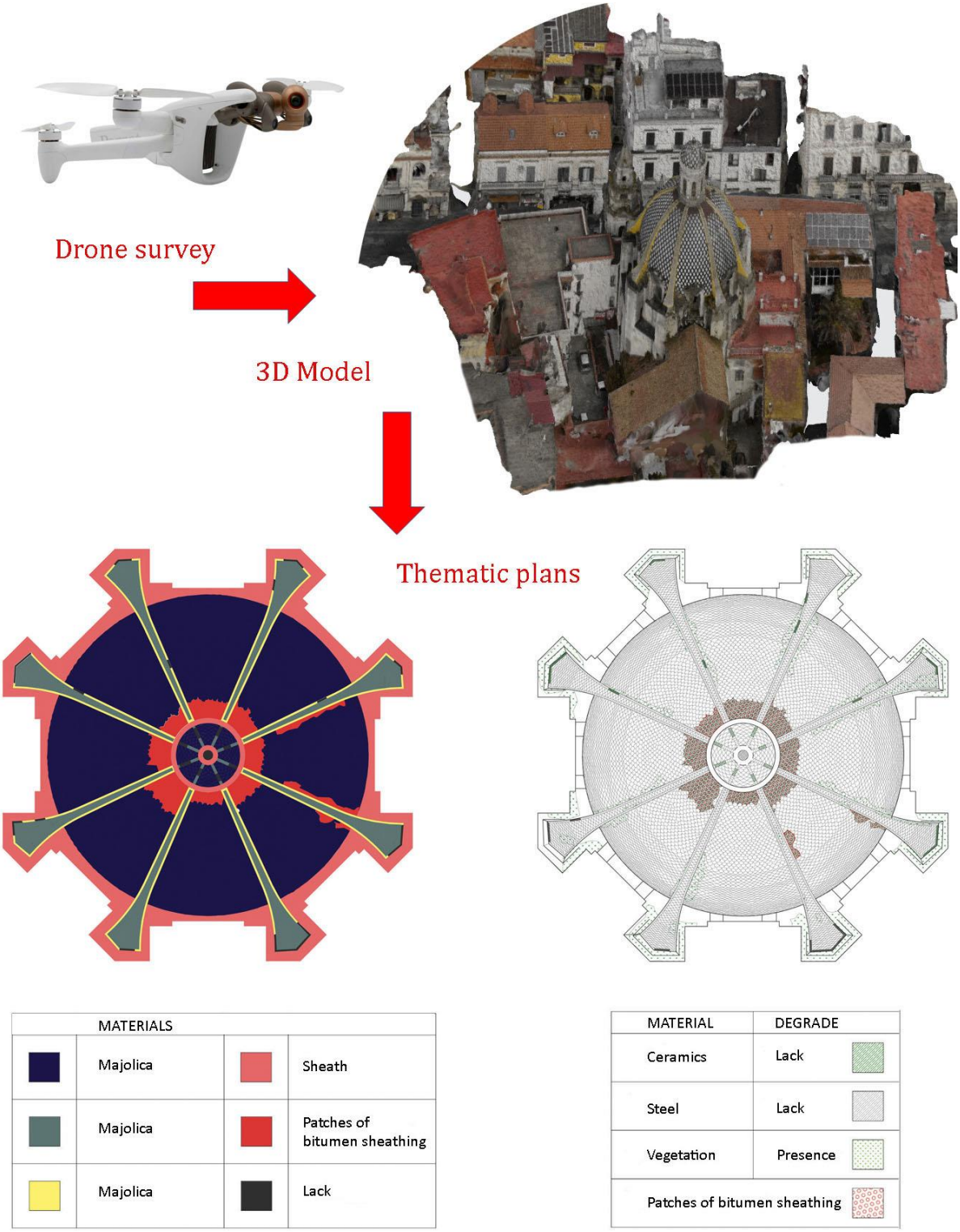

Fig. 3: Survey workflow. Drone survey and related outputs. Drawings by Mario Ronca, supervisor Manuela Piscitelli.

was to develop a flight plan necessary to ensure an optimal coverage, in terms of survey, of the investigation area. The planning followed well-established procedures regarding the camera focal length, the image resolution, and the distance of the instrument from the subject to be photographed (Tumeliene et al, 2017). A set of digital frames of the object taken in sequence and with an appropriate overlay was acquired. The fusion of the photographic shots through matching points was performed through an automatic image matching procedure, which allows the extraction of many matches between different images. The superposition of the points thus identified allowed the frames to be fused to obtain a three-dimensional model in the form of a points cloud. It can be comparable to that obtained through survey techniques with active optical sensors such as laser scanners. (Pierrot-Deseilligny et al, 2011).

The drone model used is the "Parrot ANAFI Ai". During the flight, the drone sent images directly to *Pix4D cloud* for further processing. This was performed with *Pix4Dmapper* software, which can automatically generate DSM, orthophoto, point cloud and meshes. During the image fusion process, the software also eliminates the perspective deformation present in the images due to the low altitude of the shots. In addition, the drone's equipment with an internal GPS makes it possible to determine the spatial position and the camera attitude when the images were captured, so that the subsequently processed orthophotos are georeferenced (Luhmann et al, 2014). The obtained orthophotos highlighted the presence of vegetation and areas affected by degradation and gaps in the tiled covering of the dome. The elaboration of this information produced thematic plans related to the materials and degradation of the dome's extrados represented according to the current norms (fig. 3). The same operation was carried out on the facades, with better results than the terrestrial laser scanner, which could not get a complete coverage due to the height of the building and the reduced space for imaging (fig. 4). Again, from the acquired and reprocessed data it was possible to produce thematized elevations with the materials and the degradation map.

Instead, for the survey of the interior of the church, the use of a terrestrial laser scanner was chosen, whose output is once again a three-dimensional model in the form of a point cloud (Remondino, 2011). The instrument used was the "Leica Cyclone register 360 Edition BLK," a light and handy scanner, chosen for its speed of acquisition in a context such as the one described where the time spent inside the building was limited due to the risk of falling parts of stucco and plaster. The first task was to establish the most appropriate station points to avoid the presence of visual obstacles and cover the entire area of interest. Twelve station points had to be used for a complete mapping of the structure, from which as many acquisitions were made. The appropriately georeferenced point clouds were then superimposed on each other, and through cloud decimation operations and removal of unwanted points, a single three-dimensional model useful for interpretation of the artifact was obtained (fig. 5) (Yang & Zang, 2014).

The surveys conducted in this way made it possible, with reduced cost and time, to obtain a documentary basis to be used for a desirable future restoration of the building, with a level of accuracy considered adequate at this stage, which does not include the drafting of an executive restoration project. The availability of a survey at the date may also be useful for monitoring the possible progression of the level of deterioration of the structure in the absence of an appropriate conservative restoration, through the comparison of orthophotos and models related to the current conditions with surveys that may be carried out in the coming years.

The survey drawings described are addressed to a specialistic knowledge of the artifact. Since the building has been inaccessible for many years, we also wanted to use three-dimensional surveying technology to create a navigable model dedicated to a virtual tour of the church, to return it at least virtually to the community's enjoyment, in a perspective of knowledge and reappropriation of cultural heritage (Cetorelli & Guido, 2017).

The creation of the tour started from a surveying activity with another instrument: the “Matterport Pro2 3D Camera”, a three-dimensional survey camera capable of automatically capturing 360-degree photographs and 3D data of the environment using infrared structured-light sensors. To cover the entire area, several scans with an appropriate level of overlap must be made. For this, scan points have been set at a maximum distance of 4 meters from each other. The specific software then automatically aligns the scans and uploads them to the cloud for the 3D model generation.

Thus, this technology requires little technical

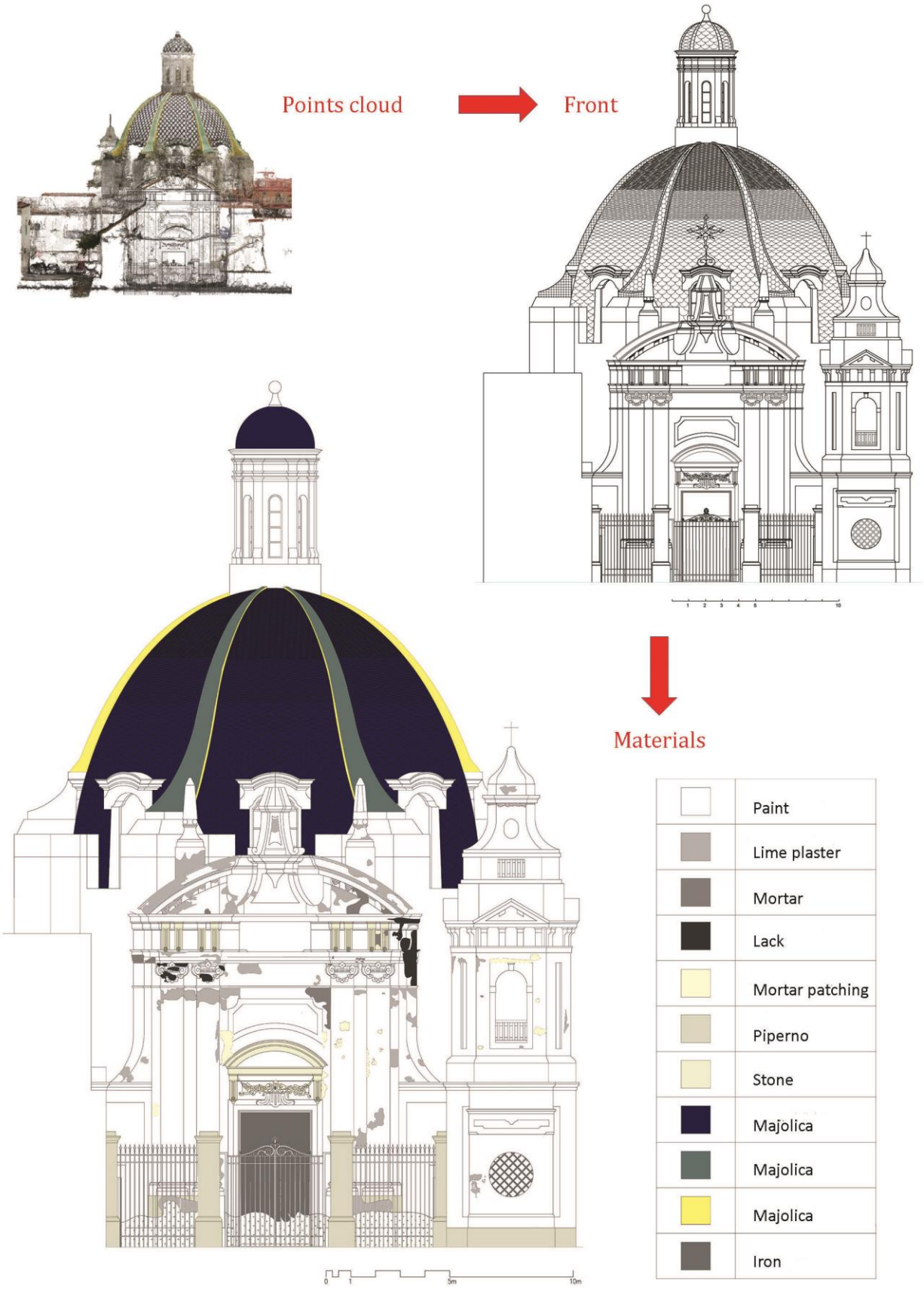

Fig. 4: Survey workflow. From the points cloud to the drawing of the church front and the thematic representation of materials. Drawings by Mario Ronca, supervisor Manuela Piscitelli.

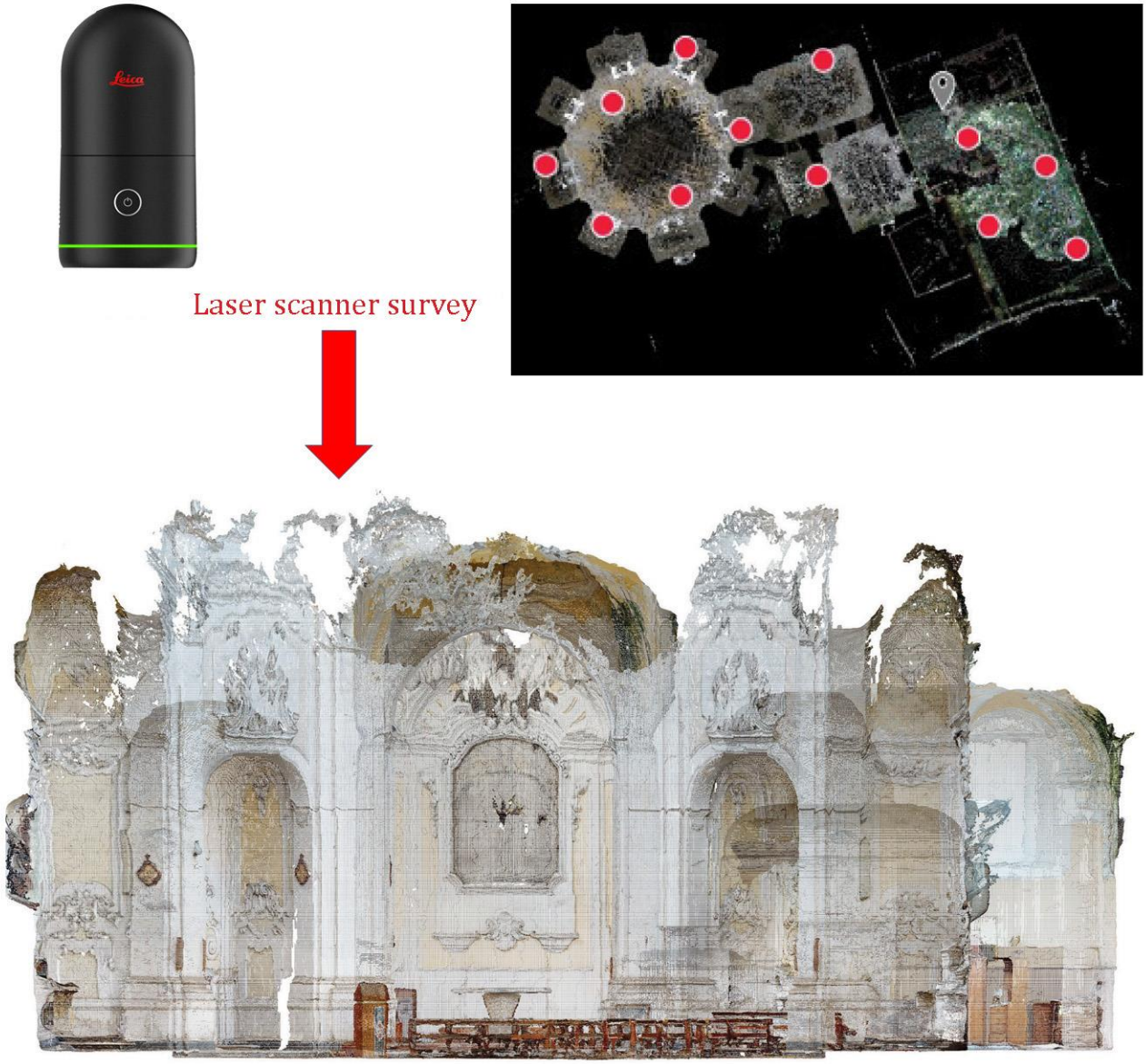

Fig. 5: Survey workflow. Laser scanner survey: station points and section. Survey by Mario Ronca, supervisor Manuela Piscitelli.

expertise. It allows users to obtain a model that can be navigated interactively, with extremely reduced time compared to traditional technologies, both in the survey and data processing phases (fig. 6). The resulting virtual tour can be enjoyed from any device via web browser, maintaining the same interface on both desktop and mobile versions, and can be enriched with various information and multimedia content using hotspots. It can also offer a fully immersive navigation in VR mode, through a visor and a dedicated app to be installed on the mobile device or directly from the web browser. This immersive mode exploits the eye interface, so that it is sufficient to stare at the hotspots for a few seconds to interact with the surrounding space and to move between environments. In the example of the church of Santa Maria della Purità (fig. 7), it was decided to dedicate the hotspots at the visualization of the artistic works that were removed from the church to preserve them from the decay afflicting the building. In such way, visitors can have an idea of how the church originally appeared. So, the virtual tour informative content involves historic notes and adds the temporal dimension by comparing different moments in the building's history.

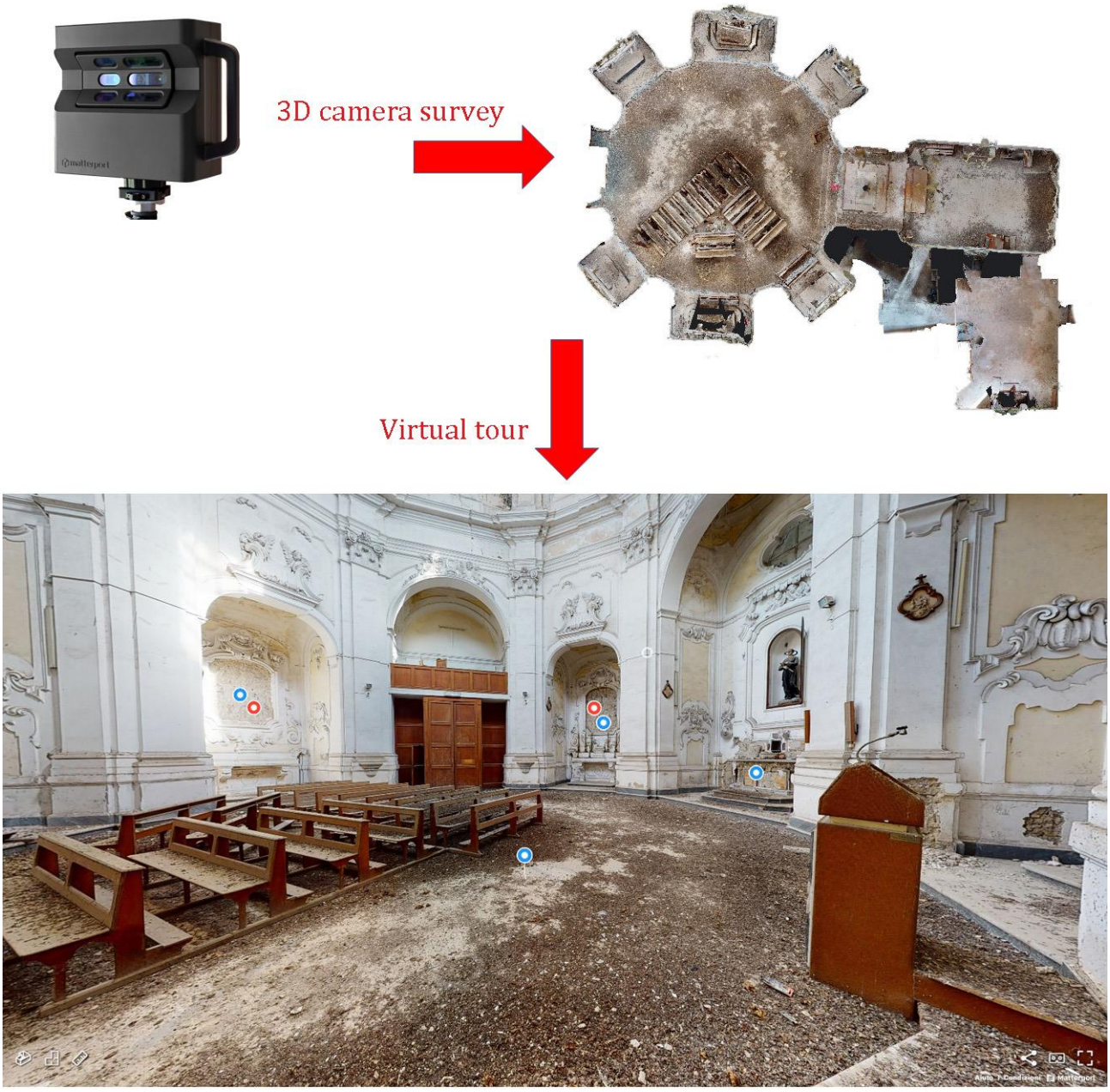

Fig. 6: Survey workflow. From the 3D camera survey to the virtual tour. Survey by Mario Ronca, supervisor Manuela Piscitelli.

Other information content concerns more in-depth notes and archive documentation, such as the historical plan created by engineer Domenico Gaetano Barba in 1763. Through the inclusion of these additional contents displayed on demand, the fruition is enriched compared to a real visit. It can be customizable through elements that each user can access according to his or her own interests (fig. 8-10). Virtual fruition leads, in this way, to an 'extended' perception of reality, through multisensory, emotional and intellectual stimulation, seeking a connection between the user's perception and the historical-narrative background that accompanies the architecture (Silva & Teixeira, 2021).

Navigation starts from the building plan, from which you can directly access the environment you want to visit. From there you can continue the navigation by moving to other adjacent rooms or return to the overall view. You can also use the measurement function to find out the dimensions of parts of the building or objects in it (fig 11).

Fig. 7: QR code to access the navigable model of the church of Santa Maria della Purità.

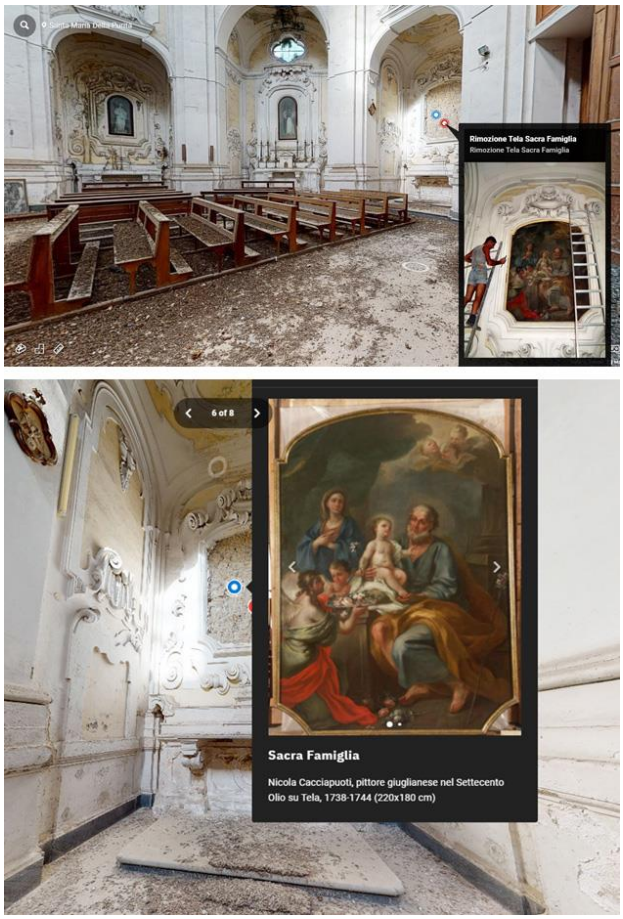

Fig. 8: Information hotspots dedicated to the painting of the Holy Family by Nicola Cacciapuoti (1738). Photograph of the removal and the painting. Image research by Mario Ronca, supervisor Manuela Piscitelli.

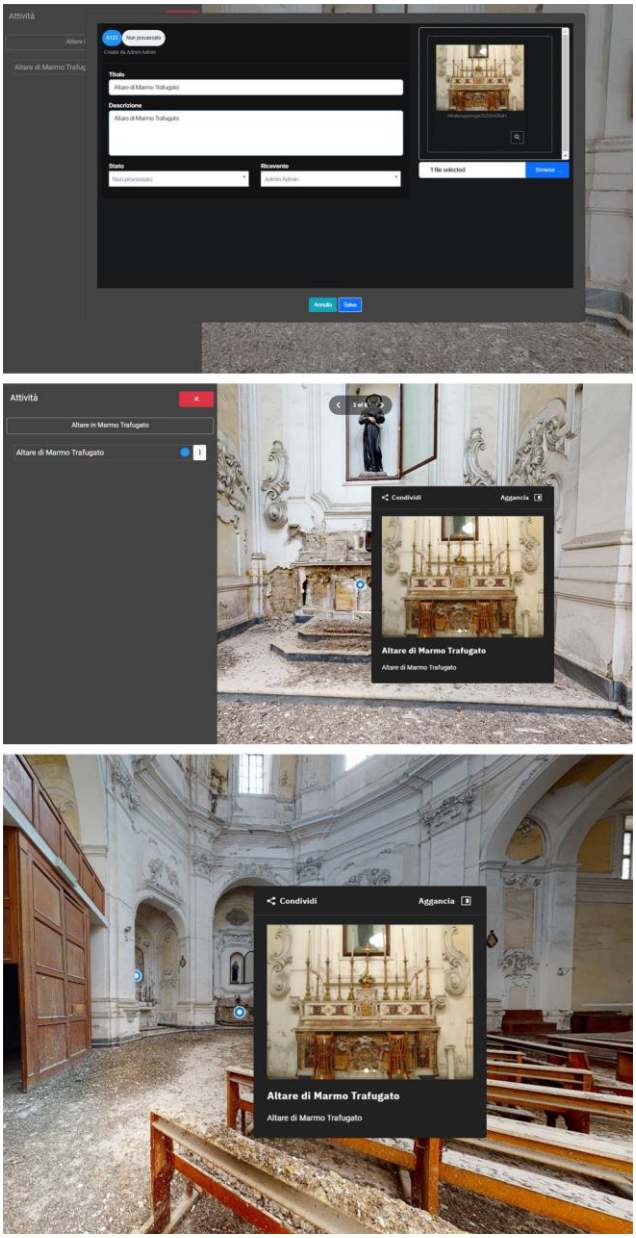

Fig. 9: Creation and visualization of an informative hotspot concerning a stolen altar.

Fig. 10: Tridimensional view of the navigable model.

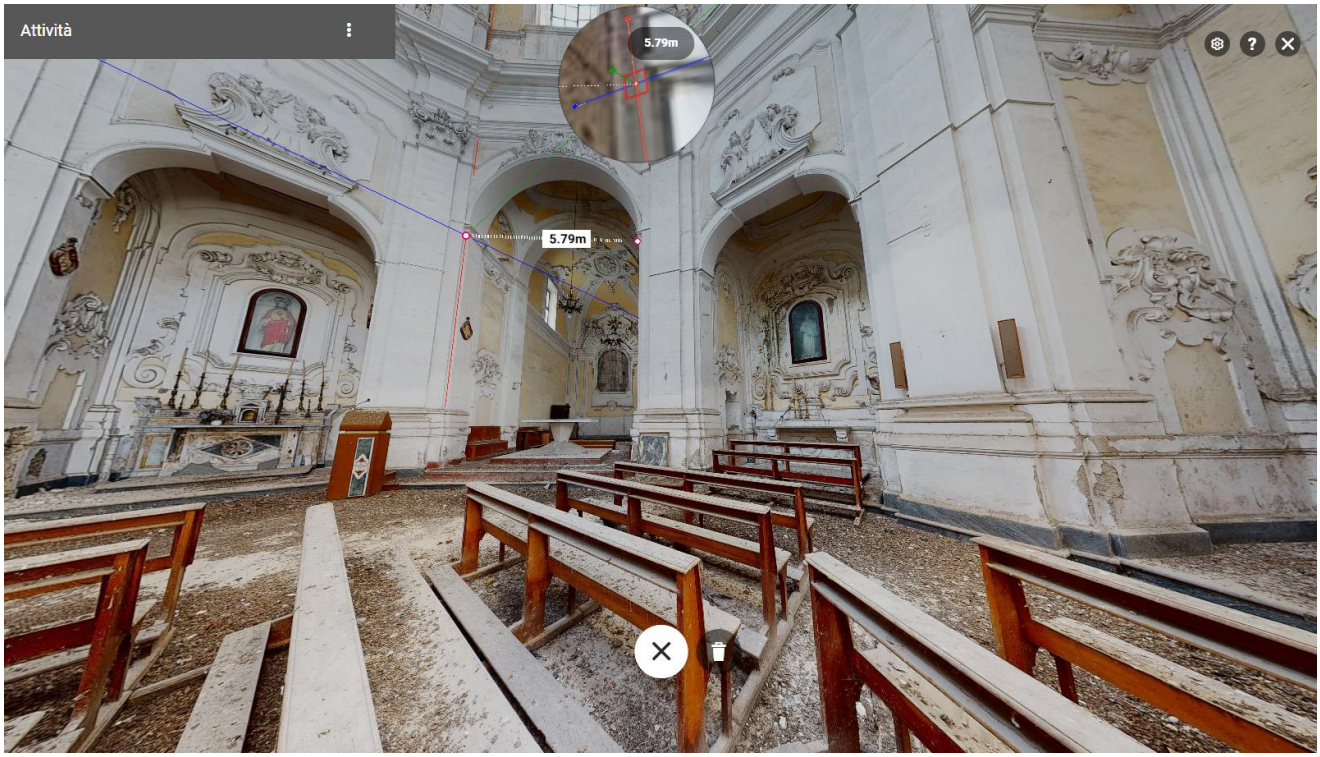

Fig. 11: Measurement function in the virtual interactive tour.

4. *Discussion of results*

Compared to traditional manual survey methodologies, the benefits obtained from the use of the instruments and procedures described are: a) the time factor, which was fundamental in this case considering the dangerous conditions inside the church; b) the extremely reduced costs due to the rapidity of data collection; c) the possibility of surveying parts of the building that could not be reached through a manual survey, such as the dome; d) the simultaneous acquisition of metric and photographic data, which is useful for interpreting the materials and building's condition of degradation; e) the several output possibilities of the 3D model, from the production of damage maps for a specialist use to the creation of virtual tours for tourists.

From a geometric point of view, it has been confirmed that the octagonal plan is indeed the intersection of two Greek crosses, of which the one on the larger side is on an axis with the entrance, and the one on the smaller side is rotated 45 degrees with respect to it. These characteristics are in accordance with the historical plan drawn up by engineer Barba. Regarding the conditions of degradation, it was possible to estimate their entity and obtain thematic drawings useful for the future elaboration of a preliminary project of conservative restoration. Finally, the survey has been an opportunity for a broader reflection about the opportunities offered by ICT for the fruition of the inaccessible architectural heritage.

Given the ease of use of this technology, which does not require great expertise from a technical point of view in the transition from three-dimensional scanning to a navigable model, attention in the creation of a virtual tour should be focused on defining the informative contents. They should be designed to engage users and respond to their interests. To this purpose, it is appropriate to keep in mind the experiences that are associated with the physical enjoyment of a cultural heritage site, and which can also be a reference in the design of a virtual tour. The types of experiences seeked by visitors are: *Recreational experience*, through free and unstructured activities that can be carried out at certain times during the visit; *Socializing experience*, which refers to the possibility of meeting other visitors, socializing, sharing impressions, and exchanging ideas; *Educational experience*, which involves gathering and acquiring information by stimulating curiosity and discovery; *Aesthetic experience*, to be enjoyed through immersion in different forms of sensory perception by letting one's senses take over;

Celebratory experience, in observing works in celebration of a historical figure or event; *Exciting experience*, such as admiring with interest and wonder, empathetic and imaginative transport, to the point of arousing emotions (Kotler & Kotler, 2004).

An adequate planning of the virtual tour, not limited to a single building but systematized in a thematic network to compare different edifices, build one' s own narrative and compare it with the ideas of other users, can be a stimulus to activate the different types of experience and return inaccessible cultural heritage to its function. In this direction, the virtual tour of the church of Santa Maria della Purità was created with the same technology used for the church of the Pio Monte della Misericordia in Naples. whose virtual visit was already available on the web. This will allow in the future to create a connection between the two churches within a path dedicated to religious buildings in the Naples area. The chapel of the Pio Monte della Misericordia in Naples, in fact, was the model from which Vaccaro drew inspiration for his design, taking up the octagonal plan on which the dome is grafted and the composition of the side chapels. The possibility of comparing the two works may be a further added value in the perspective of an extended fruition where the virtual dimension becomes a new and captivating cognitive dimension (fig. 12).

5. Conclusion

The creation of virtual tours can facilitate the reintroduction into the circuit of cultural enjoyment of important testimonies of historical and architectural heritage that risk oblivion due to their inaccessibility. If properly enhanced, they can represent important elements in strengthening the cultural identity of the local community. Indeed, access to heritage is a primary need, deeply linked to the exercise of critical thinking and the functions of imagination, aesthetic experience, and identity construction. Among the benefits of the availability of virtual tours is the knowledge of places, which consequently can stimulate the growth of the tourism market (Huang et al., 2016). But it is primarily the local community that should be involved in operations of reappropriation of forgotten places. Historical religious buildings, such as the case study presented here, are more susceptible than other valuable architectural types to abandonment and consequent inaccessibility caused by social and economic changes that make their maintenance impossible. On the other hand, they are buildings that witness local history and traditions, and strongly identification points for the community. As such, they should be enhanced encouraging processes of social interaction and cultural interconnection. Experimented procedures have shown that it is possible to obtain navigable models of great perceptual impact through expeditious surveys with low costs. Their use allows to quickly retrieve the lost accessibility. At a later stage, after and appropriate restoration to retrieve physical accessibility as well, the virtual tour can be a useful complement to the physical visit thanks to the added value of the informative component described.

6. Credits

The surveying and modeling activity in the church of Santa Maria della Purità was carried out by Mario Ronca as part of the thesis for a master's degree in Architecture, supervisor Manuela Piscitelli, May 2022. We would like to thank engineer Antonio Iannuzzi of the Analist group for his collaboration.

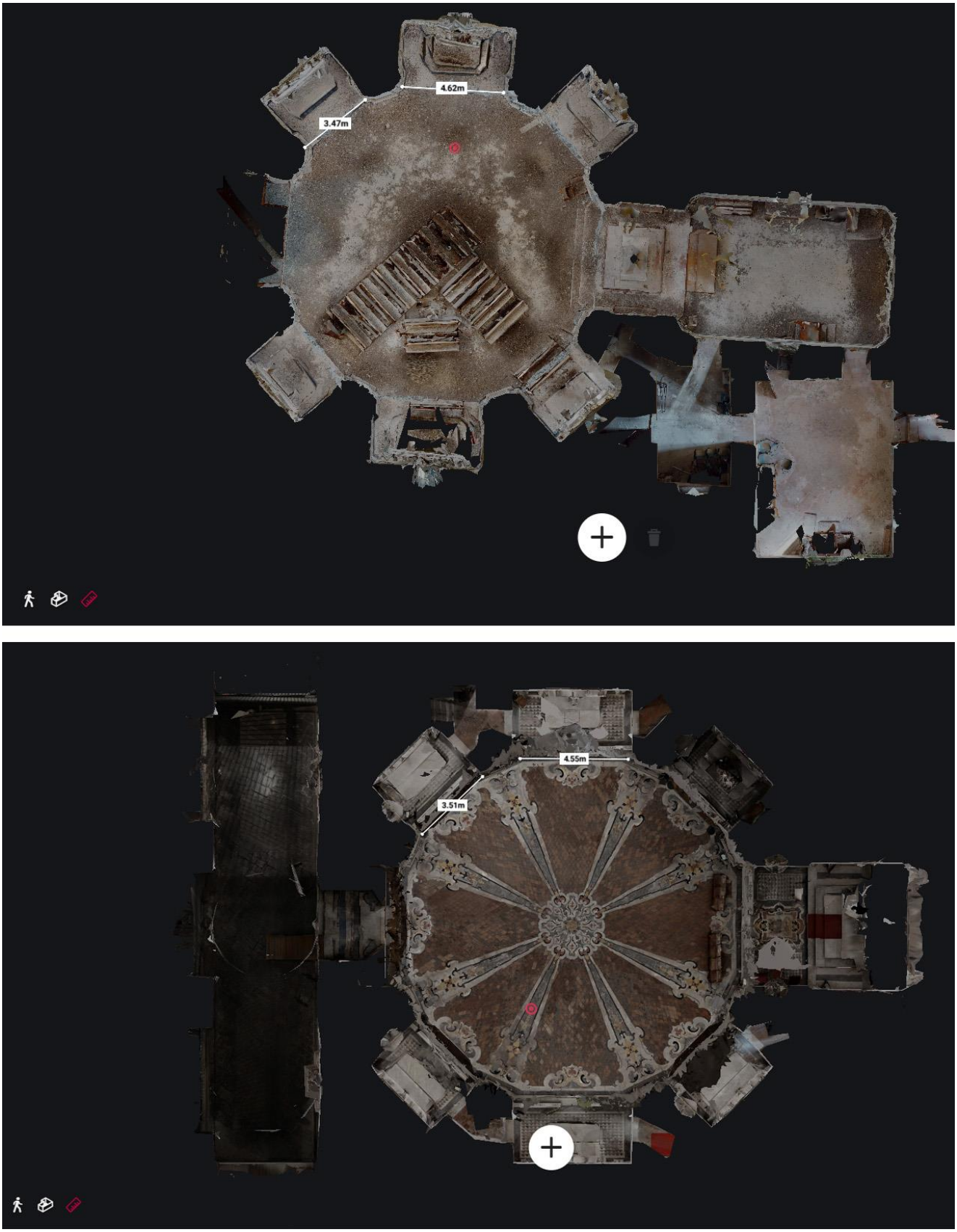

Fig. 12: Navigable model of the Church of Santa Maria della Purità (upper image) and the Chapel of Pio Monte della Misericordia (lower image). Comparison between the two buildings is facilitated by the possibility of taking measurements.

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