The Virtual Tour as a Digital Tool for Linking the Disciplines of the Drawing and the Archaeology of Buildings

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Abstract

The tools and methods aimed at the documentation of the built heritage often follow different paths depending on the own languages of the different frameworks involved in the knowledge process. It is clear how this assumption comes out when working in fragile contexts, where the risk of losing heritage due to natural and/or anthropic events is especially high. Therefore, in order to promote a multidisciplinary research approach, it is often necessary to find a connection, even on methods, able to allow to reach in a shared way the common goal of the knowledge aimed to the conservation and communication of the heritage. Herein are presented the results of a research study aimed at testing the potential of a digital system for the integration of the languages of two fields: architectural drawing and architectural archaeology. Our spotted tool, the Virtual Tour, is flexible and easy-to-use, and when properly designed, it becomes a hub capable of linking several thematic readings and to make them available, in addition to the various professionals, also to a wider audience, promoting the managing of the Cultural Heritage by the institutions-owners, and the heritage's fruition. This tool's potential is here outlined through the application to a case study, the church of San Menna at Lucoli (AQ) characterized, despite its small size, by different constructive phases and by a rich decorative apparatus of great historic-artistic value.

Keywords: knowledge of historic architecture, architectural survey, archaeology of buildings, fruition and promotion of Cultural Heritage, 360° Virtual Reality.

Introduction

The national and international scientific community usually gives great importance to the digital representation of the artefacts of the Cultural Heritage (from the GIS 3D to HBIM, going for semantic models where the topological link of information is possible), constantly trying to find in this expression a hub able to link the languages used by the various experts making them available and accessible. Therefore, the 3D digital model has been, and continues to be, the privileged tool able to guarantee an efficient managing of data derived from geometrical-formal, diagnostic, archaeological and historic-artistic analyses aimed to increase the heritage's knowledge and preparatory to the restoration planning. Thanks to it, the data acquired by classic methods of investigation flanked by those derived from in-depth analyses can be visualized, stored and managed, realizing a real integration between the disciplines involved in the knowledge process.
Despite the evidence that this is the preferable tool, the time required for building the model often conflicts with the necessity of a quick documentation of the heritage, in ordinary condition as well as in emergency. In order to overcome this issue has been tested a tool, the Virtual Tour, that sets itself in an intermediate temporal phase, between the survey and the building of the 3D digital model, representing an alternative manner to visualize and share data. In the case of study chosen to outline the system's potential, the church of San Menna, the Virtual Tour has been created starting from the rectangular images obtained during

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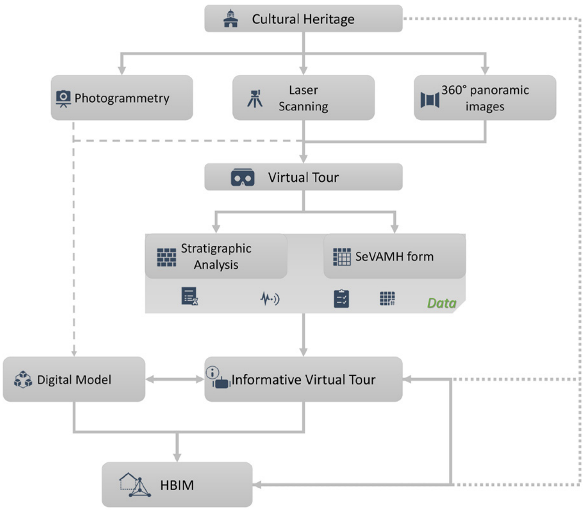
the laser scanner survey campaign. The visualization digital system, which simulates a tour of the artefact through its 360° photorealistic representation, has been properly enriched with the research study contents and turned into an Informative Virtual Tour capable not only to guarantee the collaboration among the various professionals but even to remotely support the building of digital models, numeric and parametric. Furthermore, the potential of the system has emerged especially with respect to the particular historic moment we are living, marked by the pandemic and the impossibility to perform *in situ* inspections. The flexibility and the connectivity potential of the Virtual Tour allows indeed to visualize and to access a lot of information that could be easily increased over time, turning the tool into a complex virtual repository capable of linking heterogeneous data to the virtual representation of the artefact (fig. 1). The Informative Virtual Tour, when well designed using a logical as functional architecture, finally provides a real opportunity for the spreading of data and information of a scientific nature given that it can reach not only the insiders but also a wide target of users with different cultural backgrounds, interests and age groups.

Fig. 1. Flowchart for the implementation of the knowledge and documentation process through the use of digital systems (elaboration by Adriana Marra).



The church of San Menna in Lucoli (AQ): territorial organization and historical background

The church of San Menna is located in the small eponymous hamlet in the municipality of Lucoli, in the province of L'Aquila, 25 km far from the Abruzzo's capital. The scattered settlements distinguish still nowadays this municipality, consisting of sixteen hamlets situated in the Rio torrent's valley, at the northern borders of the Sirente-Velino regional natural park. The so-called *Ville* of Lucoli in fact, recall the settlement systems that distinguished this territory, as the one of the italic *vicus*, of the scattered villas in the Roman era, of the settlements organized around the curtes and the *farfense cellae* of the early middle ages or the forms of the medieval *encastellation*. On the territory of the municipality of Lucoli are still present many material traces that, when properly interpreted, can describe the evolution of the territory and its past importance. This is the case, for instance, of the pre-roman high-ground settlements [Mattiocco 1995], the many Latin inscriptions signs of the Roman age, of the monastic holdings of the VIII century cited in the *regesti farfensi* (monastic chronicles) [Chr. Farf. 1903], the military medieval architecture [Chiarizia and Properzi 1993] and of a large number of religious buildings [Chiappini 1986; Murri 1983].
The church of San Menna (fig. 2) has a peculiar configuration that reveals the several interventions and reconstructions undergone over time. It is a modest masonry building, with a bell gable on the rear side, divided in its inner into two naves compounded by two rooms located behind the choir, serving as a sacristy. Apparently poor in its appearance, this small artefact houses refined frescoes of the Abruzzo Renaissance, as the Crucifixion attributed to Saturnino Gatti [Arbace 2012] and realized in the late 15th century during his period of apprenticeship in the workshop of the painter Sebastiano di Cola of Casentino.

The digital integrated survey of the church

The building was surveyed through the integration of laser scanning and photogrammetric procedures aimed at the stereometric survey of the fabric and the acquisition of high-quality orthomosaics, with high metric precision and image resolution (fig. 3). The laser scanning acquisition was carried out with a FARO Focus S70, equipped with an integrated camera with HDR function, in two survey campaigns for a total amount of 24 scans. The scan parameters (definition, quality, HDR) were set up according to the dimensions of the surveyed spaces, their complexity and the articulation of the decorative apparatuses to be acquired, as well as on the lighting condition, inside and outside, at the time of acquisition. The post-processing was carried out in the software SCENE 2018, grouping the scans into two clusters (one for the interior and the other for the exterior) and continuing with the registration phase and the processing of a point cloud formed by over 315M points. A rectangular image was acquired from each station point and was used as a starting point for the creation of the Virtual Tour of the church.

The photogrammetric survey was carried out with a set of 299 photos acquired by a Nikon D610 camera equipped with an AF-S NIKKOR 24mm f/1.4G ED lens. The images were processed in the software Agisoft Metashape Professional 1.5.1 in two different chunks: one for the inner, obtaining a dense cloud of over 35M points; one for the exterior with a point cloud of over 17M points. The clouds, according to a procedure previously tested on similar artefacts, were subsequently merged thanks to the common points located at the entrance door. After validation of the metric data through comparison with TLS, from the total cloud was generated a mesh of 500K faces. From this model, properly scaled, and post-processed in the colorimetric data thanks to the application of photorealistic textures, the high-resolution orthomosaics of the external façades were cre-

Fig. 2. Church of San Menna of Lucoli AQ (photos by authors).

ated, used as support for the archaeological analyses of the masonries.
The point clouds obtained from the two different survey methods were used as a base for the two-dimensional restitution of the church (floor plans, elevations and sections) as well as for the building of the parametric model in BIM environment within which some architectural elements and part of the decorative apparatus were parametrised [Trizio et al. in press a] and, during the implementation phase of the parametric model, 'families' of sensors, useful in terms of management of data for the monitoring of the artefact, were also added [Marra et al. in press]. During the definition of parametric modelling, the Virtual Tour resolved the issue related to the impossibility of performing in situ inspections (due to the pandemic), testing the effectiveness of the tool also in this phase and showing an unexpected potential of the virtual informative system.

Archaeology of buildings: the constructive phases and the evolution of the church

Every historic building, as a real palimpsest, tells its past preserving the material traces related to the construction and destructions phases due to anthropic as natural causes. The archaeology of buildings [Francovich, Parenti 1988; Brogiolo, Cagnana 2012], a branch of the archaeological discipline, deals with tracking down these aspects through the application of the stratigraphic method to the masonries and the subsequent data interpretation concerning the characteristics of the territory, to the settlement dynamics and the power strategies that characterised the places over time. The application of the stratigraphic method to the built heritage is aimed at the identification of the Stratigraphic Unity of Masonries (SUM) and to their link with the phases of the artefact (construction, interven-

Fig. 3. Digital survey of the church: top, the laser scanner cloud point; below, the photogrammetric model (graphic elaboration by Francesca Savini).

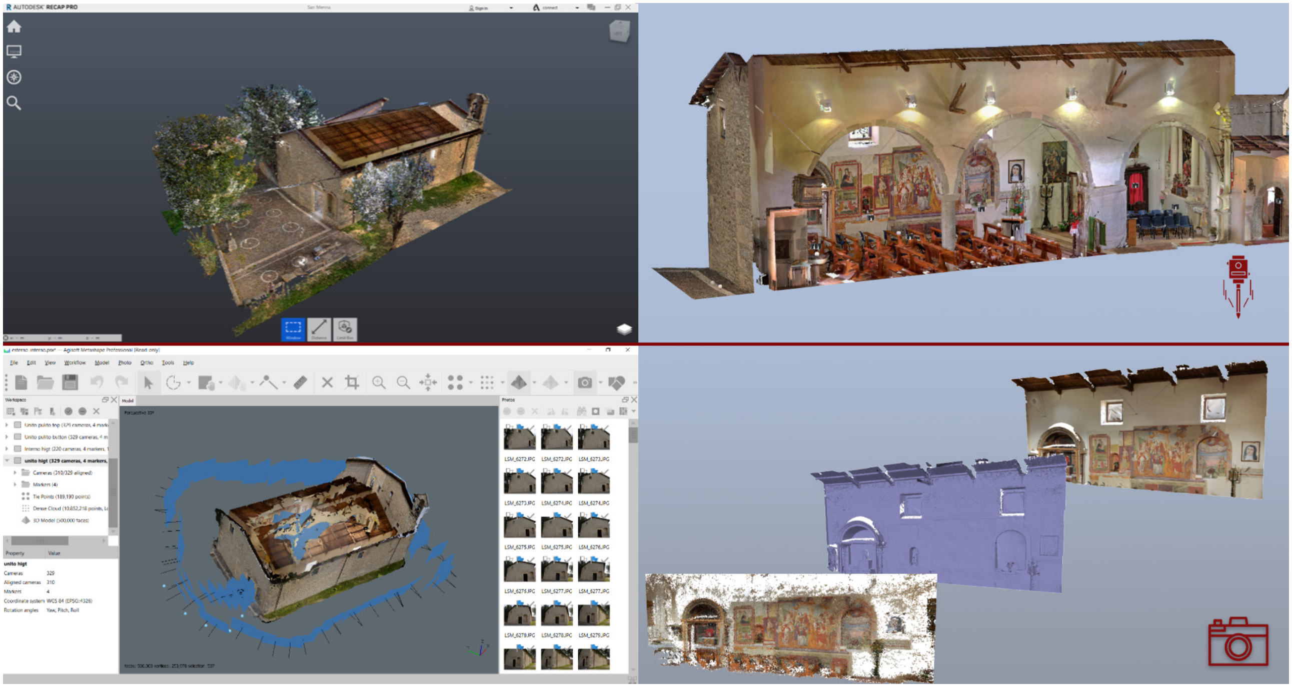
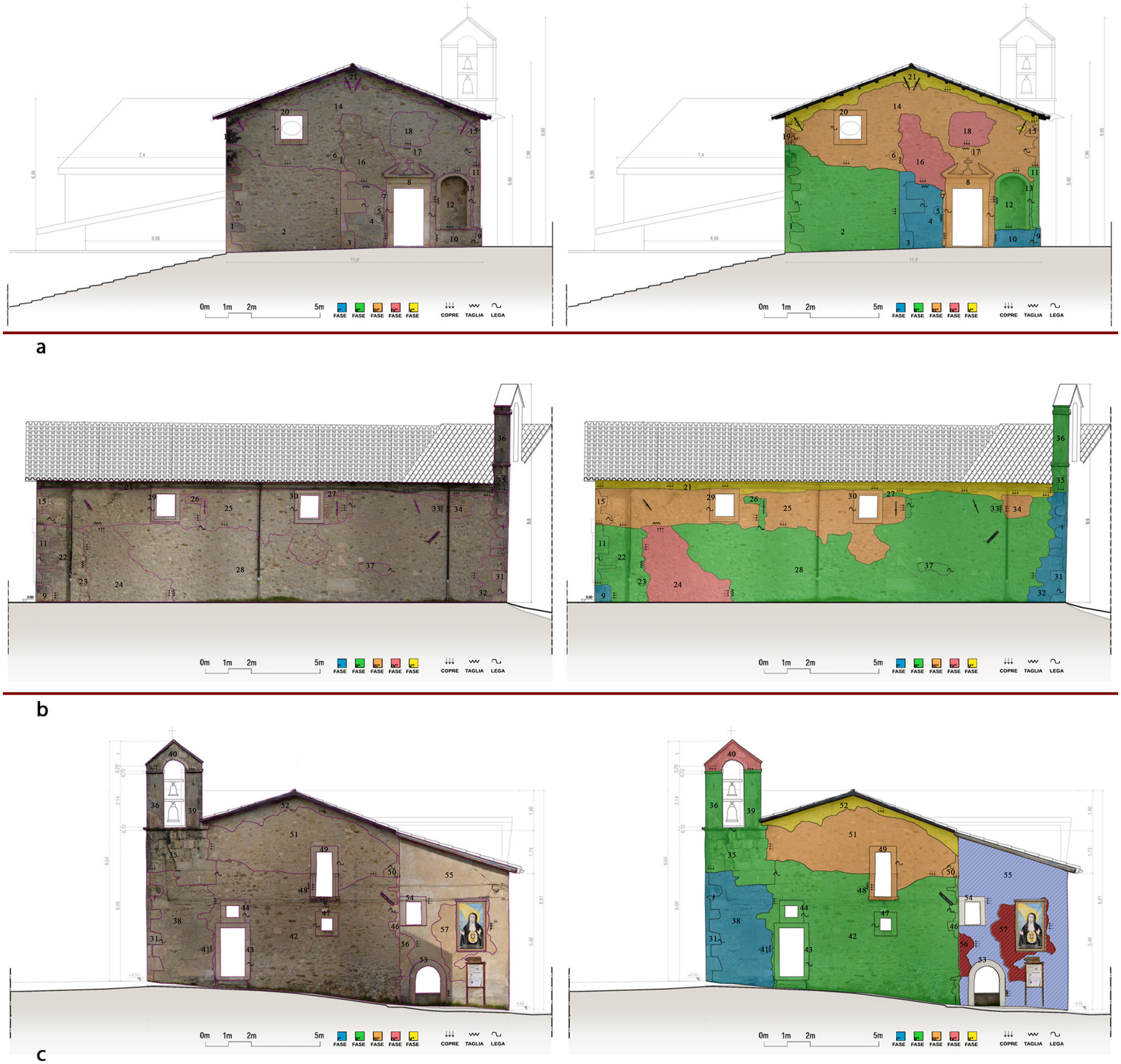
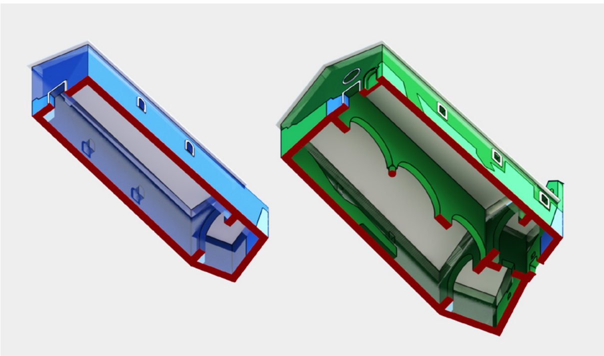


Fig. 4. Church fronts with the results of the stratigraphic analysis of masonries: a) main elevation; b) side elevation; c) back elevation. (graphic elaboration by Francesca Savini).



tions, maintenance) and so to the definition of a chronology, relative first, and absolute then.
The church of San Menna, analysed from this perspective, is rich in material traces witnessing its historical evolution which can be correlated to the settlement dynamics and to the power strategies that characterised these places. Though the first documental evidence of the artefact dates back to 1215, when it is cited in the Papal Edict by Pope Innocenzo III [Placidi 1988; Lico 2001], the toponym *Sancto Mennate*, already documented in the 8th-9th century, refers to an older occupation of the area. The hypothesis that the toponym refers to the *villa* of San Menna [Marcotulli 2008 and 2011] is supported also by the documents of the early Middle Age that refer to the presence of the name "S. Mendati" to identify the church under discussion [Muratori 1742, p. 950].
Unfortunately, the massive modern and contemporary restoration interventions that interested the building both in the 19th century and after its closing during the 1970s, have considerably complicated its archaeological interpretation. The finishing of the masonry joints carried out during these interventions has turned the masonries chromatically uniform and, even though it was still possible to recognize the different methods of laying the material, it was not possible to identify, through the only visual inspection, remarkable differences regarding the mortar used. However, the stratigraphic analysis of the masonries (fig. 4) allowed the recognition of different masonry types, distinguished on the basis of the installation method and the typology of stone material used and also, although the stratigraphic reports were not always clear, the identification of five phases corresponding to actions ranging between the edification of the artefact and the contemporary restoration.
The first phase refers to a single nave church, about 20 meters long and 6 meters wide, probably closed by an irregular polygonal apse. At this phase belong the two corner walls of the current south-west side front and the SUM 3 right visible on the façade. The masonries in phase with the corner walls are characterised by small and medium sized limestone, installed with larger well-squared blocks, probably reused. The second phase corresponds to the enlargement of the building that determined the actual layout, through the adding of the left nave, well visible in the stratigraphic report of the façade (with the SUM 2 resting on SUM 3), and of the bell gable on the rear side, in line with the first phase's wall and heavily altered by the late 19th restoration [Vivio 2011]. The masonries that characterize this construction phase are more uniform than the earlier and are composed mainly of medium size blocks installed in sub-horizontal courses. It is also possible to ascribe the windows to this phase, walled later and still visible at the sides' front, realized in bricks with the low arch typology. At the third phase, it is possible to attribute the upper part of the building, probably realized after a collapse. The presence of brick wedges in the masonry, combined with the style of the windows and the portal, allows to assume that this is a restoration intervention realized after the 1703 earthquake. The fourth phase can be attributed to restoration interventions most likely occurred after collapses and failures, such as that visible in the SUM 24 on the side elevation, where clearly appears the restitching slightly off-squared performed. The location of this SUM and its particular shape refers to a local damage mechanism with the ejection of part of the masonry [Borri et al. 2020]. The disruption of parts of masonry belonging to phases two and three, suggests a collapse following the event of 18th century, that might be caused by one of the seismic events that struck the territory during the 19th century. This hypothesis is supported by some documents kept at the National Archive of L'Aquila, witnessing the necessity of urgent restoration work on the church of San Menna [Vivio 2011]. The fifth phase certifies, instead, the more recent interventions starting from the post-war reconstruction documented for the north-east wall [Chierici s.d.] up to the recent restorations concluded in 2000. The last two phases,

Fig. 5. Hypothetical evolution of the building defined from the archaeological data: 3D reconstruction of the first two phases (graphic elaboration by Andrea Ruggieri).



characterised by massive interventions on the masonries, has considerably affected the stratigraphic analyses of the walls, therefore it was only possible to assume hypotheses about the evolution of the building (fig. 5). Nevertheless, it could not be excluded that the building, nowadays visible in its medieval facies, was built on older structures, as suggested by the re-use of the material of Roman origin in the masonries [CIL IX, pp. 534-535], that may have influenced the particular planovolumetric layout.

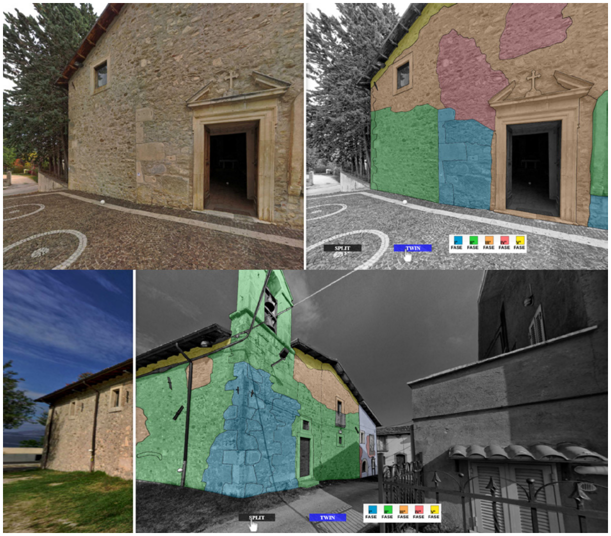
VR environments for the integration of data

The use of digital technologies for the representation and documentation of the cultural heritage represents a particularly topical field [Ioannides et al. 2018], as well as is recent the study of digital environments aimed at the management and integration of multidisciplinary data arisen from the investigations on the historical buildings to promote the system interoperability and the conservation of the built heritage that characterizes the whole of the national territory.
Within this framework, much efforts of the international scientific community are aimed at the comprehension of the potential of the most common digital environments in the field of valorisation and education through gamification techniques, and to evaluate this system's flexibility with regard to research fields intended to increase the knowledge, documentation and analyses of historic built heritage [Apollonio et al. 2018].

Fig. 6. Virtual Tour of the church for the enjoyment of historical and artistic information (elaboration by Francesca Savini).

Among the various available tools, those used for the Virtual Reality experiences are able to match at its best the technics requirements with the valorisation and dissemination ones, due to the communication skills broaden by the immersive environments. In addition to the virtual worlds created with Game Engine platforms, which allow to visualize and explore the representation of real artefacts, virtually reproduced through photorealistic meshes [Trizio et al. 2018] or numeric or parametric models [Banfi 2020], are widespread the Virtual Tours generated started from the images. This latter type is widely used in the field of museums and archaeological sites enhancement since it promotes the fruition and the accessibility of the heritage [Neovesky, Peinelt 2015; Kersten 2018; Maach et al. 2018; De Fino et al 2020]. The use of the Virtual Tour, however, has great potential also for the recording and the interchange of data since, when properly structured, it becomes a hub capable of storing multiple information and meeting the requirements of different professionals, as well as the ones of operators and administrators involved in various ways in the field of the built heritage. In this direction, the multilevel structure promotes access, after prior authorization, to more technic-scientific information,

Fig. 7. Mode of overlapping thematic readings for data access in the Virtual Tour (digital elaboration by Francesca Savini).



as for the case of the structural monitoring of the architectural and infrastructural heritage [Trizio, Savini, Ruggieri 2020; Trizio et al. in press a] Furthermore, the widespread use of these tools is promoted by the ease of acquisition of the representation and the quite short time required for its realization. Indeed, although the case of study used to test the tool shows an example of the tour created starting from the images taken at each station point of the laser scanner, the single spherical panoramas can be easily obtained with an image taken from a Cam360 or through sketching operations (processed by specific proprietary or free software) of a set of images acquired with a digital camera assembled on a rotating head and taken with a good superposition.

The Virtual Tour of the church of San Menna, partially realized for the inner of the building during a monitoring project of the state of conservation of the frescoes [Trizio et al. 2019], has been subsequently implemented with the adding of the stations at the exterior of the building. The images acquired during the laser scanner survey campaign have been expressly edited in the original dimensions in order to uniform them at the equirectangular format, and subsequently imported in the proprietary software 3DVista Virtual Tour Pro (release 2020.5.23) to generate spherical panoramas and link them to each other, thanks to specifics hotspots that allows to move into a simulated view.

The Virtual Tour of the church, used also for the building of the parametric model of the church, was from time to time enriched with multidisciplinary data arisen from the scientific research, redesigned in a divulging way and enjoyable from the drop-down menu, constantly accessible, as through appropriate buttons that can be triggered by each panotour (fig. 6). Particular attention was paid to the integration of the data from archaeological analysis with the 360° VR representation of the artefact, and through specific paths to which was added information derived from the superposition of thematic readings obtained by editing the equirectangular images. In this case the Virtual Tour, thanks to specific commands as 'split' or 'twin' allows to visualize simultaneously on the spherical images the scientific results (fig. 7). In addition, to promote the comprehension of the historical evolution of the building, reconstructed starting from the evidence of the archaeological analysis of the masonries, was designed a diachronic view that, through the activation of appropriate buttons, allows to visualize the building in the identified historical phases (fig. 8). Furthermore, in order to increase the knowledge of the artefact and the exchange of data between professionals, the Virtual Tour was designed in a multilevel manner, making possible the access to more technical data (fig. 9), peculiar of the archaeology of architecture (fronts whit stratigraphic analysis of the masonries, matrix etc.) and to the discipline of drawing (graphic restitutions of the survey, digital models etc.). The strength of the proposed system, therefore, appears to lie in the ability to bring together into the tool, through containers inherent in the software and links to external platforms, different formats of data: from the bi-dimensional drawings to the historic photos, from the alphanumeric data to the digital numeric and parametric models (fig. 10). Indeed, the research team has been conducting for a long time tests aimed at the three-dimensional representation of the archaeological stratigraphic analysis in a digital environment: from the texturing of photogrammetric models to 3D GIS and the creation of HBIM starting from archaeological data (Marchetti et al. 2017; Trizio et al. 2019; Trizio, Savini 2020), which have demonstrated the potential of the BIM environment. Therefore, the parametric model already connected to the Virtual Tour will be implemented with the results of archaeological analysis guaranteeing its management and its use in the monitoring and design phases of conservation, interventions, or fruition.

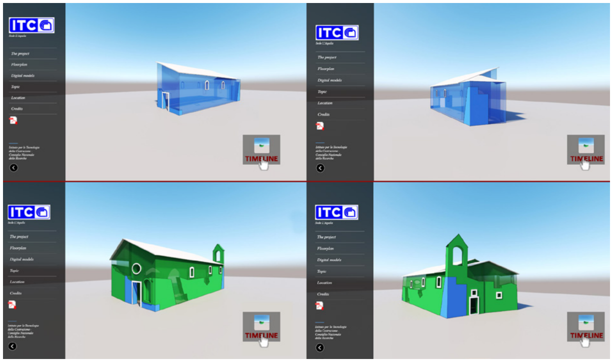
Conclusions

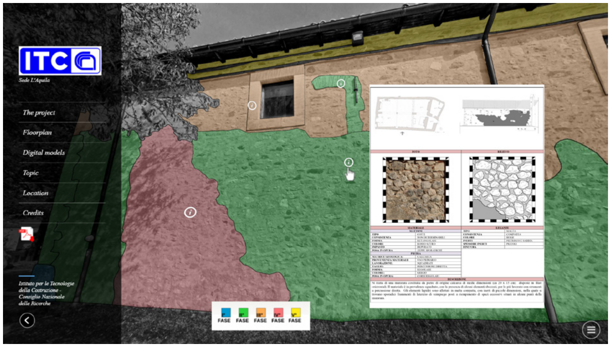
The three-dimensional models deriving from the process of digital acquisition of the real, in addition to connect the research of the various disciplines involved in the knowledge process, owns intrinsic flexibility that can be used in a divulging way. Indeed, the strong communicative value of the science of drawing is broadened and enriched by the digital technologies, and the integration process of languages from different disciplines, like those of drawing and archaeology, is promoted by computer vision and the world of graphics and 3D animation. The test carried out on the church of San Menna in Lucoli actually confirmed that the Informative Virtual Tour represents a quick method able to integrate the heterogeneous data promoting, at the same time, the fruition and valorisation of the cultural heritage. The fruition is guaranteed by the various modes, ranging from the desktop and tablet format to the immersive version, that allow to descend into the virtual world with a simple smartphone paired with a cardboard

Fig. 8. A diachronic virtual tour for moving in the space and viewing the building in its historical phases (digital elaboration by Francesca Savini).

Fig. 9. Visualisation of archaeological data and form in VR environment (digital elaboration by Francesca Savini).

Fig. 10. Link to online platforms for displaying digital models (digital elaboration by Francesca Savini).





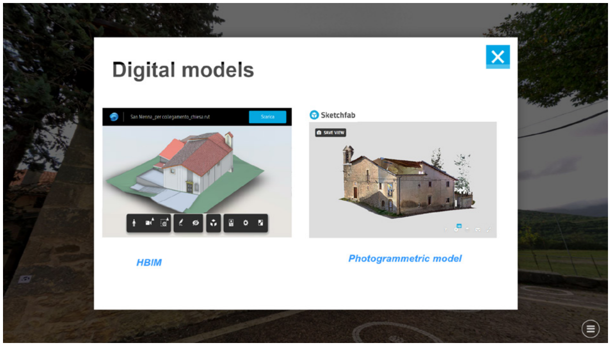


Fig. 11. Ways of using the Informative Virtual Tour (photo by authors).

or a VR box (fig. 11) and, when well converted, the Virtual Tour can be enjoyed with more performing devices like the Oculus Go. The tool, furthermore, has proved to be suitable even for a constant implementation in the time, enriching itself with informative contents, more and more articulated and complex, in relation to the progress of the research study and the analyses conducted on the artefact.

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