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Multi-sensors acquisition for digital documentation. Application to a damaged area of Navelli village

Digital technologies draw continuously novel opportunities and potentialities in the area of the documentation of architectural and cultural heritage and deliver to the research community questions and problems associated to the different and sometimes complementary applications, which range from protection and conservation to fruition and valorisation. This is particularly true when valuable assets are located in fragile and damaged contexts, due to particular morphological and typological conditions. The use of fast and efficient surveying techniques is often the optimal solution to meet these requirements, as these techniques can combine the needs for documenting complex heritage with those for protecting and safeguarding operators. In particular settings, the results of rapid acquisitions made by remotely piloted vehicles or mobile technologies suffer due to inhomogeneous level of information and therefore, the integration of data recorded by different sensors must be well designed and carried out.
The paper reports some results of the integrated survey of a complex site, located in the urban centre of Navelli, and characterized by several dwellings now ruined and compromised by the 2009 earthquake.
The procedure adopted within the integrated survey of case study moves from the analysis of the methodologies employed in the scientific literature in the context of multi-scale and multi-sensors data acquisition and their integration, aligning with them. The survey was carried out via a mobile laser scanner based on SLAM technology and a Dij Mini2 drone for aerial photogrammetry. The integration of the two technologies was optimized by the placement of control points acquired with a GNSS-based coordinate system, which permitted to adequately document the investigated area.

Keywords:
UAV survey; SLAM technology; Integrated digital survey; Data management; Expeditious survey

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1. INTRODUCTION

The digital documentation of the architectural and cultural heritage for its knowledge is a current issue as it is indispensable and preparatory to multiple actions, ranging from preservation and conservation to enjoyment and enhancement. This activity becomes more relevant working in fragile contexts or on damaged assets, subject to particular morphological and typological conditions. In these cases, the field data acquisition is characterised by an underlying complexity and must meet requirements strictly related to the safety and security of the operators; therefore, it is necessary to design appropriate operational workflows. These procedures have been favoured both by robust protocols codified within highly specialised disciplines, such as geomatics, and by advances in new technologies with increasingly powerful hardware and software solutions. As a result, point clouds with high levels of precision, i.e. with a dispersion of points in the order of a centimetre, were obtained. These point clouds can be used as a reference for knowledge analyses on heritage, and this has increased the use of 3D surveying tools in the context of documenting cultural heritage exposed to any type of hazard.
Velocity and efficiency of the survey procedures are the main features of any technical approach in responding to such needs, as it can combine the needs of documenting the heritage, in all its complexity, with those of operators' safeguard and safety. Several studies demonstrate the effectiveness of data acquired using rapid sensors and systems in surveying emergency contexts for the material and structural knowledge of damaged cultural heritage to plan the actions to be performed (Chiabrando et al., 2016; Di Stefano et al., 2020).
The most popular expeditious systems include remotely piloted ones for aerial photogrammetry that are used in hazardous conditions and also for surveying different contexts, ranging from precision agriculture to the safety of industrial plants and renewable energy to the survey of archaeological sites and cultural heritage. In addition to these systems, there are mobile laser scanners that use Simultaneous Localisation And Mapping (SLAM) technology to quickly acquire point clouds from which to obtain geometric and spatial data.
There are currently technological solutions on the market capable of integrating remotely piloted systems with laser detection ones, such as the most common Mobile Mapping Systems (MMSs) installed on drones. Very interesting are the mobile lasers mounted on automated robots, as in the case of SPOT, the agile mobile robot developed by Boston Dynamics, that the archaeological park of Pompeii is testing for monitoring and inspection of the tunnels excavated clandestinely in the past. Although these systems are efficient for laser surveys in emergency contexts, the combination of data acquired with the two different techniques, laser and photogrammetric, which are often used in parallel and independently of each other, is equally significant. The integration of data derived from these different sensors is even more appropriate in particular environmental and typological contexts in which the results of expeditious acquisitions suffer from an inhomogeneous level of information. As in the case, for example, of the survey of artefacts that are difficult to access or narrow alleyways that characterise the urban contexts of minor centres in Inner Areas (Barca, Casavola, & Lucatelli, 2014).
In particular, the application of multi-sensors, image and range-based techniques by researchers from different disciplinary fields has demonstrated the reliability of integrated, indoor and outdoor survey procedures (Sammartano & Spanò, 2018; Savina Malinverni et al., 2018; Spanò, 2019; Keitaanniemi et al., 2021) and the accuracy of multi-scalar data acquired in the context of different types of cultural heritage (Pulcrano et al., 2019; Patrucco, Rinaudo, & Spreafico, 2019; Bronzino et al., 2019; Rinaudo & Scolamiero, 2021). The diverse datasets integrated within a single point cloud support, on several levels, the knowledge for the conservation, management and enhancement of cultural heritage. The reliability of these procedures has been demonstrated by the application of laser scanning –terrestrial and mobile– and photogrammetric procedures –terrestrial, aerial or with a 360° camera– to archaeological sites and complex urban and architectural areas, i.e. historical buildings, parks, gardens and elements of furniture (Chiabrando et al., 2017; Spanò, 2019; Rabbia Sammartano, & Spanò, 2020; Teppati Losé et al., 2020; Barba et al., 2020). The various acquisition techniques provide point clouds that can be used to produce two- and three-dimensional data, such as semantic models, that facilitate the information sharing between several experts. These products, thanks to the photorealistic textures obtained with photogrammetry, are suitable for qualitative and quantitative assessments of the current condition of artefacts. In addition, the resulting models can be used to create Complex Information Systems obtained by applying Virtual Reality techniques and tools that are effective both for the virtual enhancement and fruition and for heritage monitoring and maintenance.
This is the background of the present paper, which deals with the main outcomes and results of the integrated survey of a complex and multi-stratified site located in the historic centre of Navelli, characterised by several buildings in ruins abandoned over time and further compromised by the 2009 earthquake that struck L'Aquila city and its territory. The preliminary analyses of the urban landscape and the encouraging results delivered by integrating the data collected during the survey direct the research towards different investigation. Indeed, the resulting data favour the development of digital solutions useful for the protection, management and enhancement processes by the technicians and public administrations, also in the perspective of e-conservation (Trizio et al., 2021a; Savini et al., 2022; Marra et al. 2021). In addition, the acquisition and analysis phases result in new data that can be structured hierarchically within the semantic web to define new ontologies for minor historical centres (Acierno et al. 2017; Trizio et al., 2021b).

2. THE VILLAGE OF NAVELLI, AN OVERVIEW

The Inner Areas of the central Apennines, especially in Abruzzo and Molise, are characterised by the widespread presence of minor historical cen-

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tres with a distinctive landscape and construction features that have been severely compromised by abandonment and depopulation processes and by recurring seismic events (Oteri & Scamardi, 2020).
An attractive village in the Abruzzo Apennines is the municipality of Navelli, located about 35 km from the city of L'Aquila, on the south-western mountain slope of *Monte San Nicola*. It is a municipality that, along with its hamlet of Civitaretenga, oversees the plateau of the same name located below (Fig. 1).
Navelli village was developed between the 10th and 12th centuries, coinciding with the growth of encastellation's characteristic in the Abruzzo region, for which various theories have been proposed (Wickham, 1982; Clementi, 1996; Redi, 1997). However, the municipal territory has a long settlement history, as well demonstrated by several funeral archaeological finds that attest to the plateau's frequentation since the *Vestino* period (Persichetti, 1894; D'Alessando, 2014; Acconcia & Ferreri, 2015). Indeed, the area of Navelli in Roman time was occupied by the vicus *Incerulae*. The toponym remained in documents until the 11th century (Leuzzi, 2007), and it is recalled by the name of the *Santa Maria In Cerulis* church (Coarelli & La Regina, 1984), located in the area below the current town. According to oral tradition, the nine territorial communities, known as *ville*, gathered in a single settlement to meet the needs of defence, communication, exposure and sustenance (Ferreri, 2015). The hypothesis that the name of the municipality derives from the union of the nine *ville* is suggestive.
The Navelli village, like the whole territory, has a complex evolutionary history, starting from its first settlement in the early Middle Ages, which can be hypothesised in the foundation site called *Piaggia* (*Piceggia*) *Grande* (AA.VV., 2002; AA.VV., 2005), to the many transformations over time (Fig. 2). Some of these transformations were affected by military and catastrophic events, i.e. recurring earthquakes, but also by the partial and gradual abandonment of the historical centre. This phenomenon started between the end of the 19th century and the 20th century and was intensified due to the migration of the population to other countries triggered by the sheep farming crisis (AA.VV., 2005).

Fig. 1 - Identification of the village of Navelli, the hamlet of Civitaretenga and the plateau of Navelli.
Fig. 2 - Historical evolution of Navelli (Re-elaborated from: Comune di Navelli & Università degli Studi di Parma, 2013).

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Among the others, the earthquake that hit the Appenine region in 1456 is particularly relevant due to the extension of the damage caused in the towns of Abruzzo and Molise (Meletti et al., 1988), and the 1703 one that damaged the city of L'Aquila and its surrounding territory.
The layout of the village of Navelli suggests that its evolution has been driven by the above mentioned natural events. In particular, following the earthquake of 1456, the inhabited area was relocated further downstream and was built the first city walls. With the reconstruction after the 1703 earthquake, the urban area was extended outside the city walls. In this phase, several small palaces were built on the main roads to the village and near the three city gateways, resulting from the unification of neighbouring units (Cacciavillani et al., 2007).
On the analogy with many centres in the same area, the village's urban fabric is characterised by four building typologies: the terraced house built parallel to the contour lines (Fig. 3a), the two- or three-level terraced house placed orthogonally to the contour lines (Fig. 3b), the arched house (Fig. 3c), and the fortress house (Fig. 3d).
Among these, the building typology of the arched house is very interesting since, on the one hand, it improved the response of aggregates to seismic stress and, on the other, allowed the connection between two terraced houses, creating suggestive covered passageways within the urban fabric (Cacciavillani et al., 2007).
The village of Navelli, already mostly compromised by abandonment and neglect, suffered further damage and the loss of typical and distinctive elements due to the earthquake that struck the Abruzzo region in 2009. To repair the damage induced by the earthquake and recover the building and landscape features, as well as the historical and cultural values of the hamlet, the municipality of Navelli adopted the Reconstruction Plan (PdR) drawn up by the University of Parma in 2013, according to the law no. 77 of 24 June 2009 (Ventura, Montepara & Zazzi, 2019). The PdR represents a strategic and urban planning instrument aimed at the economic-financial programming of resources, the regulation of building interventions and the definition of guidelines for public and private reconstruction (Fico et al., 2019).

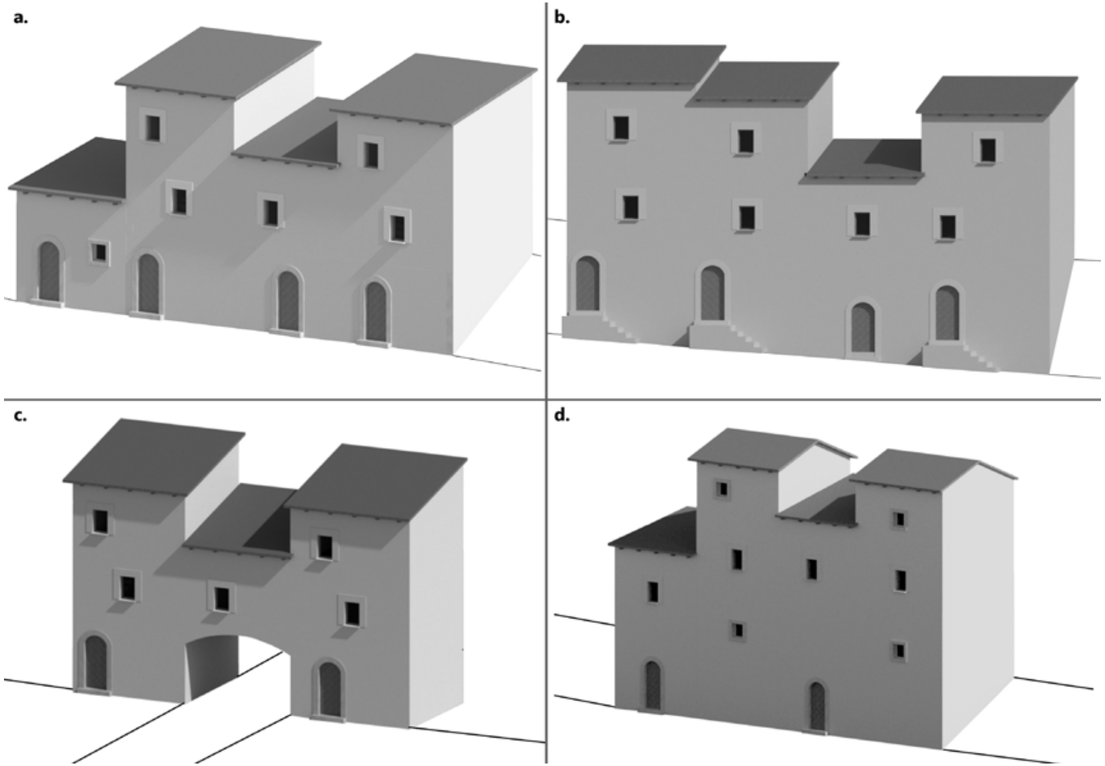

Fig. 3 - Building types identify in the historical centre of Navelli: (a.) terraced houses parallel to contour lines; (b.) terrace houses perpendicular to contour lines; (c.) arched houses; (d.) fortress-houses.

The portion located to the northeast of the village was considered a study case; it is placed near the steps of *Via Forno da Capo*, built on the steepest slope of the settlement (Fig. 4). The building fabric consists mainly of terraced houses with two or three levels orthogonal to the contour lines and fortress houses (Fig. 3b e Fig. 3d). This area was affected by the gradual abandonment that began in the 19th century and is currently in a state of ruins, conditions worse with the 2009 earthquake.
The pre-existing damage to the area and the impossibility of reconstructing the buildings, despite the presence of some private properties and the panoramic location, have led to the creation of an archaeological garden park in this part of the settlement. Indeed, the PDR envisages the consolidation of masonry portions surviving in a state of ruins and the greening of urban spaces or outdoor real estates to create a terraced garden from which to enjoy panoramic views of considerable landscape value (Comune di Navelli & Università degli Studi di Parma, 2013), also leading to the hypothesis of some design solutions (Trizio et al., 2020).

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Fig. 4 - An image collection of the investigated eastern area in Navelli village.

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Fig. 5 - The aero photogrammetric survey: on the left the images of the instruments used; on the right the result of image processing..

3. SURVEY STRATEGIES

The municipality of Navelli, already investigated for drafting the post-earthquake PdR (Vernizzi & Zerbi, 2012; Ventura, Montepara, & Zazzi, 2019), has been the focus of a new expeditious survey at the architectural scale and for the knowledge phases, since the area is still neglected (Ciuca, 2022). The procedure adopted within the integrated survey of the Navelli case study moves from the analysis of the methodologies employed in the scientific literature in the context of multi-scale and multi-sensors data acquisition and their integration, aligning with them (Chiabrando et al., 2017; Spanò, 2019).
The urban and built fabric characteristics of the analysed area were acquired using a mobile laser scanner based on SLAM technology (Barrera-Vera & Benavides-López, 2018; Sammartano & Spanò, 2018; Barba et al., 2019; Rinaudo & Scolamiero, 2021) and a Dji Mini 2 drone with a 2/3'' CMOS sensor for aerial photogrammetry (Ulvi, 2021; Teppati Losé et al., 2020).
The aero photogrammetric survey (Fig. 5) was carried out with three flights, each lasting ap-

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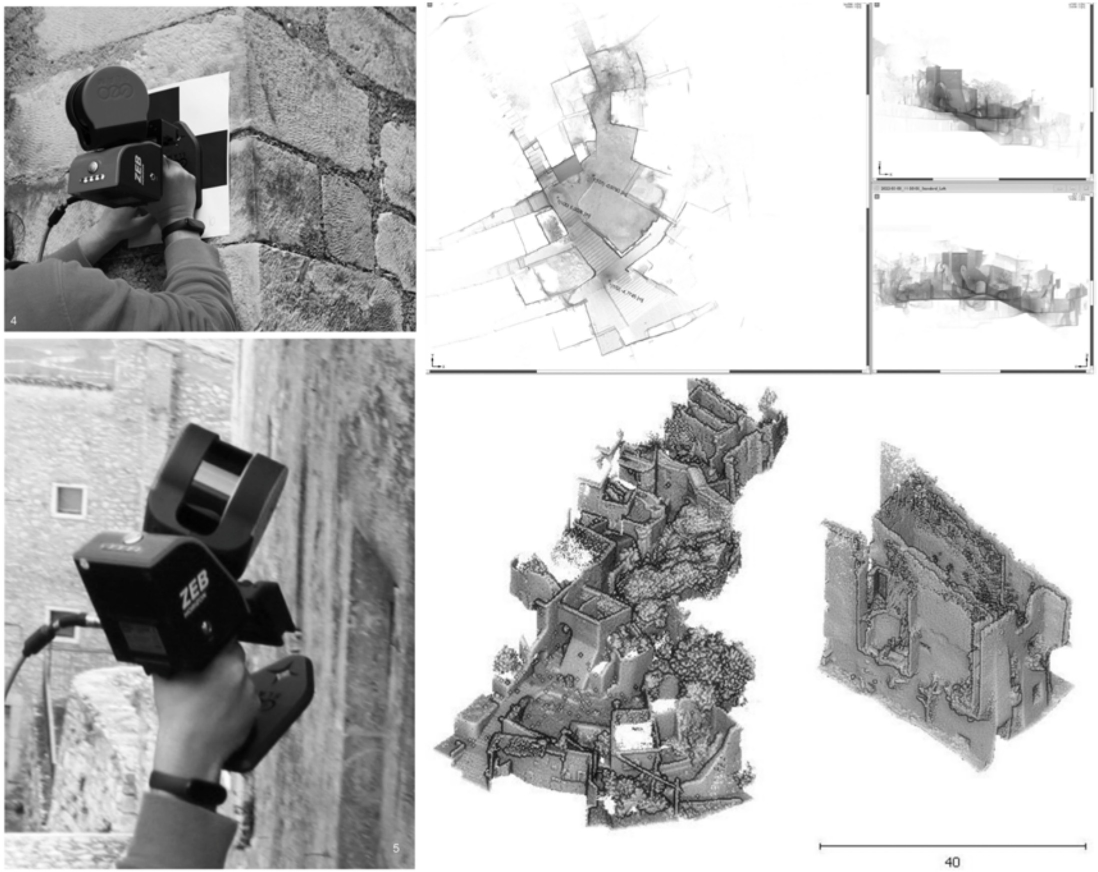

Fig. 6 - Survey with MMS: left, ZEB Horizon laser; right, results of the scanning process..

Tab. 1: Summary of data acquired with the MMS system

Loop	Acquisition time [min]	Points
NAVELLI_1_3	11,45	80.310.000
NAVELLI_1_2	7,07	44.630.000
NAVELLI_1_1	7,00	43.200.000
NAVELLI_2_2	4,18	34.320.000
NAVELLI_2_1	4,14	35.340.000
NAVELLI_2_0	6,12	49.020.000

proximately 15 minutes. These enabled the acquisition of 1020 nadiral and oblique images at an altitude of between 20 and 25 m.
During the photogrammetric process, carried out using the Agisoft Metashape software, topographic coordinates were placed on the six markers physically positioned in the area before the survey - 3 Ground Control Points (GCPs) and 3 Check Points (CPs). Data processing returned a cloud of approximately 198 million points, with an average quadratic error (RMSE) of about 50 mm for the CPs.
At the same time, the laser survey with the ZEB Horizon mobile scanner by GeoSLAM (2022) was carried out. This instrument allows acquiring good quality point clouds thanks to its inertial measurement unit and SLAM technology. The laser has a range of 100 m and produces scans of indoor and outdoor environments in a short time, with an accuracy ranging from 1 to 3 cm. The ZEB Horizon scans were acquired through the execution of closed loops with an average duration of 10 minutes, covering a portion of the park and a specific building unit located along the steps of *Via Forno da Capo* (Fig. 6).
This acquisition approach facilitates cloud alignment by minimising errors along the trajectory and increasing the system rigidity. The data were processed using default settings in the GeoSLAM Hub cloud computing service. Table 1 shows the data acquired through the mobile mapping system (MMS).
Finally, the integration of the two technologies (Fig. 7), aerial photogrammetry and SLAM, was optimised by positioning control points acquired with a GNSS-based topographic coordinate system. During the planning phase of the integrated survey campaign, points were materialised through the topographic targets on which mobile markers, visible during drone acquisition, were placed. These points were also acquired during the SLAM campaigns by stationing the instrument on the target.
Each target was acquired by Geomax's Zenith 16 receiver (Fig. 8), which delivered the geographic and cartographic coordinates (Tab. 2) functional to achieve a proper georeferenced and alignment of the data acquired through the two different survey procedures.

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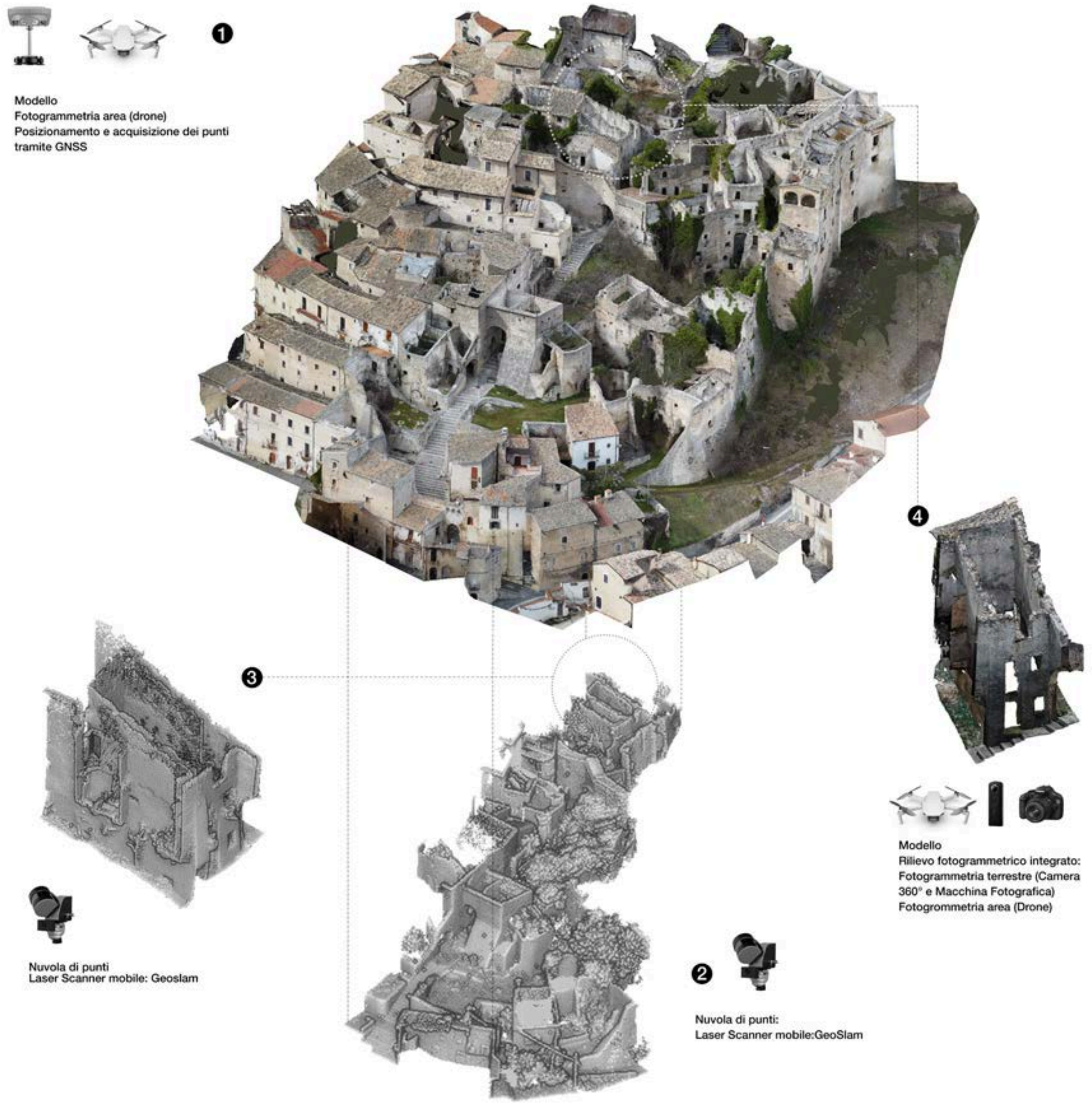
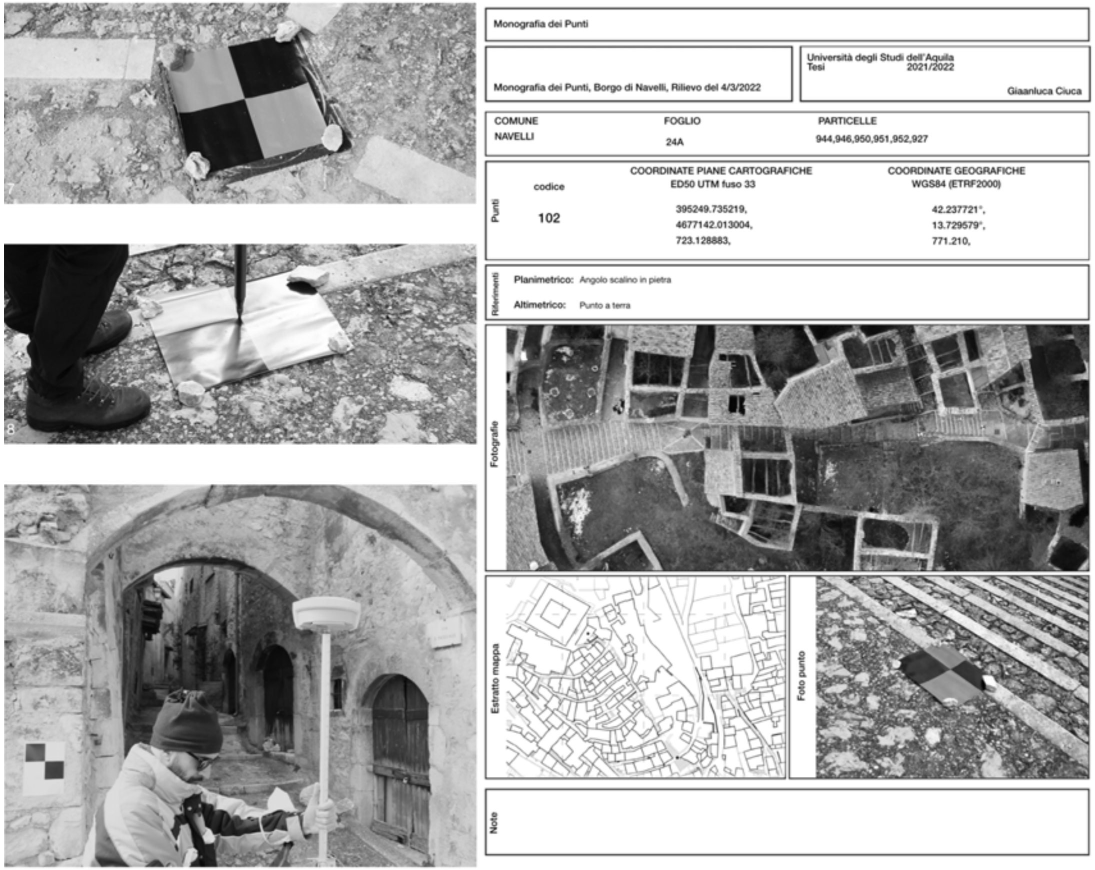


Fig. 7 - Results of the integrated survey.



A comparative analysis of some portions of the same point clouds obtained by laser and photogrammetry was carried out with the aim of assessing the integrability of surveys and confirming their validity in terms of the precision of the final product. In particular, the comparison between the two clouds was carried out on two different cloud portions of the surveyed area (Fig. 9) using the Cloud-to-Cloud (C2C) tool of CloudCompare software. This tool uses the 'Nearest Neighbour' algorithm (of the 'Hausdroff' distance type) to calculate the Euclidean distance between each point in the compared cloud and the nearest point in the reference cloud (User Manual Cloud Compare; Rockafellar & Wets, 2009; Bronzino et al., 2019; Batur et al., 2020).
The main parameters for the comparison were then defined (Fig. 10), assuming the UAV photogrammetric cloud as the reference cloud and setting 0.50 m as the maximum distance value not to be compared in order to exclude points in the compared cloud with an irregular distance to the reference cloud.
The comparison between the two clouds has calculated the absolute distance C2C values that are displayed by mapping the scalar fields on the GeoSLAM cloud (Figg. 11, 12). A consistent geometric pattern can be observed in both test areas among the compared clouds. The main differences, marked with warmer colours, are associated with the vegetation and the non-acquisition of points relating to features that cannot be detected by aerial photogrammetry, such as vaults and filiform elements. The values of the average distance and standard deviation obtained in the comparisons of the two-test areas (Figg. 11b, 12b)

Fig. 8 - On left, the GNSS-based topographic coordinate system acquisition; on right, example of a monograph of surveyed points.

Cartographic plane coordinates				Geographical coordinates			
ED50 UTM spindle 33 DATUM ED50 oriented Italy Ellipsoid, international UTM projection				WGS84 (RDN corrections: ETRF2000 system) Latitude: decimal degrees Longitude: decimal degrees Ellipsoid height (WGS84 ellipsoid)			
100	395240.982344	4677156.645105	727.897336	100	42.237852°	13.729470°	775.979
101	395247.245654	4677160.407843	726.915126	101	42.237886°	13.729545°	774.996
102	395249.735219	4677142.013004	723.128883	102	42.237721°	13.729579°	771.210
103	395229.392584	4677178.252505	734.834504	103	42.238045°	13.729326°	782.916
104	395225.957660	4677181.136920	736.208799	104	42.238070°	13.729284°	784.290
105	395225.601816	4677183.646535	737.426085	105	42.238093°	13.729279°	785.507

Orthometric (geoid) elevation relative to the geoid Italy 2008

Tab. 2 - Summary of geographical and cartographic coordinates acquired.

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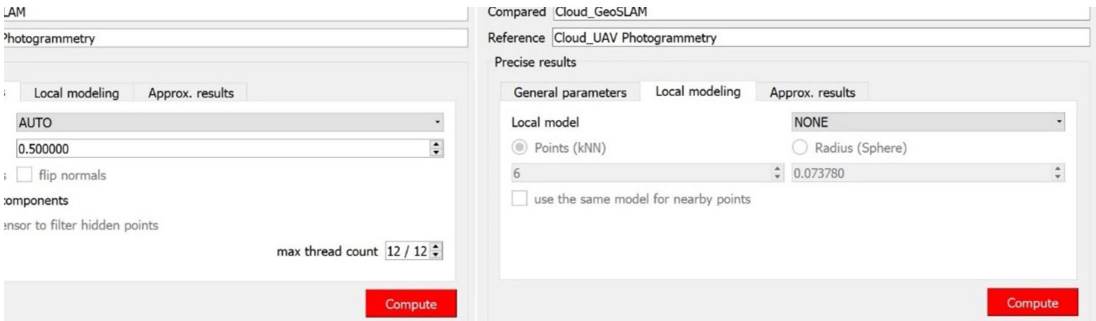
Fig. 9 - Indication of the test areas compared.

Fig. 10 - Main setting parameters of the C2C tool in the CloudCompare software.



show that the average differences between the two clouds are almost similar, as the values of the average distance differ by a few mm. On the other hand, the standard deviation values show a difference of a few centimetres caused by both noises from the acquisition of a larger area and the presence of vegetation. As shown by the scalar field maps (Figg. 11a, 12a), the areas of masonry present smaller absolute distances than the ones characterised by vegetation. This difference, in the order of 2 cm, falls within the instrumental accuracies of the two techniques used.

4. RESULTS

The main goal of the integrated survey of the north-eastern area of Navelli was to acquire the information needed to understand the qualities, both geometric and formal data, of the urban and building fabric to generate documents useful for the study and analysis of the built environment in this area.
For the elaboration of the plans and facades, it was necessary to integrate the point clouds acquired with the different sensors, as each had specific properties. The GeoSLAM point cloud was poor in data at the top parts and rich in information on the ground connections of buildings and facades. While that acquired with the aero photogrammetric survey was very detailed in the upper section and particularly noisy and deficient in the ground attachments of the artefacts surveyed due to the presence of small streets and contrasting arches between the buildings. Comparison between the two clouds showed a consistent trend in the scalar fields associated with the C2C distance and a minimum deviation, calculated in terms of average distance and RMSE, between them. In addition, the results obtained from cloud comparison pointed out centimetric precision for both techniques, thus permitting the integration between the two clouds. Therefore, after the editing phase to eliminate unnecessary and redundant data, a single point cloud was generated and used as a starting point for the two-dimensional drawings. These were performed by exporting from the opensource software

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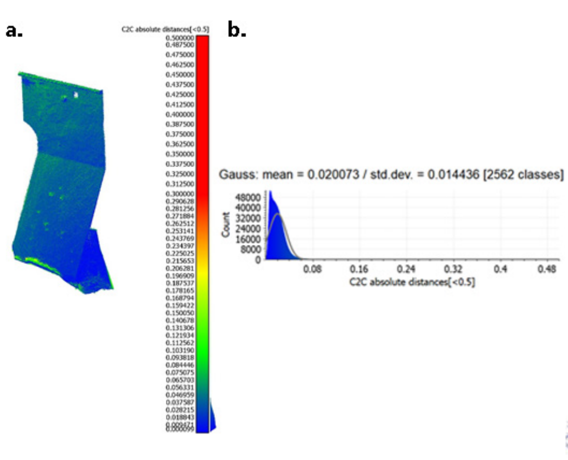

Fig. 11 - (a.) C2C result area test 1; (b.) Histogram with Gaussian curve and statistical parameters relating to absolute C2C distance in test 1.

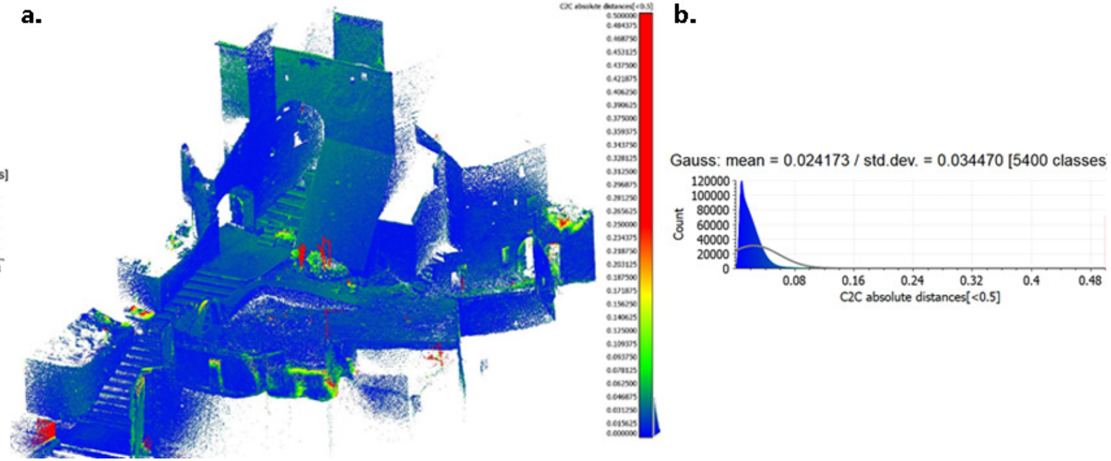

Fig 12 - (a.) Result C2C area test 2; (b.) Histogram with Gaussian curve and statistical parameters relating to absolute C2C distance in test 2.

Fig. 13 - Geometric survey on a scale of 1:100 of the area under investigation.

CloudCompare the slices of the point cloud, which then were imported into assisted digital drawing software for subsequent processing into plans, elevations and sections. These were produced at different metric scales, ranging from 1:100 for the morphological-dimensional understanding of the entire area (Fig. 13) to 1:50 for the masonry and degradation classification of the artefacts.
The two-dimensional drawings were enriched with colour data thanks to the orthomosaics obtained from the photogrammetric survey, with a Ground Sampling Distance (GSD) of 6.5 mm/pixel, which ensured their good resolution. In-depth knowledge of the artefacts in the area under investigation is necessary for a correct interpretation of the architectural features and the peculiarities of the building fabric. The high level of information obtained by processing the data acquired and integrated during the survey phases represents the ideal starting point for detailed thematic analyses (Fig. 14) and for developing three-dimensional models through the consolidated Scan to BIM procedures (Godinho et al., 2020; Barba et al., 2021; Costantino, Pepe & Restuccia, 2021).

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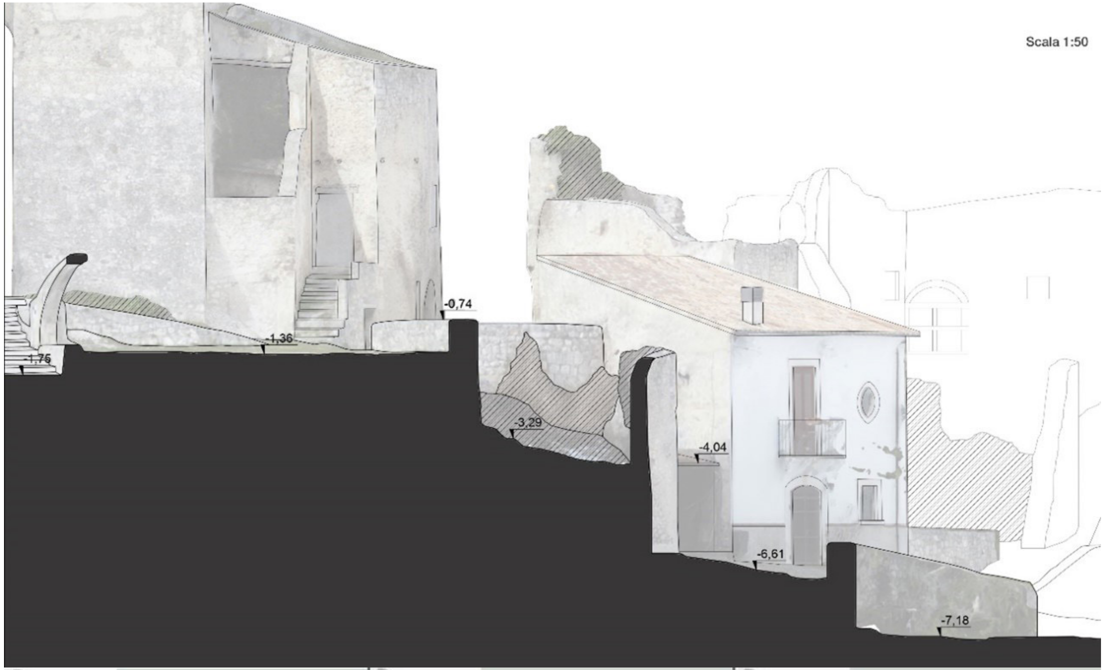

Fig. 14 - Two-dimensional representation of the investigated area and integration with aero photogrammetry orthomosaics.

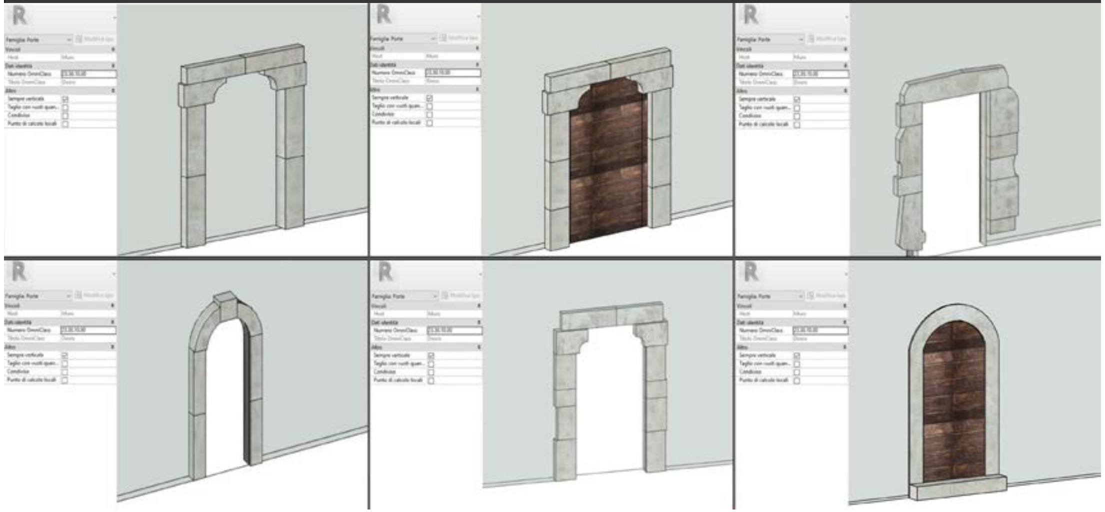

Fig 15 - Modelling in a parametric environment of the architectural features of the building fabric.

As a consequence, the integrated point cloud provided parametric three-dimensional models of some valuable architectural elements detected within the investigated area, with the aim of making available new data useful for the knowledge and analysis of the diffuse heritage in smaller historical centres. The models of the portals identified within the urban fabric were produced, within the Autodesk Revit software, following the critical analysis of the geometric information acquired from the survey. The two-dimensional drawings obtained were imported into a ''generic wall-based model'' to create a specific family for each type of portal. The single features constituting the architectural element were appropriately parameterised (Santagati, Lo Turco, & D'Agostino 2017) and enriched with shared parameters that better describe each portal's component (Savini, Fabbrocino & Marra, 2021). The parametric models created for the architectural elements of the openings in the building fabric of Navelli (Fig. 15) represent the first step towards the realisation of the HBIM model of the entire village and for the implementation of the SLATE 3D Catalogue, previously created for the other settlements located in the same territory (Savini, Fabbrocino & Marra, 2021).

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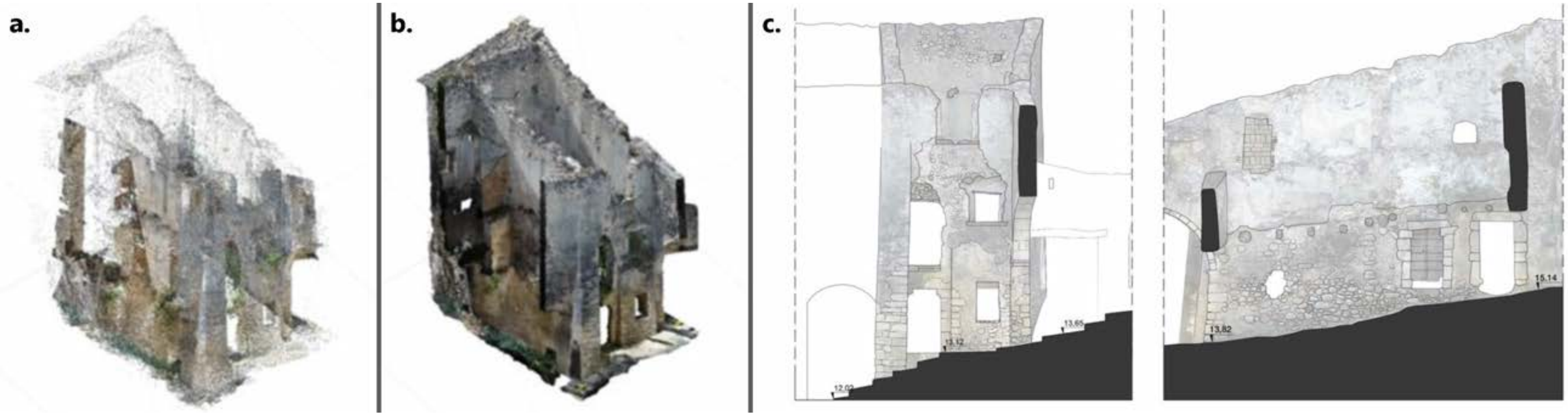

Fig. 16 - Results of terrestrial photogrammetry: (a.) sparse point cloud; (b.) dense point cloud; (c.) incorporation of high-resolution orthomosaics within the two-dimensional drawings.

	n. photos	Aligned photos	Marker	Tie points	Dense clouds
Parcel 927	735	735	5	560.289	275.697.591

Tab. 3 - Terrestrial photogrammetry dataset and processing results in Agisoft Metashape software.

The results presented here can be further improved with respect to the scale of detail, as demonstrated by an experiment on the 927 cadastral parcels. In this case, the aero photogrammetric data of the building were integrated with those from terrestrial photogrammetry performed with a Canon reflex camera EOS 1100D (Tab. 3). This step permits to move from the urban scale to the scale of the single artefact, obtaining a complete 3D model enriched with semantic data and high-resolution photorealistic textures with a Ground Sampling Distance (GSD) of 0.73 mm/pixel (Fig. 16). This approach can adequately support the needs of specific and different thematic analyses, such as buildings archaeology and diagnostic investigations. These analyses allow assessing the consistency of structures, the identification of construction phases, and the state of conservation of the masonry surfaces.

5. CONCLUDING REMARKS

The multidisciplinarity is the key feature of efficient and reliable strategies for the conservation and protection of the built heritage based on a detailed and validated knowledge of the assets in a multiscale environment. One of the key issues of the process is the shareability of the data along with its velocity and efficiency. The target community are numerous and heterogenous ranging from the specialised technical and scientific operators to the officers and the authorities involved in the management and conservation processes, even though it is easy to recognise that some sets of data and information are certainly of interest for a large non-specialist public for cultural and touristic purposes. In this context, the application of new digital technologies, with the development of information systems based on Virtual or Augmented Reality or digital replicas of artefacts (such as 3D models GIS, NURBS or BIM), has brought different benefits and advantages to the field of knowledge for the identification of strategies of maintenance, conservation and enhancement of the historical built. The application of multi-sensor systems in the survey of morphologically and typologically complex areas and buildings is the most effective and suitable solution for the expeditious acquisition of information for multi-scale documentation of cultural heritage.

The results of the research are intended as a contribution to the area of knowledge of digital and instrumental surveys, confirming the quality of the innumerable information achievable through integrated approaches based on specific thematic analyses. The acquired and processed data for the Navelli village are appropriate to be used within the multidisciplinary processes aimed at documenting and knowing the heritage built to define, after the qualitative and quantitative assessments, the most appropriate strategies for the conservation and restoration of the built heritage. The speed acquisition and processing of information through the adopted procedure can facilitate the hierarchical ordering of the data to describe exhaustively the historical constructions and the contexts of reference, as well as the processes connected to it, thus leading to the identification of new ontologies. In fact, these first results from preliminary analysis represent the starting point

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for future research aimed at defining the ontology of the minor historical centres of the Inner Areas of the country. The recorded point clouds and the following elaboration will be used to implement the HBIM models of the area examined and Complex Informative Systems, developed in VR and AR, with the aim of providing tools for increasing the conservation and fruition of heritage and territory from the perspective of e-government and e-conservation.

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The research presented is the result of the authors' collective work, continuous comparison and a common discussion. Adriana Marra wrote sections 4 and 5. Francesca Savini wrote sections 1 and 2. Marco Giallonardo realized the integrated digital survey and wrote section 3. Giovanni Fabbrocino and Ilaria Trizio supervised the research and reviewed the work.

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