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Digitization of historical architectural elements, a workflow for knowledge of minor centers in inner areas

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The architectural heritage is subject matter of several scholars, whose approach depends upon the cultural and technical background, with the same objective of increasing its comprehension in order to protect and enhance it. A concurrent effort like this points out the need of a common and shared language and method to exchange data and knowledge.
Digital models enriched by semantic engines are able to correlate several disciplines, facilitating data management and exchange for a real interoperability encouraging novel process of documentation and fruition of historical heritage. In this paper, an approach to the problem is discussed with reference to specific architectural elements, the historical portals. The key phases of an operational procedure are illustrated. They move from traditional approaches used in the field of buildings archaeology and architecture towards the implementation of parameterized architectural elements to be used in a Historical Building Information Model (HBIM). Moreover, an Integrated Information System of 3D architectural elements (3DIIS), in a virtual environment is presented, which respond to the needs of several disciplines. This Virtual Reality (VR) system, through open-access tools, guarantees the topological connection of the data to the digital model for sharing and the diffusion of the knowledge.
An Augmented Reality (AR) application designed for mobile devices can achieve a twofold objective: i) support the digital management and preservation of the architectural assets by entrusted authorities ii) empower the memory of the sites and valorisation of historical heritage in Inner Areas.

Keywords:
Architectural heritage; Inner areas; Digital model; Documentation, VR based Informative System.

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1. INTRODUCTION

The Italian regions are characterised by the widespread presence of historical centres that can be defined as minor in relation to the loss of their original political and economic function and rich architectural heritage, consisting of road infrastructures, religious heritage, residential buildings, and vernacular architecture. The assets typical of these centres, located in the areas of central Italy and affected by the recent seismic events, are involved in the process of knowledge aimed at both the damage repair of the heritage of the sparse and minor centres in Central Italy, according to Reconstruction Plans (USRC, 2017; Pierantoni, Salvi & Sargolini, 2019), and the preservation pursued by restoration and constant monitoring and maintenance. The safeguarding strategies are the outcomes of multidisciplinary analyses that produce a large amount of data useful for the single disciplines involved in the process and that become more efficient if properly organised and integrated. Therefore, methods, languages and tools based on digital technologies seem to fit the needs of combining and supporting the integration of different expertise.
The paradigm of the digital transformation of the modern society finds a solid background in the widespread capacity of generating, storing and processing huge amount of data. The potentialities of the Information and Communication Technology (ICT) combined with the power of advanced sensors and devices able to provide accurate measures of a large variety of parameters is pushing toward an irreversible transformation of the approach to the documentation, assessment and maintenance of the built environment. It is a great opportunity to combine in an optimized way the several disciplines concurring to the preservation and documentation of the large architectural and historical heritage located in areas identified as Inner Areas according to relevant National regulatory frameworks (Noguera & Copus 2016; Copus, Mantino & Noguera, 2017).
This is the one of the best ways, the technical and scientific recommendations can assist the administrators and professionals involved in the protection, conservation, and reconstruction processes of the historic architectural heritage. The complexity of the heritage is related to the several modifications that occurred over time according to the territory characteristics. Its analysis produces big data, which are heterogeneous both for the type of information and the different formats. These features represent one of the main challenges within the processes aimed at defining digital procedures for the documentation and management of historical artefacts.
Consequently, several national and international studies on the management and sharing of multi-data resulting from heritage documentation have focused on the use of digital and three-dimensional visualization of artefacts. Mesh, mathematical and parametric models are widespread, and several environments have been tested for their management (3DGIS, CIM etc.). These approaches are useful for heritage conservation strategies, and the effectiveness of each has led to identifying in the digital models the tools able to connect different disciplines and languages. Greater attention and skills are required when strategies have to be defined not for a single asset (building, architectural complex or aggregate) but for a large area, such as a historical centre. The latter has complex features that added values to the assets, and for the management and planning of operation aimed at its conservation, an increased effort is required (Marra et al., 2021). Although the digital model can connect language and methods, it is necessary to define the systemic architecture and standardize data acquisition. The most challenging task is represented by the transition of digital models in digital twins to the built environment (Jouan & Hallot, 2020). It is still an open problem, which needs a concurrent effort of archaeologists, architects and engineers, in the characterization of the construction as well as of the valuable elements that populate the villages and minor historical centres located in the Inner Areas. In the Inner Area analyses, the advantage of assessing the architectural heritage, in its detail and its structural and non-structural elements, lies in the need for conservation activities. Indeed, the analysis of architectural elements has a key role because it supports the understanding of the dynamics of building and settlement through the stratigraphic interpretation, and the identification of constructive features about specific types that can be referred to at a specific time (Redi, 2014; Lorenzetti, 2020).
Therefore, the data must be structured in an efficient and scalable manner by using census and catalogue tools and favouring the semantic modelling, which is useful in the reconstruction operations of historical centres damaged by a catastrophic event, such as the areas located in Abruzzo (damaged in 2009) or in central Italy (2016). This approach aims to support the definition of intervention strategies, enriching the level of detail of digital replicas that facilitate the management of architectural heritage by authorities in charge of protection, management, and reconstruction.

2. SLATE CATALOGUE: A TOOL FOR THE KNOWLEDGE AND DOCUMENTATION OF HISTORICAL ARCHITECTURAL ELEMENTS

The cataloguing has a key role in multidisciplinary processes for documentation and knowledge of built historical heritage because it provides the formal and cultural understanding of the assets that must be preserved and enhanced as "pieces of evidence having a cultural value" (Legislative Decree 42, 2004, art.2). Indeed, the cataloguing systems have provided, since their codification, significant information on cultural assets about their geographical-spatial location and morphological and formal features by the means of specific classes and terminologies, enabling the identification of their dating and cultural context (Miele, 2011).
Inventories implemented at the National level on cultural heritage, starting from the control activities on the condition of assets, and the heritage categorization in single assets (Kelly, 2009) have led to cataloguing standards specific for heterogeneous assets categories (ICCD, 2018). The catalogue forms range from a single object, namely the movable heritage, to urban

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and territorial assets, including immovable and demo-anthropological assets. The fields of the different forms ensure an increasing level of data acquisition: from inventory to cataloguing level. Moreover, shared vocabularies and univocal codes have been defined after the changing need related to the data digitization and online availability of catalogued heritage. These vocabularies and codes have facilitated the standardization of cataloguing results and the correlation between data concerning complex systems of assets.
The opportunity to achieve a comprehensive knowledge of cultural heritage assets has led to the introduction of other tools that are related to national cataloguing systems and provide additional information on specific aspects. Among these tools, some are shared at a national level, such as the vulnerability form of the SIT MARIS system (Accardo, Cacace & Rinaldi, 2005); others assume regional or even local specificities, such as the scheduling systems related to the architectural elements characterising the openings of historical buildings. The analysis of architectural elements is shared by the fields of architecture and archaeology of architecture that increase their knowledge for a different purpose. The first studies the architectural elements for the development of typological atlas necessary for drawing up land-use and reconstruction plans (Carocci, 2012; Modena, 2013; Cravaggio & Meda, 2004). The buildings archaeology studies these elements for the creation of chronological atlas that facilitate dating and understanding of the dynamic evolutions of buildings (Ferrando, Mannoni & Pagella, 1989; Mannoni 1994). Besides, several research teams of the buildings archaeology have developed different cataloguing systems: from census forms to managing data systems related to the stratigraphic analysis of masonries (Nucciotti, 2009; Febbrario & Susini, 2012; Decri et al., 2015; Forgione, 2016; Nazionale, 2016).
The integration of results, gained from the architectural and archaeological analysis, can favour the knowledge process of single architectural elements belonging to historical built heritage and, as a consequence, can support the conservation and management processes of the heritage.The *hiStoricaL ArchiTectural Elements* – SLATE – catalogue has been developed in this perspective, starting from the available catalographic tools, such as the ICCD forms and those specific of different disciplines. The catalogue's strength is the interoperability that can be assured with information derived from several knowledge domains and available in other databases (Fabbrocino & Marra, 2018; Marra & Fabbrocino, 2020; 2021; Savini et al. 2021). Therefore, the SLATE catalogue is designed in order to be scalable in terms of level of detail associated to the in-situ surveys, in agreement with the Level of Geometry (LoG) codified in the context of the Building Information Modelling environment (UNI 11337, 2018) for new constructions. (Fig. 1).
The general information is accessible to the technical and scientific community. It reports data on the geographical and territorial location and preliminary identification and description of the artefact (Fig. 2).

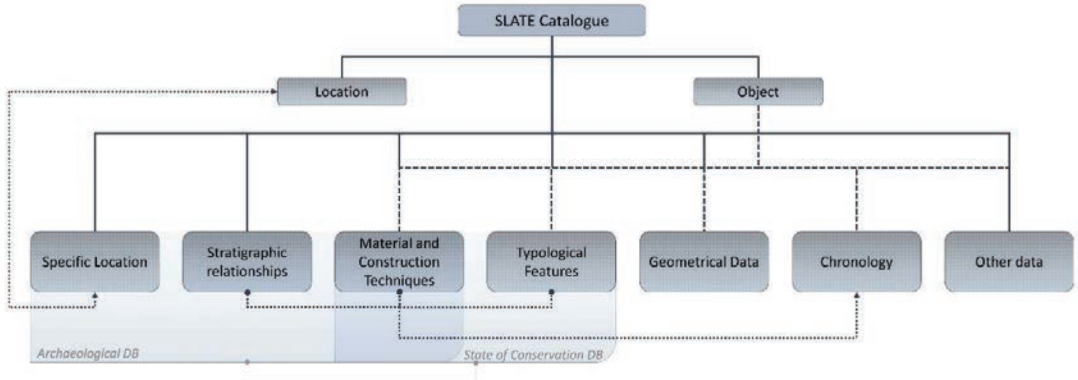

Fig. 1 - Hierarchical structure of data in SLATE catalogue.

Fig. 2 - First level information of SLATE catalogue form.

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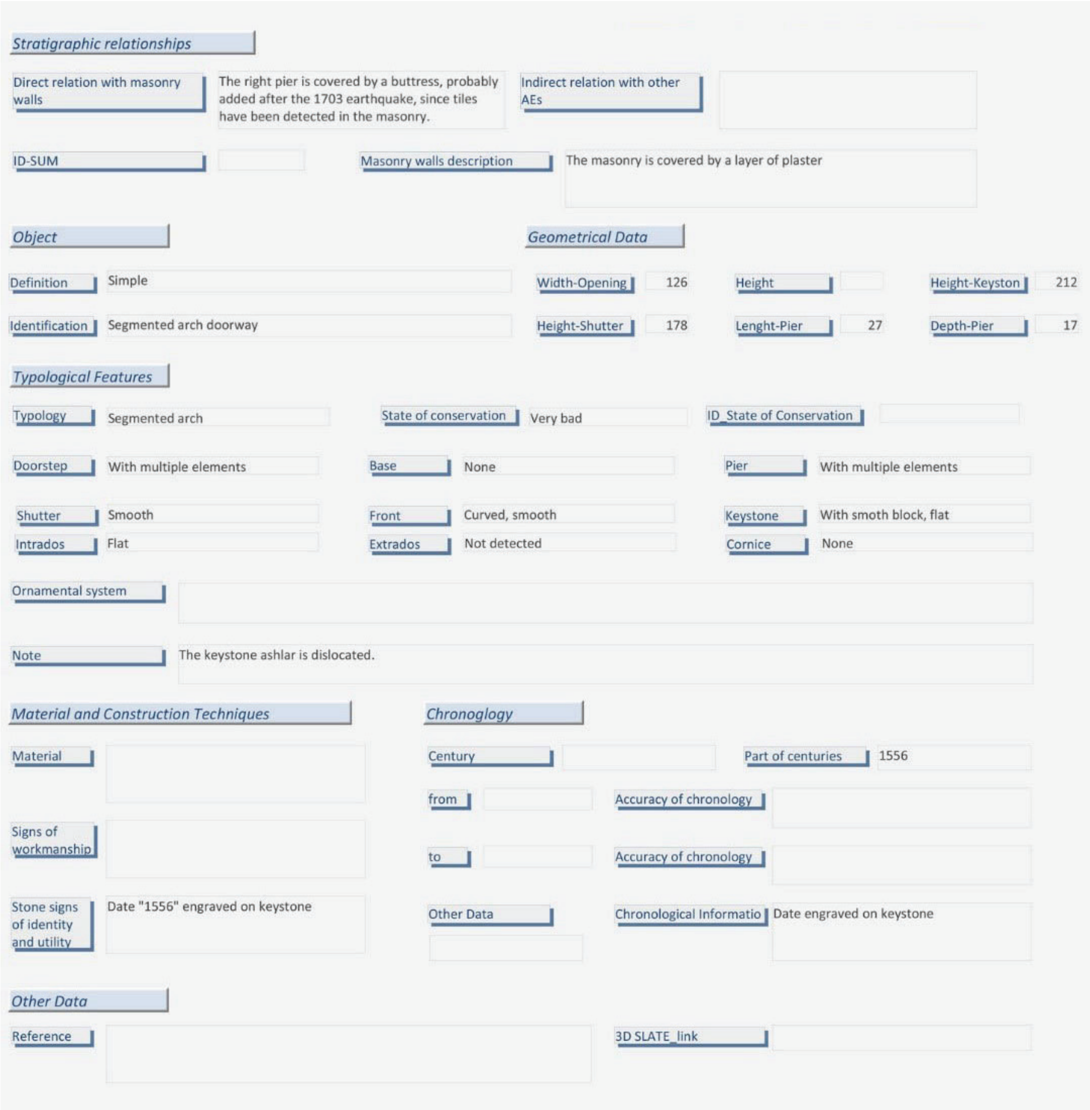

Stratigraphic relationships

Direct relation with masonry walls: The right pier is covered by a buttress, probably added after the 1703 earthquake, since tiles have been detected in the masonry.

Indirect relation with other AEs:

ID-SUM:

Masonry walls description: The masonry is covered by a layer of plaster

Object

Definition: Simple

Identification: Segmented arch doorway

Geometrical Data

Width-Opening: 126
Height:
Height-Keyston: 212
Height-Shutter: 178
Lenght-Pier: 27
Depth-Pier: 17

Typological Features

Typology: Segmented arch
State of conservation: Very bad
ID_State of Conservation:
Doorstep: With multiple elements
Base: None
Pier: With multiple elements
Shutter: Smooth
Front: Curved, smooth
Keystone: With smoth block, flat
Intrados: Flat
Extrados: Not detected
Cornice: None

Ornamental system:

Note: The keystone ashlar is dislocated.

Material and Construction Techniques

Material:

Signs of workmanship:

Stone signs of identity and utility: Date "1556" engraved on keystone

Chronoglogy

Century:
Part of centuries: 1556
from:
Accuracy of chronology:
to:
Accuracy of chronology:
Other Data:
Chronological Informatio: Date engraved on keystone

Other Data

Reference:

3D SLATE_link:

Fig. 3 - Second level information of SLATE catalogue form.

The second level of the catalogue presents three different macro-categories of information that allows achieving a systemic view of the historic built heritage thanks to the decomposition in different modules (Fig. 3). Therefore, fields concerning the *Specific location* of the architectural elements are included within the catalogue, providing the correct identification and definition of the building. This first macro-category is linked to the fields concerning the stratigraphic relations that can be compiled after careful analysis of elevations using an archaeological approach. In such a way, the constructive relations between different units of the building can be understood and the history and transformations of the building can be traced. The alphanumeric identification codes in the *Stratigraphic relation* module – *ID-Building* and *ID-SUM* – provide the link between the SLATE catalogue and external databases with information on building and archaeological data. The second catalogue macro-category brings the characterization of the architectural element in its morphological and formal features. Indeed, the specific fields of the geometric and typological characteristic of the investigated object are included in this section. In addition, the fields' materials and signs of workmanship enable the characterization of the element and the understanding of its state of conservation. This aspect can be investigated more in detail in an external database defined starting from the Seismic Vulnerability Assessment of Movable Heritage – SeVAMH – protocol (Fabbrocino & Marra, 2018). The relation between the two databases is ensured through the identification code *ID-State of conservation*.

Finally, specific fields for the dating of elements are included in the form. However, the module *Chronology* can be compiled after an exhaustive analysis of territorial context and archaeological analysis of masonry elevations, investigating the signs and workmanship on stones and identifying elements belonging to the same type and recognisable in an objective manner.

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It should be noted that the technological advances in ICT have significantly affected the cataloguing and census of historical built heritage and its elements. Therefore, the last SLATE catalogue macro-category contains the link to the 3Dimensional historical ArchitecTural Elements – 3D SLATE – catalogue.

3. ARCHITECTURAL FEATURES OF THE ABRUZZO INNER AREAS: HISTORICAL PORTALS IN FOSSA (AQ)

Abruzzo is one region of central Italy distinguished by the widespread presence of minor historical centres, municipalities that have valuable architectural features, evidence of the different historical period. Some of those minor historical centres are undergoing the process of abandonment accentuated by natural and anthropic factors such as seismic events or lack of infrastructures (Cervellati, 2009; Oteri & Scamardi, 2020). Therefore, it is important to carry out studies for understanding and characterising the building types and traditional construction techniques since this information has a significant role in the planning of strategies for the conservation and recovery of the historic built heritage in a region. Multidisciplinary studies of Abruzzo's built heritage identify different settlement features (Fig. 4), characterised by techniques and materials, which recur within the fabric of the villages. Among the most representative building typologies, perfectly integrated with the landscape and homogeneously spread in the area, are the single-family house, the tower-house, the wall-house and the terraced house (Bonamico & Tamburini, 1996; Zordan et al., 2002; Redi, 2003; Caravaggio & Meda, 2004; Varagnoli, 2008; 2009; Bartolomucci & Donatelli, 2012).
Single-family houses on the slope are the main building typologies. These are defined by one or more overlapping spaces and are aggregate in complex building blocks with linear development. The standard building type consists of a room on the ground floor used as a warehouse and living spaces on the upper floor. The original layout of this building type influenced the subsequent

Fig. 4 - Panoramic view of some minor historical centres of Abruzzo's inner areas: from top to bottom, San Pio delle Camere, Fossa and Fontecchio in the L'Aquila province.

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modifications due to the changes in housing needs and consisting in the realisation of overlapping spaces, the advance of the main front and the fusion of neighbouring rooms. The residential spaces of different buildings located on steep slopes are accessible by impressive external masonry stairs, called *profferlo* or *vignale* in the Italian language. The material and construction techniques reflect the geological and geographical characteristic of the area and, above all, its cultural and economic history. The vertical structures are made of stone elements and have a quality and accuracy in the construction that improves over time thanks to the dissemination of new knowledge. The horizontal structures are made by stone or brick vaults and by wooden floors. Iron beams and small brick vaults floors were used frequently starting from the end of the 19th century. They are defined by small brick vaults, laid with header or rowlock face brick perpendicular to the curve, built on the lower part of iron beams, with double T or C profiles. The roof structures of the buildings are also made of wood, in some cases with thrusting behaviour.
Finally, the architectural language of historical buildings is enhanced by several elements. Simple elements in carved stone, sometimes enriched with decorations in relief in stucco, plaster or brick, define the plastic-ornamental character of portals, windows, cornices and balcony.
The municipality of Fossa, located near L'Aquila city, represents an interesting minor historical village of Abruzzo's inner area and therefore it has been selected to check and validate the process.
The typological analysis resulting from the gathering of data, about historical portals located in the urban pattern in the municipality of Fossa, in the SLATE catalogue allowed the identification of seven different types according to the geometrical form (Fig. 5).
The most frequent types are the lintel portal (Type A) and the segmental arch ones (Type B). Rounded arch (Type C) and polycentric segmental arch portals (Type D) are also widespread, while the pointed arch portals (Type E), the round arch framed (Type F) and the mixed ones (Type G), namely those with both arched and lintel components, are less usual (Fig. 6).

Fig. 5 - Example of portal types identified in the historic centre of Fossa.

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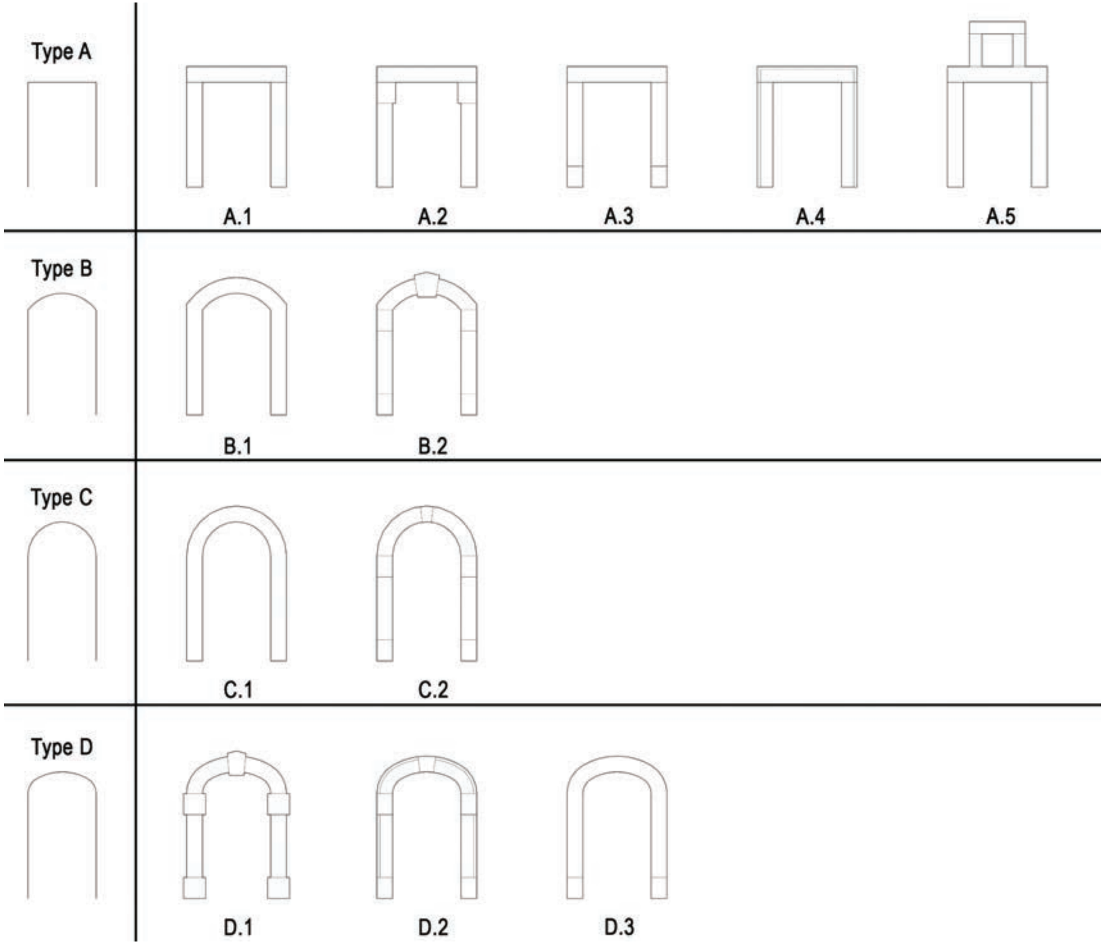

Fig. 6 - Types of portals detected in the historical centre of Fossa.

The recurrent type of the lintel portals does not exhibit any decorative or formal elements (Type A.1), indeed, only a small part of the sample displays brackets, decorated or smooth, at the impost level (Type A.2). The further classification was made according to the presence of the base at the piers (Type A.3), which is absent in most cases or consists of a smooth block flat or projecting, and of mouldings with straight or curved profiles (Type A.4), which frame the extrados of the piers and lintel. Another type is represented by the lintel portals with an upper opening, rectangular or square, simple or with a moulded frame (Type A.5). Many Type B portals have an undecorated segmental arch front (Type B.1) or a keystone (Type B.2). This element is generally pentagonal or with a curvilinear profile, smooth or decorated with plant or flowers. Portals with or without an ashlar at the base and impost were detected for each type. The rounded arch portals of Type C were characterised in the same manner. The main differences, also for this type, were found in the presence (Type C.1) or not of the keystone (Type C.2) rather than in the presence of the base and the impost ashlar, which are generally with a smooth or decorated block. The last widely observed type is the polycentric portals (Type D), whose typological differences are due to the presence or lack of the keystone, impost and base blocks, as well as to the presence of a perimeter cornice. Type D.1 is characterised by a pentagonal or curvilinear keystone, smooth or with plant, flower or geometric decorations, often in high relief or carved. Type D.1 has the bases and shutters decorated, often projecting and sometimes with a curvilinear section. Type D.2 has a moulded cornice with straight or curved profiles, which surrounds the extrados of the piers and arch front, and sometimes interrupted at the base. The last type, D.3, consists of simple polycentric portals, namely portals that do not have a keystone or impost elements but show a block at the base, flat or projecting, smooth or decorated. The remaining portal types represent a small part of the sample with specific characteristics, whose detailed analysis is missed herein without lack of significance of the study.

4. DIGITIZATION OF THE HISTORICAL PORTALS

The constructional techniques and the architectural peculiarities of the vernacular building located in the historical centre of Fossa, above mentioned, led to identifying this area as a case study. In the first phase of the research, an extensive survey of building patterns, excluding a few areas forbidden for safety and reconstruction reasons, was carried out. In such a way, some considerations on the architectural elements were carried out to direct the research towards a broader analysis, still in progress, of the historic buildings that constitute the village.

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The analysis of architectural elements (EAs) was aimed at a typological classification of the historical portals, starting from a generic approach to arrive at more exhaustive levels of knowledge. An operational procedure, scalable, replicable and transferable to other elements, was defined thanks to this approach. In such a way, the architectural heritage can be documented according to a modular scale that starts with a general analysis of forms and characteristics and arrives to investigate the particular.
Therefore, the research was divided into mutually connected steps: the first of in situ acquisition; the second of data processing, starting from the systemic classification based on the ontology, and preparatory for numerical and parametric modelling; the third of modelling aimed at HBIM parametrization, to enhance the quality of contents in the perspective of the ontology-based approach; the last of multi-data organization in an Integrated Informative System (3DIIS), in VR environment, for the knowledge and conservation of the built heritage of minor historical centres.
The purpose of in-situ operations was the expeditious acquisition of the morphological and formal information of the historical portals, detecting and recording the metric data for each one in specific forms associated with eidotypes. The geolocation and photographic recording of the portals were carried out using Google's MyMaps web application, a system with broad potential ranging from census and interoperability among the people involved in the research (Savini et al., 2021) to spatial representation (Vernizzi & Bontempi, 2020). The development and sharing of the interactive map of the municipal territory guaranteed, on the one hand, the georeferencing of the portals and the correlation of the on-site photographic documentation and, on the other, the opportunity to operate simultaneously with own mobile devices, thus accelerating the census operations and the following data processing phases. At the same time, photo datasets were acquired for the photogrammetric survey of portals that have complex and unique characteristics and do not have other similarities in the analysed area, such as the monumental portals of the church or the decorated ones of the aristocratic palaces, in order to obtain digital models of architectural elements. In the end, the visual analysis of the portals enabled the acquisition of preliminary information, useful to populate the SLATE catalogue. A photographic survey was carried out to collect a rich dataset of images that, if linked with the research data, will be useful for the development of Artificial Intelligence (AI) applications to be integrated with Augmented Reality systems (Spallone & Palma, 2020).
The second operational step was focused on the data analysis and integration, through more detailed technical investigations, for the data entry in the SLATE catalogue. In this phase of data

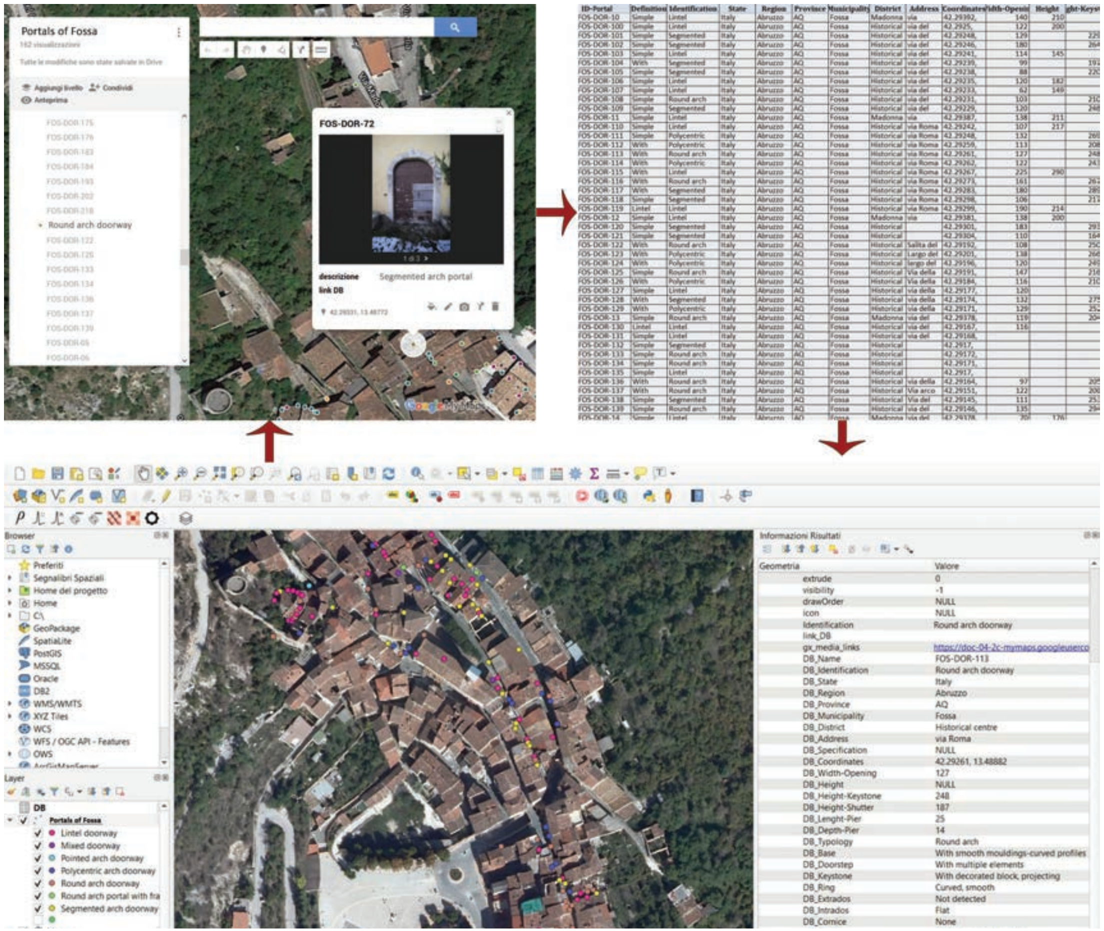

Fig. 7 - Interoperability between the MyMpas, DB and GIS.

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processing were performed spatial analyses of the distribution of the portals, in addition to the image processing for the photogrammetric surveys. The interactive map of MyMaps was imported into the GIS environment associating a univocal code to each portal, which guaranteed the link to the SLATE Catalogue. In such a way, the code ensures the data correlation for the single georeferenced points, providing for the analysis of the typological distribution of the portals on the territory (Fig. 7).
Geographical Information Systems, generally GIS-based, ensure the collection, use and processing of the acquired information. Nowadays, these systems are increasingly oriented towards the management of three-dimensional data (Trizio et al. 2019a) and integration with the BIM environment (Saccucci & Pelliccio 2018; Chenaux et al., 2019) or the 3D information systems tested on an urban scale (Parrinello, 2020). Contextually, the deployment of multi-scale digital models is high, thus enabling the recording of the heterogeneous data resulting from the knowledge process within the model and their correlation with digital replicas of the historic built heritage (Messaudi et al., 2018; Croce et al., 2020; Bianchini & Potestà, 2021).
It is worth noting that digital models with different levels of detail and accuracy empowers the impact of the data acquisition in sharing data among experts involved in activities aimed at safeguarding and enhancing the heritage and supporting, therefore, decision-making and management processes related to the territory and its resources (Miele, 2011; Campisi, 2020).
Therefore, digital models of the portals have been developed starting from the systemic arrangement of the data and using three different types of modelling, from photogrammetric to parametric (Fig. 8).
In particular, mesh models of those elements that are an exception within the building pattern were developed from the photogrammetry of the images acquired during the field campaigns. Parametric and NURBS models, achieving a higher level of detail, were created for the most common portal types.
The NURBS modelling was carried out after critical restitution of the single elements of the portals, starting from the geometric data and the images acquired during the survey campaign. The closed polysurfaces were created from the profiles obtained from a critical restitution and were put in specific levels, defined according to the typological and formal characteristics of the portal. The models obtained (Fig. 9) can be easily exported into a BIM environment (Trizio et al., in press) to add heterogeneous parameters, such as those referred to the archaeological information and the state of preservation recorded in the SLATE catalogue or those based on the geometric rules of HBIM models.
At the same time, the digital parametric models were created for the most common portal types.

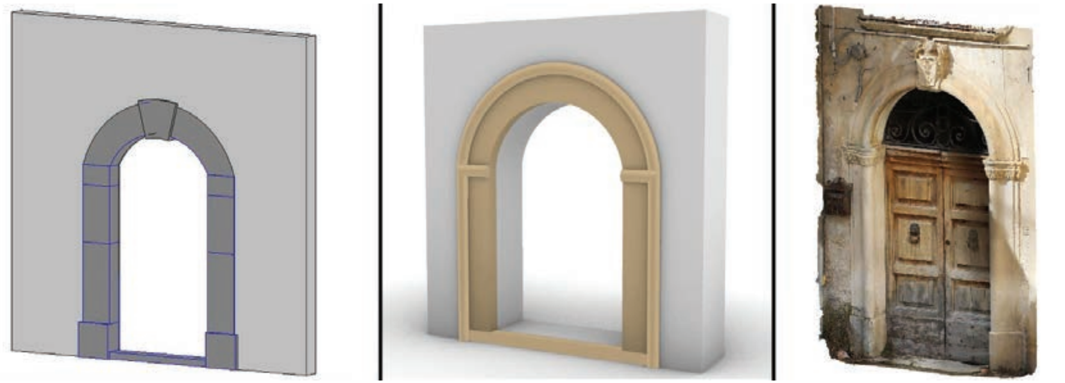

Fig. 8 - Modelling examples: parametric model, on the left; NURBS model, in the middle; photogrammetric model, on the right.

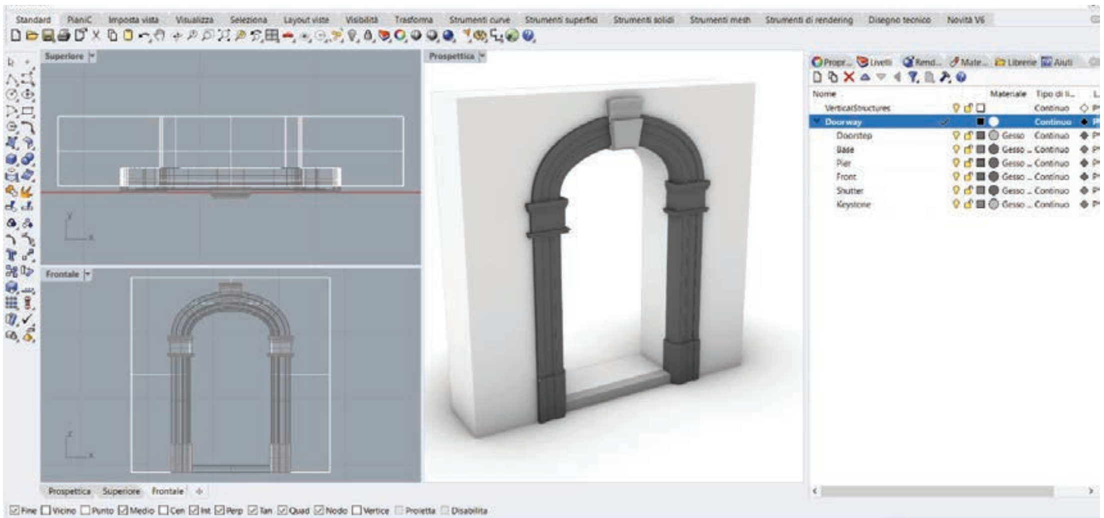

Fig. 9 - NURBS model.

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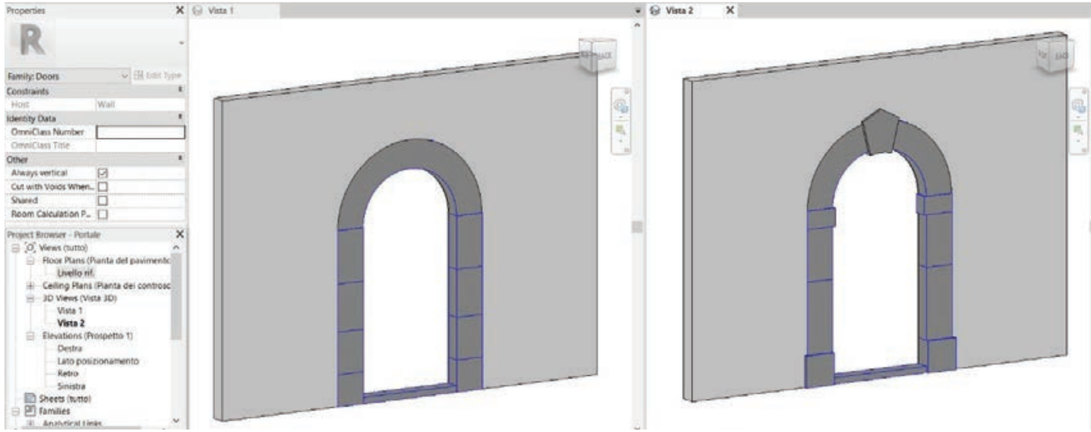
The importance of parametric shared libraries on historical heritage peculiarities is discussed widely by scientific literature, where have been developed specific workflows to combine the parametric modelling with other procedures, such as based on Structure from Motion (SfM) techniques (Santagati & Lo Turco, 2016; Santagati et al., 2016; Chiabrando et al., 2017; Miatton & Parrinello, 2017; Godinho et al., 2020). In such a way, the modelling has been directed towards the semantic digital models (De Luca, 2011) that provide the management of all the information derived from the knowledge process and are valuable in the conservation and management processes of historical heritage. As in the NURBS modelling, the parametric one was carried out after the critical analysis of geometrical features identified after the survey phase. Therefore, a new dedicated family was developed for this type – namely doors – parameterising all single elements that characterised the portal (base, pier and impost). The keystone was included in a specific label, in order to have the most frequent typologies found in the area under investigation. As a consequence, it is possible to switch within the parametric model from the simple portal, i.e. types B.1 and C.1, to the complex one, i.e. types B.2 and C.2, which includes the base, impost and keystone ashlar, selecting for the latter element also the profile type (Fig. 10). Finally, shared parameters have been defined to better describe and characterise each portal elements. These parameters have been derived from Object and Typological features modules of the SLATE form, thus creating a direct link between the model and the catalogue (Fig. 11).

5. INFORMATIVE SYSTEM AND VIRTUAL REALITY INTEGRATION

The need to connect data, gathering into the catalogue, to the digital models, ensuring their interoperability, has led to defining a three-dimensional catalogue of the surveyed architectural elements, the 3D *hiStoricaL ArchiTectural Elements* – 3D SLATE – catalogue, which enables the visualization of information connected to each single three-dimensional object.

Digital application, based on Virtual Reality systems and developed both from image and polygons, have proved to be useful tools not only in the fruition and enhancement of architectural and archaeological heritage (Ionnides et al., 2018; Choromański et al., 2019; Nicastro & Puma, 2019), but also for technical issues related to dissemination of knowledge and monitoring of cultural heritage (Trizio et al., 2018; 2019b; Banfi, Brumana & Stanga, 2019).

The 3D SLATE catalogue was built with the open-source Game Engine Unity (Unity Development Team, 2018), a multiplatform graphic engine that



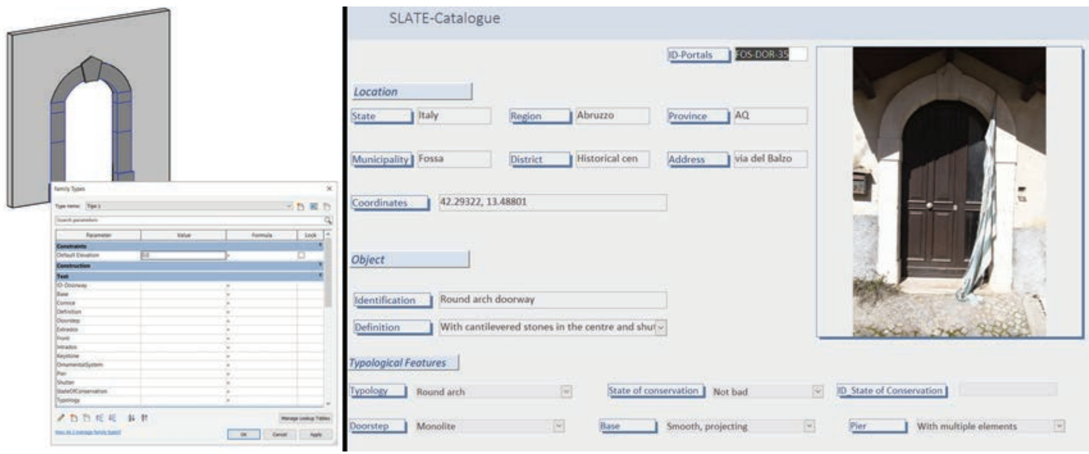


Fig. 10 - Parameric model.

Fig. 11 - Shared parameters in BIM environment and portal surveyed and its SLATE Catalogue form.

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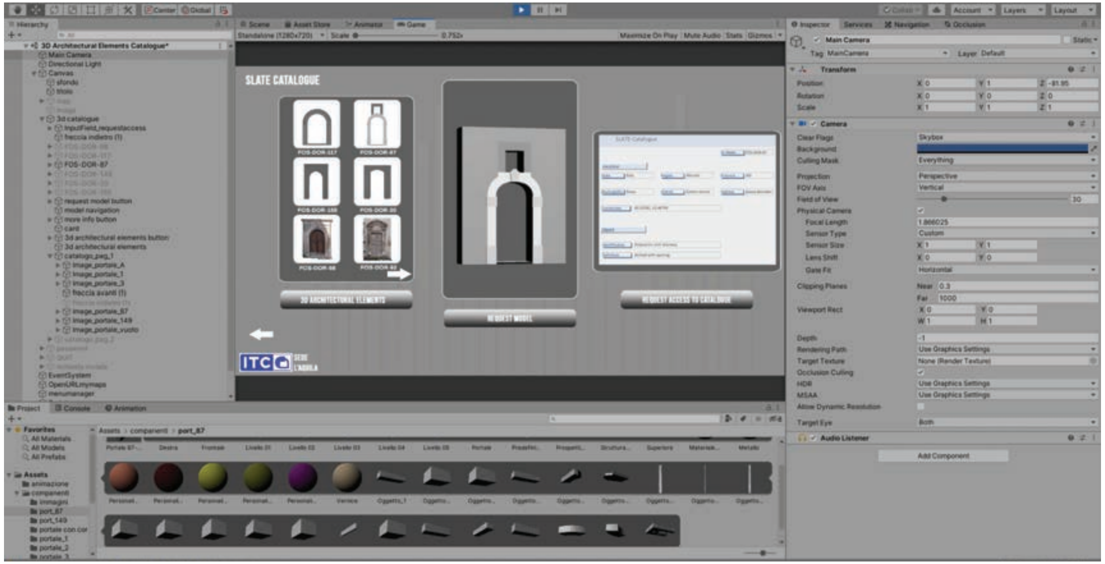

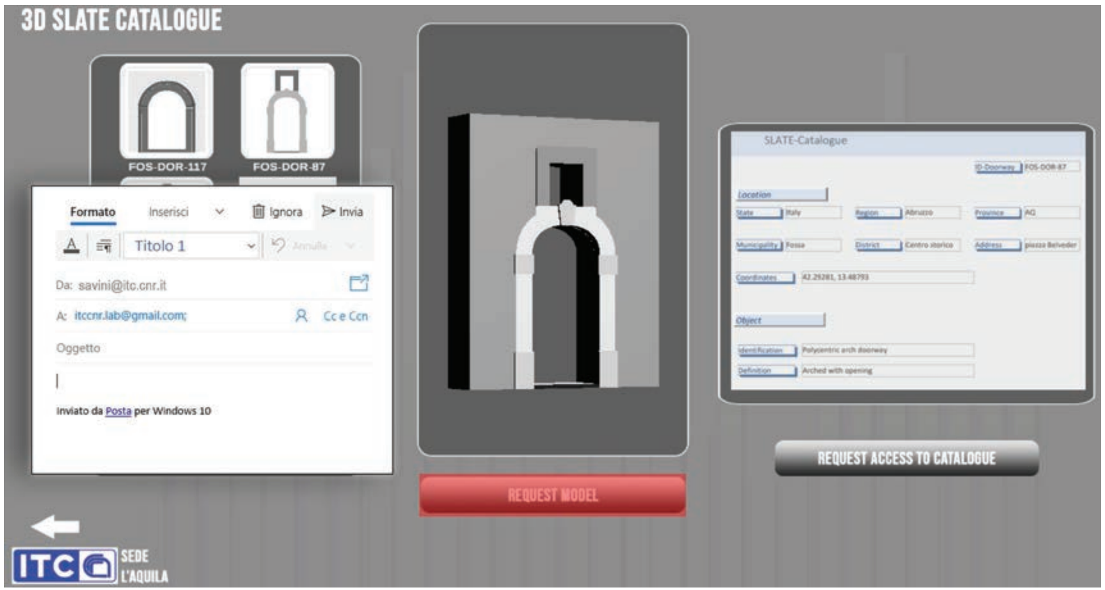

provides the management of different three-dimensional formats and their fruition in desktop and immersive modes through the association of more or less performing devices (Fig. 12). Moreover, the possibility of creating a WebGL build permits the fruition of the catalogue in the browser, facilitating its dissemination.The 3D catalogue interface consists of three sections. In the first section, on the left, there are the surveyed portals visible in 2D thumbnails that, like interactive buttons, allow the selection of the portal to be visualised. The central panel displays the selected three-dimensional model (photogrammetric mesh, NURBS and parametric models) which, thanks to special scripts, can be rotated on the Y-axis and enlarged to inspect the areas in detail. The models can be downloaded, on request, through a button that sends an e-mail thanks to the Application. OpenURL(Url) function. In the last section, for each selected model, the first level of the SLATE catalogue form is displayed (Fig. 13).

The amount of information produced by the research underlined the necessity of a connection system that could make heterogeneous data available in a single environment, ranging from plans to single images, from digital models to catalogue forms, each generated with different systems and applications. This has led to the definition of an Integrated Information System (3DIIS) in VR starting from the 3D Catalogue created in Unity, which guarantees the use of multi-data allowing access to researchers, public authorities and professionals, by exploiting the most common web applications and online repositories. Indeed, it is possible to request access through specific buttons and, after approval, to download the single catalogue forms stored on an online repository. Moreover, from the VR System, it is possible to access the interactive map in

Fig. 12 - Development of the VR Informative System in the Game Engine Unity platform.

Fig. 13 - Visualisation of a digital model in the VR System with an applicative for e-mail requests.

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MyMaps, where the spatial distribution of the portals can be analysed and visualised single architectural elements surveyed (Fig. 14).
An Augmented Reality application, which can be used on mobile devices and downloaded directly from the VR System through access to the repository mentioned above, was developed to facilitate access to a broader community by disseminating the results to non-experts. Through the APP, it is possible, by framing one of the portals analysed and available in the catalogue, to access additional content simply and dynamically. The application for Android has been developed using the free AR Foundation and ARKit plugins, which have made it possible to attach some buttons, with the data concerning the portal, to the real context, recognising the portal through the smartphone camera (Fig. 15 and Fig. 16).
The VR System highlights the potential of open digital tools for collection and systematisation of data and, in addition, it provides an understanding of the cultural value of the assets under investigation and supports the institutions in charge of management in the definition of strategies to be implemented to safeguard and enhance the heritage itself (Campisi, 2020).
The VR and AR applications are designed to enhance the built heritage and favour the knowledge of the historical architectural peculiarities in the municipality of Fossa, but also for supporting the digital management and preservation of the architectural assets by entrusted authorities and empower the memory of the sites and valorisation of historical heritage in Inner Areas.
This is the first experimentation that aims to exploit open-source web applications and platforms for the management of multi-data in a single environment, whose informative content can be improved through the creation of specific ontologies (Acierno & Fiorani, 2019; Bannour et al., 2018; Parisi, Lo Turco & Giovannini, 2019). The next step

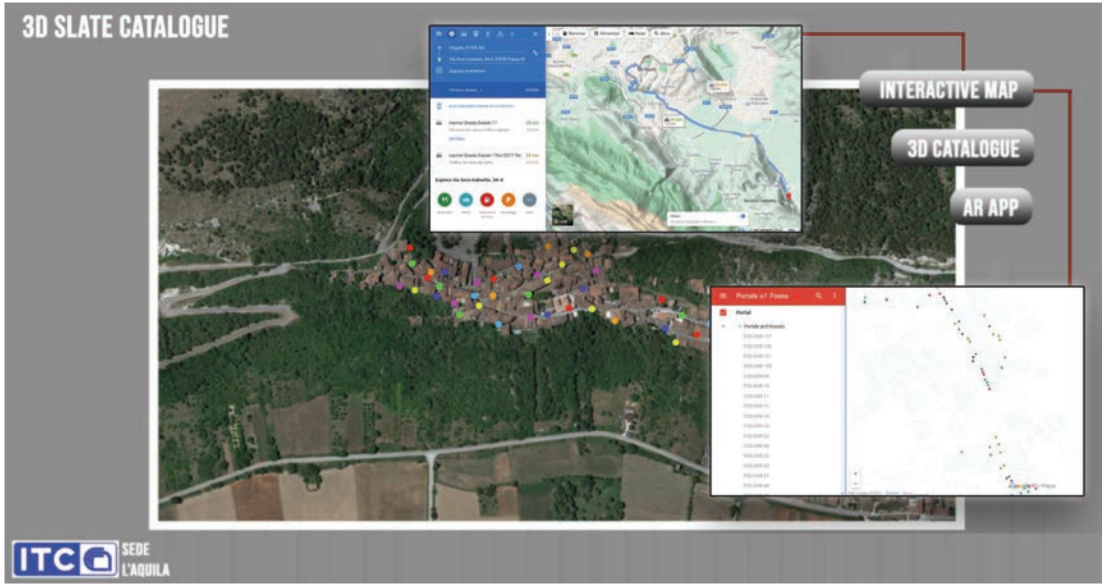

Fig. 14 - Link to the interactive map in the VR System.

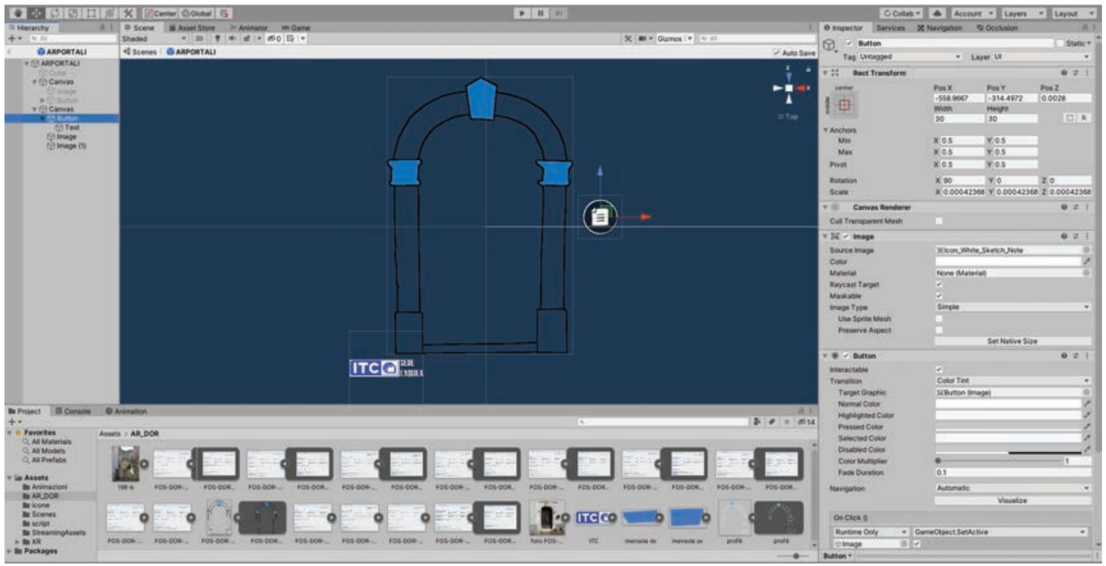

Fig. 15 - AR app development on Game engine platform.

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is to investigate the tools made available by the semantic web and use these ontologies as models that can "facilitate the integration, mediation and interchange of heterogeneous cultural heritage information" (Doerr et al, 2020, p. i). Moreover, the literature analysis proves that further efforts are needed both in linking of heterogeneous data acquired during the knowledge processes (Godinho et al., 2020) and in the identification of single and open standards that improve the interoperability between different systems (Guzzetti et al., 2021). At the same time, there is an emerging need to make the collection and classification of information more efficient, recurring to machine learning approaches (Grilli et al., 2018; Teruggi et al., 2020).

6. FINAL REMARKS

The strategies to preserve and protect the built historical heritage in Inner Areas require a comprehensive knowledge of the heritage itself, namely of all its elements, through the concurrent effort of different professionals. The authorities involved in its conservation and management can benefit from innovative solutions associated with the use of digital technologies for the development of detailed knowledge and validation of strategies of maintenance and restoration. In such context, the paper summarised the main features of a 3D Integrated Informative System (3DIIS) developed in Virtual Reality and combining traditional and innovative approaches for the knowledge, management and valorisation of the historic built heritage. Data collected in the 3D SLATE catalogue feed the informative system, which has been designed and validated with reference to a specific architectural element, the portals, whose relevance in the context of the minor centres in Inner Areas is commonly recognised. The operational workflow based on the field survey, model generation, data acquisition and management has been designed in order to be scalable and interoperable. These characteristics make the system open and suitable for the collaboration between several professionals and public administrations, which can increase their services and tools to favouring the protection, valorisation and management processes of historical centres.

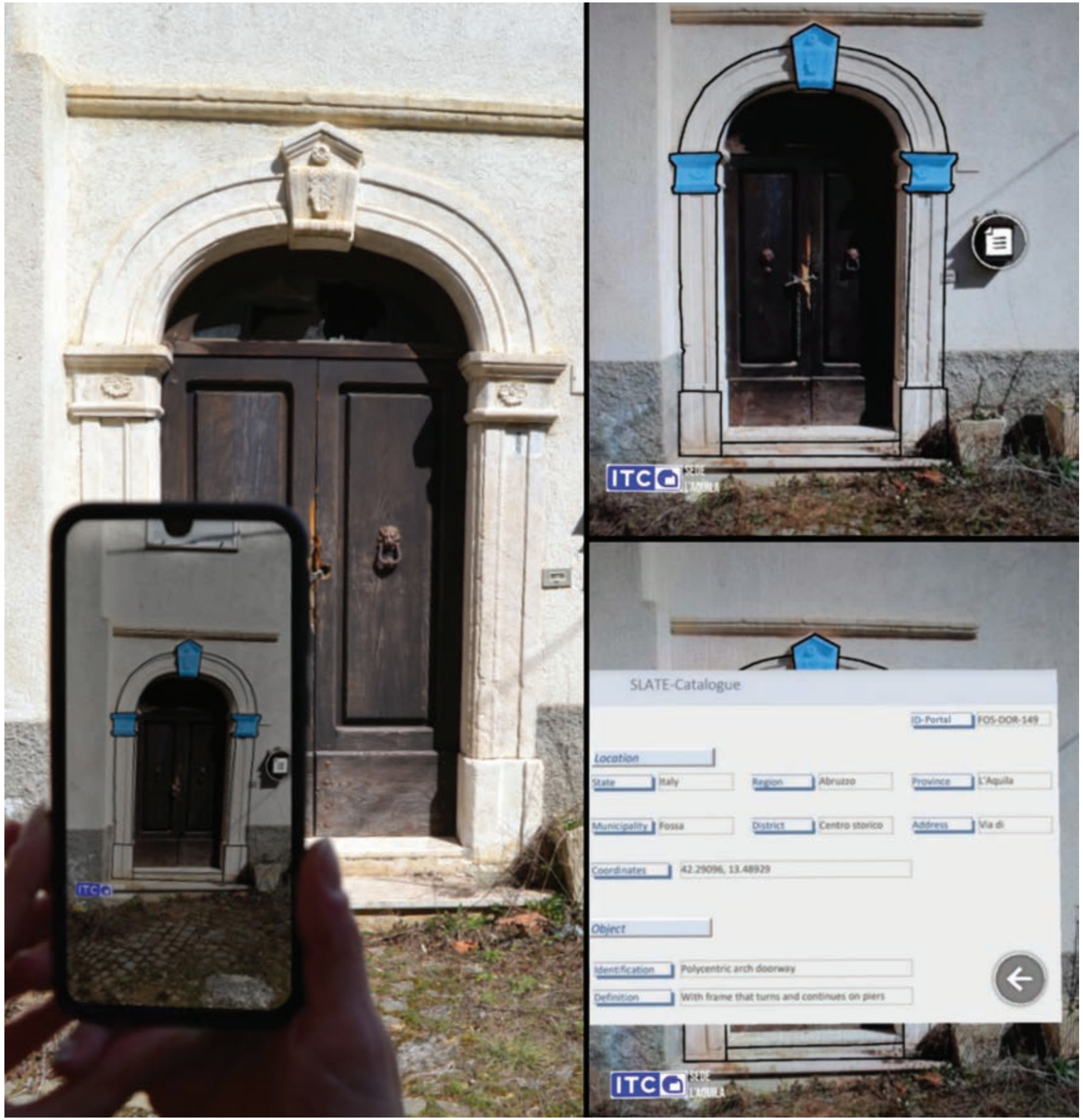

Fig. 16 - AR test on the Fossa' portal and screenshots of APP on mobile device.

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In such a way, the public administrations equipped with VR and AR applications improve the cultural supply chain, facilitating the relationship with the community in the perspective of more active involvement in heritage conservation.
The results herein reported, although positive, highlight the need to increase the dataset and to define a machine learning algorithm starting from this dataset. These tests are the starting point for future works that will be direct to the use of 3D models and segmentation of point clouds for the implementation of algorithms that will be able to recognise portals through the analysis of shapes and update 3D models according to data collected in the shared databases.

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CREDITS

The research presented is the result of authors' collective work, of continuous comparison and of a common discussion. All authors wrote sections 1 and 6. Francesca Savini wrote sections 4 and 5, she also developed the Integrated Information System in VR starting from 3D SLATE catalogue. Adriana Marra wrote sections 2 and 3, realised the NURBS and parametric models and developed the SLATE catalogue. Francesca Savini and Adriana Marra also processed data for the typological classification of portals. Giovanni Fabbrocino supervised the research, revised the work and validated the parameters in the SLATE catalogue.

REFERENCES

Accardo, G., Cacace, C., & Rinaldi, R. (2005). Il Sistema Informativo Territoriale della carta del Rischio. *ARKOS – Scienza e Restauro dell'Architettura,* 10, 43-52.

Acierno, M., & Fiorani, D. (2019). Innovative Tools for Managing Historical Buildings: The Use of Geographic Information System and Ontologies for Historical Centers. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.,* XLII-2/W11, 21–27.

Allegra, V., Di Paola, F., Lo Brutto, M., & Vinci, C. (2020). Scan-to-BIM for the Management of Heritage Buildings: the Case Study of the Castle of Maredolce (Palermo, Italy). *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, 43(B2), 1355-1362.

Bannour, I., Marinica, C., Bouiller, L., Pillay, R., Darrieumerlou, C., Malavergne, O., Kotzinos, D., & Niang, C. (2018). CRMCR - a CIDOC-CRM extension for supporting semantic interoperability in the conservation and restoration domain. In A.C. Addison, & H. Thwaites (Eds.), 2018 *3rd Digital Heritage International Congress (DigitalHERITAGE) Held Jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018)* (pp. 490–497). IEEE.

Bartolomucci, C., & Donatelli, A. (2012). La conservazione nei centri storici minori abruzzesi colpiti dal sisma del 2009: esigenze di riuso e questioni di conservazione. In G. Biscontin, & G. Driussi (Eds.). *La conservazione del patrimonio architettonico all'aperto: superfici, strutture, finiture, contesti* (pp. 101-111). Marghera-Venezia: Arcadia Ricerche.

Bianchini, C., & Potestà, G. (2021). BIM for Built Cultural Heritage: Semantic Segmentation, Architectural Stratification and LOD of the Baptistery of San Giovanni in Florence. In C. Bolognesi, & D. Villa (Eds.), *From Building Information Modelling to Mixed Reality* (pp. 1-15). Cham: Springer International Publishing.

Bonamico, S., & Tamburini, G. (Eds.). (1996). *Centri antichi minori d'Abruzzo. Recupero e valorizzazione.* Roma: Gangemi Editore.

Campisi, M.T. (2020). La catalogazione come strumento di gestione attiva. Dagli oggetti isolati alla rete di relazioni per la salvaguardia e valorizzazione dei Beni nei territori. In S. F. Musso, & M. Pretelli (Eds.), *Restauro: Conoscenza, Progetto, Cantiere, Gestione* (Sezione 1.3, pp. 234-240). Roma: Edizioni Quasar.

Caravaggio, P., & Meda, A. (2004). *Manuale del recupero di Castel del Monte*. Roma: DEI.

Carocci, C. (Ed.) (2012). *Piano di ricostruzione del Comune di Fossa.* Retrieved October 12, 2020 from <https://comune.fossa.aq.it/contenuti/143905/ufficio-piano-ricostruzione>.

Cervellati, P.L. (2009). La sorte dei piccoli centri storici: abbandonati, trasfigurati, turisticizzati. Minori e maltrattati. *Bollettino Italia Nostra*, 445.

Chenaux, A., Murphy, M., Pavia, S., Fai, S., Molnar, T., Cahill, J., Lenihan, S., & Corns, A. (2019). A Review of 3d Gis for Use in Creating Virtual Historic Dublin. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W9, 249–254.

Chiabrando, F., Lo Turco, M., & Rinaudo, F. (2017). Modeling the decay in an hbim starting from 3d point clouds. A followed approach for cultural heritage knowledge. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, 42(2W5), 605–612.

Choromański, K., Łobodecki, J., Puchała, K., & Ostrowski, W. (2019). Development of Virtual Reality Application for Cultural Heritage Visualization from Multi-Source 3D Data. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W9, 261-267.

Copus, A., Mantino, F., Noguera. J. (2017). Inner Peripheries: An Oxymoron or a Real Challenge for Territorial Cohesion?. *Ital. J. Plan. Pract.,* 7, 24–49.

Croce, V., Caroti, G., De Luca, L, Piemonte, A., & Véron, P. (2020). Semantic Annotation on Heritage models: 2D/3D Approaches and Future Research Challenges. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLIII-B2-2020, 829–836.

D. Lgs. 42 (2004). *Codice dei beni culturali e del paesaggio*. Roma: G.U. n. 45, 24/02/2004.

De Luca, L. (2011). Verso la caratterizzazione semantica di rappresentazioni digitali di artefatti architettonici: linee programmatiche di ricerca. *Disegnarecon*, 4(8), 99-106.

Decri, A., Parodi, I., Roascio, S., & Rosatto, G. (2015). Cronotipologia al tempo del web 2.0: Banca dati e mappa online dei portali di Genova. *Archeologia e Calcolatori*, 26, 265-274.

Doerr, M., Bruseker, G., Bekiari, C., Ore, C. E., Velios, T., & Stead, S. (2020). *Volume A: Definition of the CIDOC Conceptual Reference Model.* Retrieved January 21, 2021 from: <http://www.cidoc-crm.org/sites/default/files/CIDOC CRM_v6.2.9 30-4-2020 .pdf>

Fabbrocino, G., & Marra, A. (2018). Strumenti di rilievo caratterizzazione dei beni museali e artistici. In G. Fabbrocino, & M. Savorra (Eds.), *La Certosa di Trisulti* (pp. 200-219). Milano: Silvana Editoriale.

Febbraro M., & Susini F. (2012). Archeologia dell'architettura e della città. Un esempio di analisi degli elevati applicata ad un centro urbano: il caso di Pisa. *MapPapers*, 8-II, 266-276.

Ferrando I., Mannoni T., & Pagella R. (1989). Cronotipologia. *Archeologia Medievale*, 17, 647-661.

Frogione, F. (2016). Censimento e cronotipologia degli Elementi Architettonici della città dell'Aquila: dati preliminari per la realizzazione di un Sistema Informativo del tessuto edilizio medievale e delle architetture storiche. In F. Redi, A. Forgione, & F. Armillotta (Eds.). *Stratigrafia degli elevati e nuove tecnologie diagnostiche. Archeologia dell'edilizia storica in situazioni di emergenza* (pp. 21-38). L'Aquila: One Group Edizioni.

Godinho, M., Machete, R., Ponte, M., Falcão, A.P., Gonçalves, A.B., & Bento, R. (2020). BIM as a resource in heritage management: An application for the National Palace of Sintra, Portugal. *Journal of Cultural Heritage*, 43, 153-162.

Grilli, E., Dininno, D., Petrucci, G. & Remondino, F. (2019). From 2D to 3D supervised segmentation and classification for cultural heritage applications. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2, 399-406.

DOI: https://doi.org/10.20365/disegnarecon.26.2021.9

ISSN 1828-5961

Guzzetti, F., Anyabolu, K., Biolo, F., & D'Ambrosio, L. (2021). BIM for existing construction: A Different Logic Scheme and an Alternative Semantic to Enhance the Interoperability. *Applied Sciences*, 11(4), 1-13.

ICCD (2018). *Catalogazione*. Retrieved 21 January 2021 from: <http://www.iccd.beniculturali.it/it/Catalogazione>.

Ioannides M., Fink E., Brumana R., Patias P., Doulamis A., Martins J., & Wallace M. (Eds.) (2018). *Digital Heritage Progress in Cultural Heritage: Documentation, Preservation, and Protection. 7th International Conference, EuroMed 2018, Nicosia, Cyprus, October 29 – November 3, 2018, Proceedings*. Cham: Springer.

Jouan, P., & Hallot, P. (2020). Digital Twin: Research Framework to Support Preventive Conservation Policies. *ISPRS Int. Journal of Geo-Information*, 9, 228.

Kelly, C. (2009). Heritage. In N. Thrift, & R. Kitchin (Eds.). *The International Encyclopedia of Human Geography* (pp. 91-97). London: Elsevier Ltd.

Lorenzetti, F. (2020). Le cosiddette 'porte del morto' all'Aquila: la trasformazione di un modello edilizio medievale. *Archeologia dell 'Architettura,* XXV, 209-221.

Mannoni T. (1994). *Caratteri costruttivi dell'edilizia storica*. Genova: Escum.

Marra A., Sabino, A., Bartolomucci, C., Trizio, I., Mannella, A., & Fabbrocino, G. (2021). On a Rational and Interdisciplinary Framework for the Safety and Conservation of Historical Centres in Abruzzo Region. *International Journal of Architectural Heritage*, 15(4), 608-626.

Marra, A., & Fabbrocino, G. (2020). Open-access web mapping as a virtual survey tool for cultural heritage: an application to the Armenian religious architecture documented by Paolo Cuneo. *Disegnarecon*, 13(25), 7.1-7.12.

Marra, A., & G. Fabbrocino (2021). Crowd-based Tools for Indirect Condition Assessment and Conservation of Cultural Heritage. In M. Ioannides, E. Fink, L. Cantoni, & E. Champion (Eds) *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. EuroMed 2020*. Lecture Notes in Computer Science, 12642, 38-50. Cham: Springer.

Messaoudi, T., Véron, P., Halin, G., & De Luca, L. (2018). An ontological model for the reality based 3D annotation of heritage building conservation state. *Journal of Cultural Heritage*, 29, 100-112.

Miatton, C. & Parrinello, S. (2017). Modelli descrittivi per la gestione degli interventi di manutenzione sulla facciata della basilica di San Michele a Pavia. In T. Empler (Ed.). *3D Modelling & BIM. Progettazione, Design, Proposte per la ricostruzione* (pp. 260-277). Roma: Dei.

Miele, F. (2011). La conservazione della memoria materiale e immateriale. Sistemi informativi di catalogo e territoriali in Campania. *Archeologia e Calcolatori*, 22, 7-34.

Modena, C. (Ed.) (2013). *Relazione generale del Piano di Ricostruzione del Comune di Castel del Monte*. Retrieved October 12, 2020 from: <http://www.comune.casteldelmonte.aq.it/c066026/zf/index.php/modulistica/>.

Nazionale V. (2016). Proposta per la catalogazione degli elementi architettonici a L'Aquila: i Portali. In F. Redi, A. Forgione, & F. Armillotta (Eds.). *Stratigrafia degli elevati e nuove tecnologie diagnostiche. Archeologia dell'edilizia storica in situazioni di emergenza* (pp. 159-163). L'Aquila: One Group Edizioni.

Nicastro, G. & Puma, P. (2019). Virtual Heritage for the Dissemination of the Baratti in 3D Project. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W9, 529-534.

Noguera, J., Copus, A. (2016). Inner Peripheries: What Are They? What Policies Do They Need? *Agriregionieuropa*, 45. Retrived March 31, 2021 from: <https://agriregionieuropa.univpm.it/it/content/article/31/45/inner-peripheries-what-are-they-what-policies-do-they-need>.

Nucciotti M. (2009). Verso un 'atlante dell'edilizia medievale'. In M. Nucciotti (Ed.), *Atlante dell'Edilizia medievale. Inventario*, vol. I.1. Comunità montana Amiata grossetano (pp. 11-19). Arcidosso (GR): Effigi.

Oteri, A. M., & Scamardi, G. (Eds.) (2020). Un paese ci vuole. Studi e prospettive per i centri abbandonati e in via di spopolamento. *ArcHistoR* (Extra n. 7/2020).

Parisi, P., Lo Turco, M., & Giovannini, E.C. (2019). The value of knowledge through H-BIM models: historic documentation with a semantic approach. *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, 42(2/W9), 581-588.

Parrinello S. (Ed.) (2020). 3D *Bethlehem. Gestione e controllo della crescita urbana per lo sviluppo del patrimonio ed il miglioramento della vita nella città di Betlemme*. vol.2. Firenze: Edifir.

Quattrini, R., Clini, P., Nespeca, R., & Ruggeri, L. (2016). Measurement and historical information building: Challenges and opportunities in the representation of semantically structured 3d content. *Disegnarecon*, 9(16), 14.1-14.11.

Redi, F. (2003). Materiali, tecniche e cantieri: primi dati dal territorio aquilano. In P. Peduto, & R. Fiorillo (Eds.). *Atti del III Congresso Nazionale di Archeologia Medievale* (pp. 587-593). Firenze: All'Insegna del Giglio.

Redi, F. (2014). I portali di Tagliacozzo: Cronotipologia, tecniche e finitura degli apparati lapidei. In: F. Redi, & F. Armillotta (Eds.), *Restaurare in Abruzzo. Formazione e nuove professionalità per l'analisi e la conservazione dell'edilizia storica* (pp. 116-142). Pescara: CARSA Edizioni.

Saccucci M., & Pelliccio, A. (2018). Integrated BIM-GIS system for the enhancement of urban heritage. In *2018 Metrology for Archaeology and Cultural Heritage* (pp. 222-226). IEEE.

Santagati, C., Lo Turco, M., & D'Agostino, G. (2017). Populating a library of reusable H-BOMs: Assessment of a feasible image based modeling workflow. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, 42(2W5), 627-634.

Santagati, C., & Lo Turco, M. (2016). From structure from motion to historical building information modeling: populating a semantic-aware library of architectural elements. *Journal of Electronic Imaging*, 26(1), 011007.

Savini, F., Rainieri, C., Fabbrocino, G., & Trizio, I. (2021). Applications of Stratigraphic Analysis to Enhance the Inspection and Structural Characterization of Historic Bridges. *Infrastructures*, 6, 7.

Spallone, R., & Palma, V. (2020). Intelligenza artificiale e realtà aumentata per la condivisione del patrimonio culturale. *Bollettino SIFET*, 2.

Teruggi, S., Grilli, E., Russo, M., Fassi, F. & Remondino, F. (2020). A Hierarchical Machine Learning Approach for Multi-Level and Multi-Resolution 3D Point Cloud Classification. *Remote Sensing*, 12(16), 1-27.

Trizio I., Savini F., De Gasperis G., & Cordisco A. (2018). Siti perduti e inaccessibili: l'interpretazione del patrimonio attraverso applicazioni di realtà virtuale. In R. Salerno (Ed.), *Rappresentazione materiale/immateriale. Drawingas (in) tangible representation. Atti del 40° Convegno Internazionale deidocenti delle discipline della rappresentazione* (pp. 831-836). Roma: Gangemi Editore.

Trizio, I., Brusaporci, S., Tata, A., & Ruggieri, A. (in press). Advanced Digital Technologies for Built Heritage Survey and Historical Analysis. In *Proceedings of XV International Conference on Graphic Expression Applied to Building - APEGA 2021,* Redrawing the Future.

Trizio, I., Savini, F., Continenza, R., Giannangeli, A., Marchetti, A., & Redi, F. (2019a). Photogrammetric Survey and 3DGIS Management of Mesh in the Integrated Investigation of Complex Sites: The Case Study of the Church of Santa Maria in Cesoni. In C. Inglese, & A. Ippolito (Eds.), *Conservation, Restoration, and Analysis of Architectural and Archaeological Heritage* (pp. 48-80). IGI Global.

Trizio, I., Savini, F., Giannangeli, A., Fiore, S., Marra, A., Fabbrocino, G. & Ruggieri, A. (2019b). Versatil Tools: Digital Survey and Virtual Reality for Documentation, Analysis and Fruition of Cultural Heritage in Seismic Areas. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W17, 377–384.

Unity Development Team, 2020. *Unity User Manual (2020.3)*. Retrieved 21 January 2021 from: <https://docs.unity3d.com/Manual/index.html>.

USRC – Ufficio Speciale per la Ricostruzione dei Comuni del Cratere (2017). *I Piani di Ricostruzione* (PdR). Retrieved 21 January 2021 from: <http://www.usrc.it/attivita/piani-di-ricostruzione/i-piani-di-ricostruzione>.

Varagnoli, C. (2009). *Muri parlanti. Prospettive per l'analisi e la conservazione dell'edilizia storica.* Firenze: Alinea editrice.

Varagnoli, C. (Ed.) (2008). *La costruzione tradizionale in Abruzzo.* Roma: Gangemi.

Vernizzi C., & Bontempi D. (2020). Can a Map Save City Shops? Applications of Data Visualization to Represent the Material and Immaterial Urban Survey. In E. Cicalò (Ed.) *Proceedings of the 2nd International and Interdisciplinary Conference on Image and Imagination. IMG 2019. Advances in Intelligent Systems and Computing*, vol 1140 (pp 1106-1119). Cham: Springer.

Zordan, L., Bellicoso, A., De Berardinis, P., Di Giovanni, G., & Morganti, R. (2002). *Le tradizioni del costruire della casa in pietra: materiali, tecniche, modelli e sperimentazioni*. L'Aquila: Università degli Studi dell'Aquila, Dipartimento di Architettura e Urbanistica.

DOI: https://doi.org/10.20365/disegnarecon.26.2021.9