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INNOVATION AND TRADITION: INTEGRATED PRACTICES IN THE ARCHITECTURAL SURVEY OF PRETORIO PALACE IN TRENTO

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Abstract

The text and images tell of an architectural experience carried out on perhaps the most representative monument of the city of Trento, the building adjacent to the cathedral and overlooking the square. The role of the scientific method is at the centre of the reflection, which does not change when the procedures vary. On the one hand, it guarantees an informed use of advanced technologies; on the other hand, it is a fundamental training instrument. The importance attributed to ways of operating is, in fact, a discussion on interoperability: between different tools and, above all, between people with various skills. The public use of the large quantities of acquired data and produced information can only be implemented by sharing project choices and building codified archives; in this way, we overcome the dichotomy between survey as the application of pre-established actions and survey as an interpretation triggered by reality.

Keywords

Drawing, HBIM, image-based survey, 3D model, range-based survey.

1. *An idea of survey: instrument challenges and cultural roots*

In today's era, most people constantly experience the coexistence of an equally real material and an immaterial world, in life and work. The dividing line is not clear, it has a variable path, depending on the role that is reserved for digital technologies and the continuous innovations they offer in the various activities (Maldonado, 2005)[1]. Often due to market reasons, sometimes it happens that instrumental innovations are abandoned in the bud because they are mere expressions of temporary fashions incapable of offering a true contribution to the progress of knowledge, social well-being, and environmental protection. In other cases, developments in scientific research lead to practices that gradually establish themselves and modify the epistemological horizon of our actions, imparting a deep change both in the theoretical approaches and in operational tools.

The following words provide an opportunity for reflection on the ways of acting in the design field, concerning the greater or lesser use of the solutions proposed by the generalised computerised and informative transposition of reality, with regard to the use of visual communication. Here, the term 'project' does not have the specific meaning of 'prefiguration' of a physical transformation, but it is understood in the etymological sense as 'the act of advancing', 'the intention to do'. From this perspective, the usual distinction between analysis and intervention falls away; in their own right, they are project actions with different objectives.

Within this broad framework, the following considerations refer to a concrete experience carried out in 2022-23 in the monumental heart of the city of Trento: the architectural survey of Pretorio Palace[2], a project aimed at the description

[1] Thirty years after its first publication, Maldonado's book Real and virtual is still very relevant; for the topics covered here, see in particular chapter 4 'Model and project reality'.

[2] The research on Pretorio Palace is conducted by the Tridentine Diocesan Museum in collaboration with the Department of Humanities and the Department of Civil, Environmental, and Mechanical Engineering of the University of Trento, with the Municipal Library and Archives of Trento and with the Superintendence for Cultural Heritage and Activities of the Autonomous Province of Trento. The working group responsible for the architectural surveys is composed as follows: Giovanna A. Massari (scientific coordination); Ambra Barbini, Elena Bernardini, Sara Di Valerio, Francesco Giampiccolo, Gregorio Gottardo, Anna Maragno, Giovanna A.

and interpretation of space and geometric elements through measurement and representation (Masiero, 1988, p. 64). Therefore, the text and images deal with the role that the mostly numerical measurement techniques, and graphic-analogue representation, play in the design processes concerning the study of the built heritage, when it is based on more or less advanced 3D geometric modelling. Technique is not a neutral system of skills and equipment, since it expresses the relationship between object and subject of knowledge and is responsible for achieving one or another result (Heidegger, 1991).

Today, the 3D digital procedures governing architectural surveying allow the semi-continuous management of points in space. The 'direct' range-based way, entrusted to laser scanners, has developed since the beginning of the third millennium with static instruments[3] (Massari, Bonora, & Svaldi, 2010) and is currently evolving with the experimentation of dynamic and low-cost technologies. After a few years, the 'indirect' image-based way known as photo-modelling is consolidated, overcoming the short period of digital stereophotogrammetry[4] (Massari, 2003) and unconventional photogrammetry[5] (Massari, Rolando, & Salerno, 2005). The debate centred on the data acquisition phases, regarding the performance of the sensors, the accuracies that can be achieved, and the costs/times required, is followed by the ongoing discussion on the phases of returning information from point clouds, which increasingly shifts attention from construction of the parametric model to semantic analysis, i.e. the automatic extraction of contents via machine learning and artificial intelligence.

Alongside this reality-based documentation/production, enabled by the

Fig. 1: On the left, framing of the area of interest within the city of Trento; on the right, picture of Pretorio Palace from the Cathedral (left, image from Google Earth; right, picture by Francesco Giampiccolo)

Massari (topographic, longimetric and photogrammetric surveys); technical studio Alberto Leoni Rovereto, Sara Di Valerio, Gregorio Gottardo, Anna Maragno (laser scanner surveys); Francesco Giampiccolo (photomodeling surveys); Sara Di Valerio, Gregorio Gottardo, Anna Maragno, Cristina Pellegatta (geometric model processing and architectural drawings); Ambra Barbini (Castelletto parametric modeling); Architectural Survey with Design Workshop course, a.y. 2021-22 (didactic experimentation).

[3] The first scientific experimentation conducted by the LAMARC took place in the upper chapels of the hermitage of San Romedio, comparing the accuracy of the survey with a Leica laser scanner to that of topographic measurements.

[4] In 2003-2004 the laboratory directed by Vittorio Ugo at the Politecnico di Milano carried out the survey of the monumental façade of the Certosa di Pavia using Geopro RFD Evolution 152 digital photogrammetric software.

[5] See the multiscale survey conducted on Arco di Trento in 1999-2000 by the research group of the Politecnico di Milano coordinated by Vittorio Ugo.

collection and transmission of huge masses of values, a way of acting based on the traditional disciplinary fields - i.e. topography, photogrammetry, and longimetry - also survives, including the borrowed from archaeology survey of details. Three heterogeneous procedures, sometimes mutually connected, based on preventive acts of visual observation as well as a selection of the readings to be carried out, find synthesis precisely in the elaboration of the geometric model of representation. They are a valid alternative when the surfaces and volumes have simple shapes, the dimensions involved are limited, or the design purposes only require the usual graphic tables.

All the mentioned methods are essentially numerical, congruent with mathematical modelling which, by its nature, has a universal character. This does not mean that their indistinct application makes sense, also for reasons of sustainability of the work and usability of the results; indeed, we know that methodological and technical choices are always guided by the specifics of the object and purpose. The translation in quantity of the artefact's qualities, and the use of adequate computerised solutions, is not always sufficient: this is why the 'traditional' survey maintains a non-negligible potential, especially at the scale of detail and material investigation, thanks to the 'tactile' component of its operations.

Therefore, the use of cutting-edge and/or classic procedures is variable and the two approaches often coexist, as the research carried out on Pretorio Palace in Trento shows[6]: since 1963 the permanent seat of the Tridentine Diocesan Museum, over the centuries the building passed through numerous uses and construction phases, from the residence of the bishops of Trento to the seat of the College of Doctors, the Imperial Royal Circular Court and the Engineering Directorate (Fig. 1). The geometric survey, the study of the wall stratifications, and the analysis of the archival sources allow us to define a first interpretative framework of the different transformations[7] (Bianchini, 2014).

2. *Surveying today: the value of new technologies*

The progressive introduction of technologically advanced instrumentation has not changed, over the years, the essence of surveying activity. Its primary purpose remains to discretise continuous, identifying the salient, evident, and remarkable points of reality, and reproducing, with a limited number of signs, the object of study.

From this perspective, range-based and image-based techniques are not aimed at merely replicating reality but rather at acquiring a greater quantity and density of data. Therefore, the construction of a reference system – through a topographic network – is mandatory and allows a dialogue between surveying solutions, the correlation between acquired data, and ultimately the reconstruction of geometric figures in a representation model.

However, the application and integration of different acquisition techniques must be carefully evaluated with the objectives of each specific survey. Sometimes, the integration of tools is necessary for constructing a complete and sufficiently detailed model (Fiorillo, et al., 2013; Dallagiacoma, Maragno, & Massari, 2019). In other cases, an overabundance of data may generate complications in various phases of work (e.g. selection, processing, archiving, and utilisation).

The data acquisition campaign at Pretorio Palace involved the dialogue between several traditional and digital survey methods (Figs. 2, 3), intending to produce a 3D geometric model useful for historical and archaeological investigations of the building. The topographic network, consisting of 54 polygonal vertices and approximately 1,500 object points, served as the framework for referencing data obtained through range-based and image-based methods (Vacca, 2023). Consequently, natural points were identified before the photo and laser-scanning operations and markers were affixed, which were then acquired with the total station Topcon GPT 1001.

The external facades and internal spaces spread across the five floors of the building were surveyed using the static laser scanner Faro Focus S120.

[6] The described experience took place in the LAMARC Laboratory of Architectural Modelling and Analysis Representation and Communication of the University of Trento (scientific coordinator G.A. Massari). Within a shared thought, G.A. Massari wrote par. 1, F. Giampiccolo and A. Maragno wrote par. 2, A. Barbini wrote par. 3, C. Pellegatta wrote par. 4 (with the exception of the part on HBIM, by A. Barbini), G.A. Massari and C. Pellegatta wrote par. 5.

[7] The partial results, currently being published, were presented during the study day 'Pretorio Palace: from bishop's residence to seat of the Tridentine Diocesan Museum. A centuries-old history' (Trento, 1 December 2023).

A total of 172 scans were obtained, comprising 138 scans of interior spaces and 34 of the exteriors. The acquisition parameters were set to a resolution of ¼, quality 2x, and pt/360° at 10,240. In certain hard-to-access areas of the building, the laser scanner was supplemented with tablet-based surveying. The tool utilised was an iPad Pro equipped with a LIDAR sensor, which facilitated the detection of challenging areas such as narrow hatches and cluttered attics (Łabędź, et al., 2022; Ippolito, Palmadessa, Nousrati Kordkandi, & Arias Tapiero, 2023; Vacca, 2023).

The TLS scans acquired during the campaign were recorded using the Faro Scene software. The procedure, which involves aligning and georeferencing the scans with respect to the topographic points, had a margin of error less than 1 cm. Next, we progressed to the point cloud processing phase using the CloudCompare software. The objective of this procedure was to remove redundant and unnecessary points for graphic restitution purposes. Finally, the point clouds exported by CloudCompare in .e57 format

Fig. 2: The traditional methods used for acquiring the geometric and colourimetric data of Pretorio Palace; from top to bottom: hand-made survey and topographic survey.

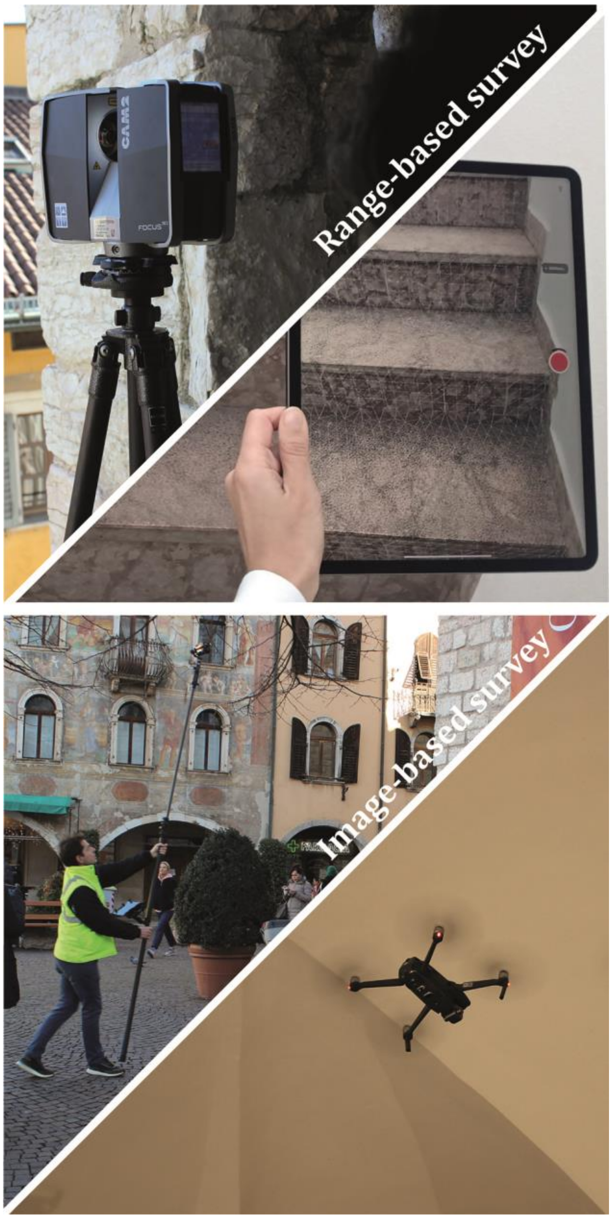

Fig. 3: The digital methods used for acquiring the geometric and colourimetric data of Pretorio Palace; from top to bottom: range-based survey (i.e. Terrestrial Laser Scanner, tablet with LIDAR sensor) and image-based survey (i.e. terrestrial and aerial cameras).

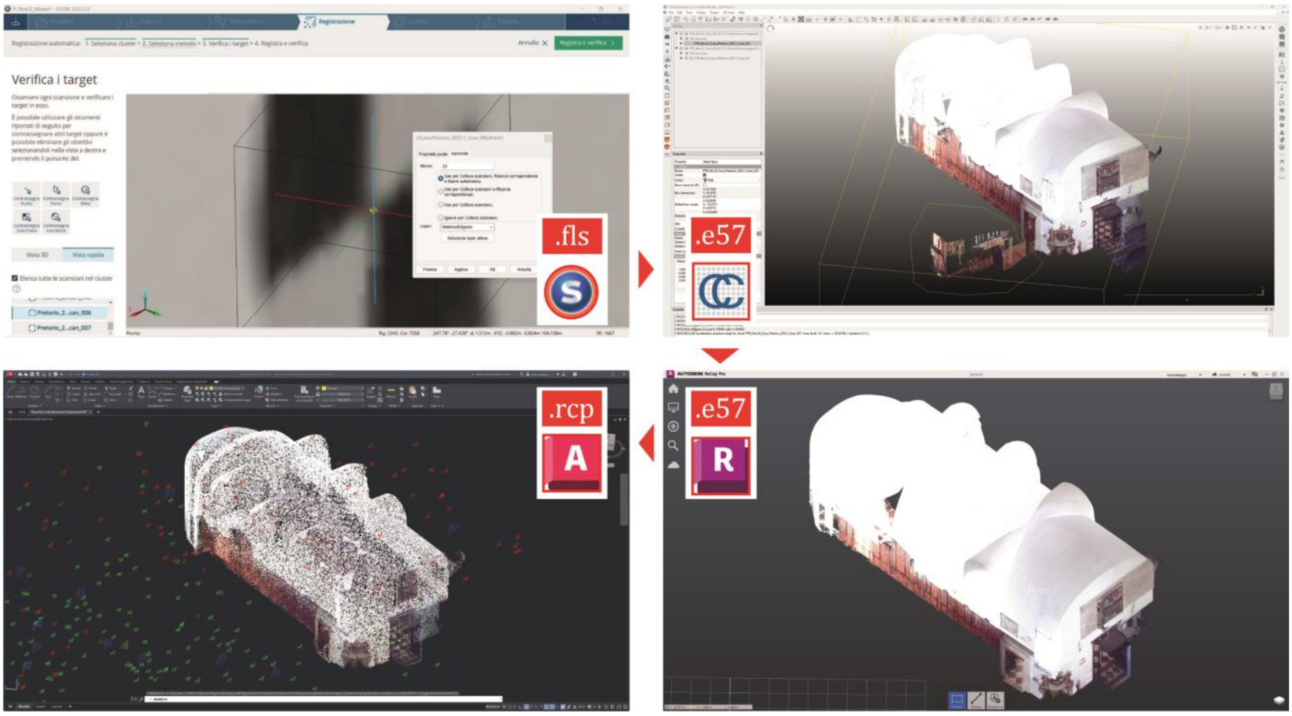

Fig. 4: The point cloud management phase; clockwise direction: recording, editing, converting, and modelling/drawing.

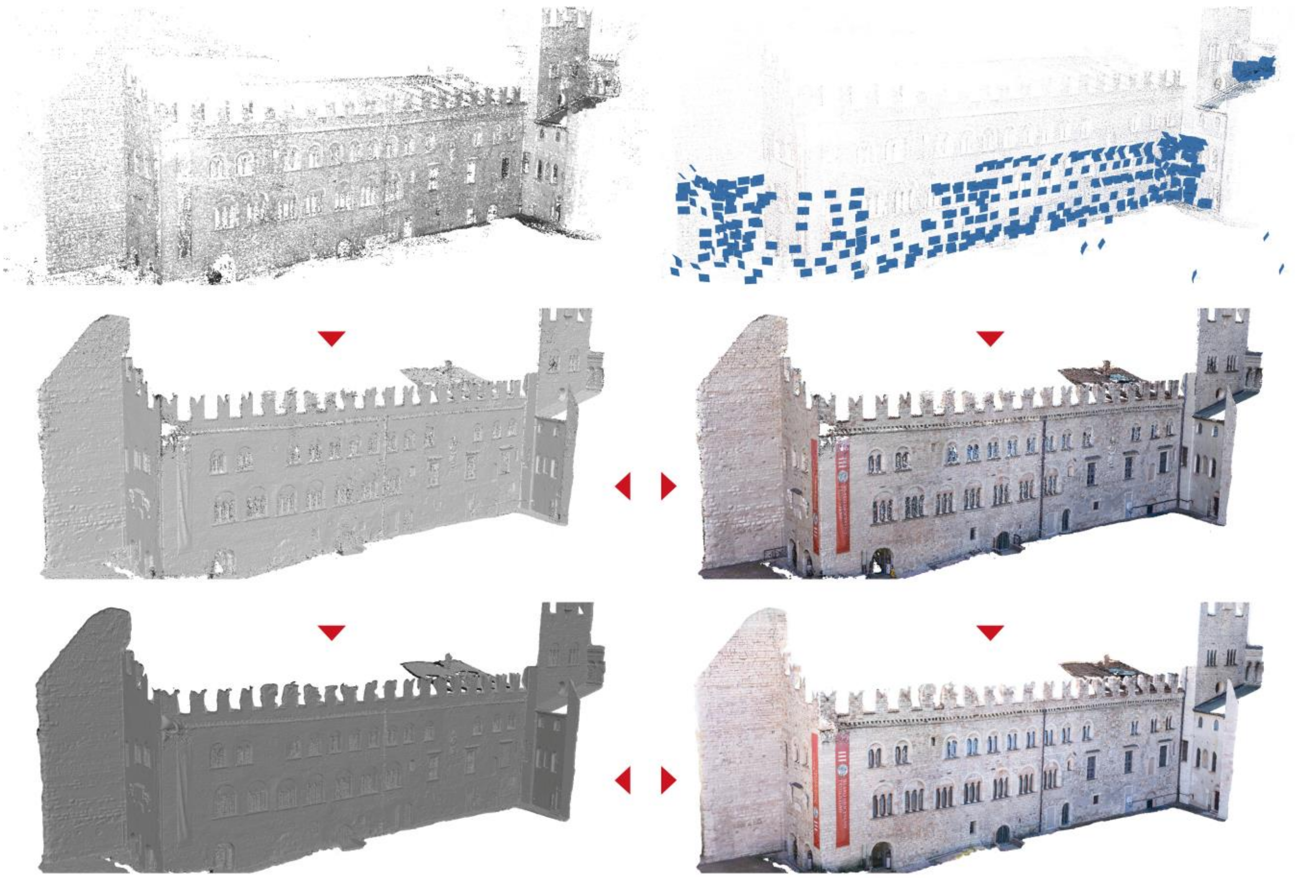

Fig. 5: From top to bottom: sparse cloud (stand-alone, left; with photographs, right), dense cloud (not coloured, left; coloured, right), surface model (mesh, left; textured mesh, right).

Fig. 6: Dense point cloud of the eastern front.

were indexed and saved in .rcp using Autodesk ReCap. This conversion allowed the clouds to be imported into the Autodesk AutoCAD environment, which was used for digitally drawing the main sections of the building (Fig. 4).

Photogrammetry was used to acquire the exteriors of the building and the internal sacristies, limited to portions with painted surfaces and visible stone walls. The equipment consisted of a DJI Mavic 2 Pro unmanned aerial system (UAS) holding a Hasselblad camera, 1' CMOS sensor and a resolution of 5472×3648 pixels. Additionally, the second imaging system Microgeo 3Deye comprised a Sony Alpha6000 DSLR camera with a CMOS sensor and a resolution of 6000x4000 pixels, mounted on a 9-metre telescopic pole, stabilised by a gimbal controllable via the FeiyuON mobile app, and remotely operated via mobile using Imaging Edge software (Fig. 5).

Due to regulatory limitations, UAS acquisition could not be done outside, necessitating the use of the 3DEye system up to the achievable height. Indoors, both systems were employed. A total of 390 photographs were taken for internal environments and 690 for external areas (210 for the eastern front, 480 for the western one). These

Fig. 7: Orthomosaic of the north front of sacristy.

images were processed using Agisoft Metashape Professional to generate dense point clouds (Fig. 6). The resulting point clouds exhibited a resolution and reliability comparable to those obtained from laser scanners (2 mm/pixel), and were perfectly alignable, being referenced to the topographic network (Voltolini, et al., 2007; Bitelli, Gatta, Guccini, & Zaffagnini, 2019; Camagni, Colaceci, & Russo, 2019).

Similar to point clouds generated by laser scanners, photogrammetric point clouds could have been imported into Autodesk AutoCAD via exportation in .e57 format and processing in Autodesk ReCap to .rcp. However, it was decided to utilise the point clouds from photogrammetry for generating orthomosaics of the facades (Fig. 7). The most favourable outcomes were observed for the external facades (eastern and western) and the two main facades of the sacristies, achieving a maximum resolution of 1 mm/pixel.

To ensure the verifiability and interoperability of all stages of the work, in line with the principles of the scientific method, data archiving was meticulously managed throughout the research process. The significant volume of acquired and processed data was organised according to a precise logical-functional framework, wherein each element was uniquely defined by a specific nomenclature (Torsello, 1988).

The point cloud models generated with the different survey tools and related software procedures were then compared and evaluated (Fig. 8). In detail, the density values (i.e., the number of points in a sphere with a radius of 50 centimetres) vary significantly, ranging from a minimum of a few thousand to several hundred thousand of points. This variation is primarily due to the performance of the instruments used, but it is also partly influenced by the specific choices made for each case, depending on the goals of each survey.

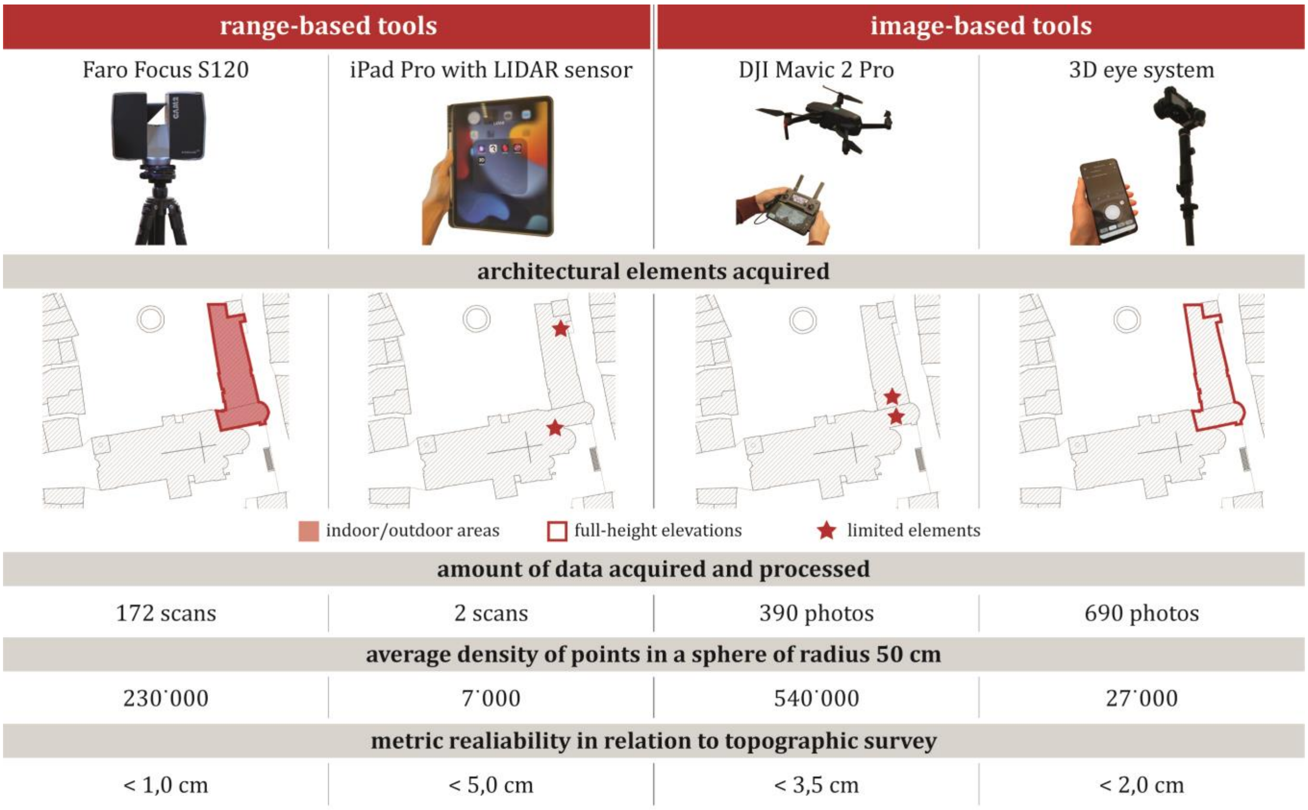

Fig. 8: The comparison between the qualities of the point clouds obtained with four different instrumental systems.

The calculation of metric reliability was based on the topographic survey conducted during the campaign. The results are in line with the literature (Russo & Manfredini, 2014; Ippolito, Palmadessa, Nousrati Kordkandi, & Arias Tapiero, 2023): the most 'reliable' numerical model is the one derived from TLS, followed by those generated by photogrammetry. Finally, the metric reliability obtained from the iPad Pro acquisition remains particularly critical and limiting for potential applications.

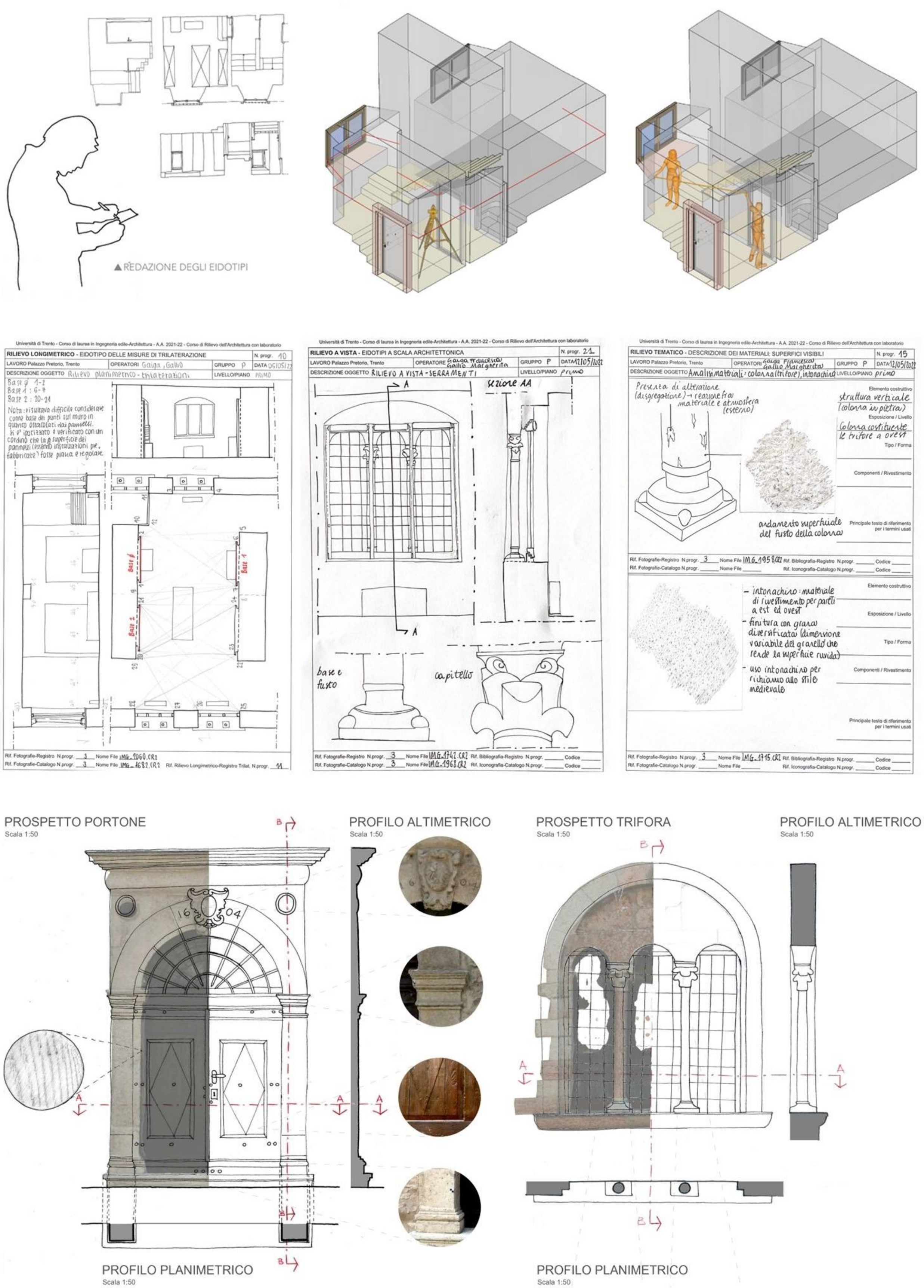

Fig. 9: Students' elaborations displaying the acquisition activities (top), the survey files with hand drawings and annotation (centre) and the combination of different acquired data to analyse the geometries and materials of building components (bottom).

3. *Surveying today: the value of conventional methods*

Despite the quantity and density of data available through a digital 3D survey, a traditional survey campaign can support both a clear description and the correct interpretation of a building and its components. Traditional techniques, based on the acquisition of a single measurement or a single picture at the time, require an upstream orientation of the on-site activities and a selective approach during the acquisition phase (Torsello, 1988), to avoid missing relevant data or wasting time on unnecessary operations. This can also be particularly meaningful for educational purposes, encouraging careful observation of the building, oriented at selecting data relevant for analysing the main features of interest, according to the survey objective, and for developing interpretive synthesis through 2D and 3D representations, useful to communicate the output of the investigation. For the case study presented, the 3D digital survey was integrated with a traditional survey as part of the 'Architectural Survey with Design Workshop' course at the University of Trento.

Thus, the university research group made up of nine expert people was joined by a team of around sixty young people who were carrying out an in-depth architectural survey for the first time. The operational 'machine' worked thanks to the clear definition and common adoption of a working method based on ordered phases and declared rules, which places reasoning on the geometries of space at the centre. To contribute to the construction of the unitary 3D model, the third-year class understood the importance of scientific rigor and the oriented use of digital technologies, without which data cannot be exchanged or used. Above all, each participant was able to practice interoperability both with 'equal' figures, in terms of age and skills, and with 'specialist' figures for the various operational areas, from a perspective very similar to that of Citizen Science experiences

After an initial inspection of the building in its complex and of its single indoor and outdoor spaces, students, divided into small groups of 2-3 people, drafted eidotypes and sketches of the assigned space. These hand-made drawings had the purpose of offering support for noting measurements, connection to more detailed or general drawings, and observations on anomalies, state of preservation, materials, and any elements considered noteworthy.

For the acquisition phase, various analogue and electronic tools have been made available, such for example self-levelling crossline laser and traditional levels to define horizontal and/or vertical planes, carpenter squares and plumb lines to verify perpendicularity between elements, and measuring tape rulers to acquire linear measurements, needle profilograph for detail elements and DSLR camera for digital photographs.

Each small group of students focused on a single space, to acquire in detail geometric, colourimetric and thematic data, to be processed and integrated with a topographic survey, as well as a 3D image and range-based digital survey. All the collected data have been accurately registered into a common system of survey files and systematically archived to allow future consultation and/or integration, as well as an interoperable collaboration among students and with the research group (Fig. 9).

The topographic survey provided the general frame for making data collected with different techniques and instruments work together, as well as bringing all the data acquired in different parts of the building into a coherent system. In some cases, the topographic survey was also used for plane photogrammetry to obtain photoplanes[8], to acquire metric and geometric information belonging to the same medium plane.

The synthesis of survey data was obtained through the development of a 3D through-section model, based on the representation, for each surveyed space, of at least one horizontal and vertical section intersected orthogonally with each other in a 3D virtual modelling space. This model serves not only as a comparison tool to validate all the collected data but also for the integration of further data (Fig. 10).

In some cases, this model was integrated with a wireframe model or used as the basis for the development of thematic maps, or informative parametric models within a BIM environment. This educational experience, aimed at supporting students in familiarising with different techniques of architectural survey, provided a large and

[8] Using the analytical method of the didactic software RDF developed by the CIRCE photogrammetry laboratory at the University of Venice.

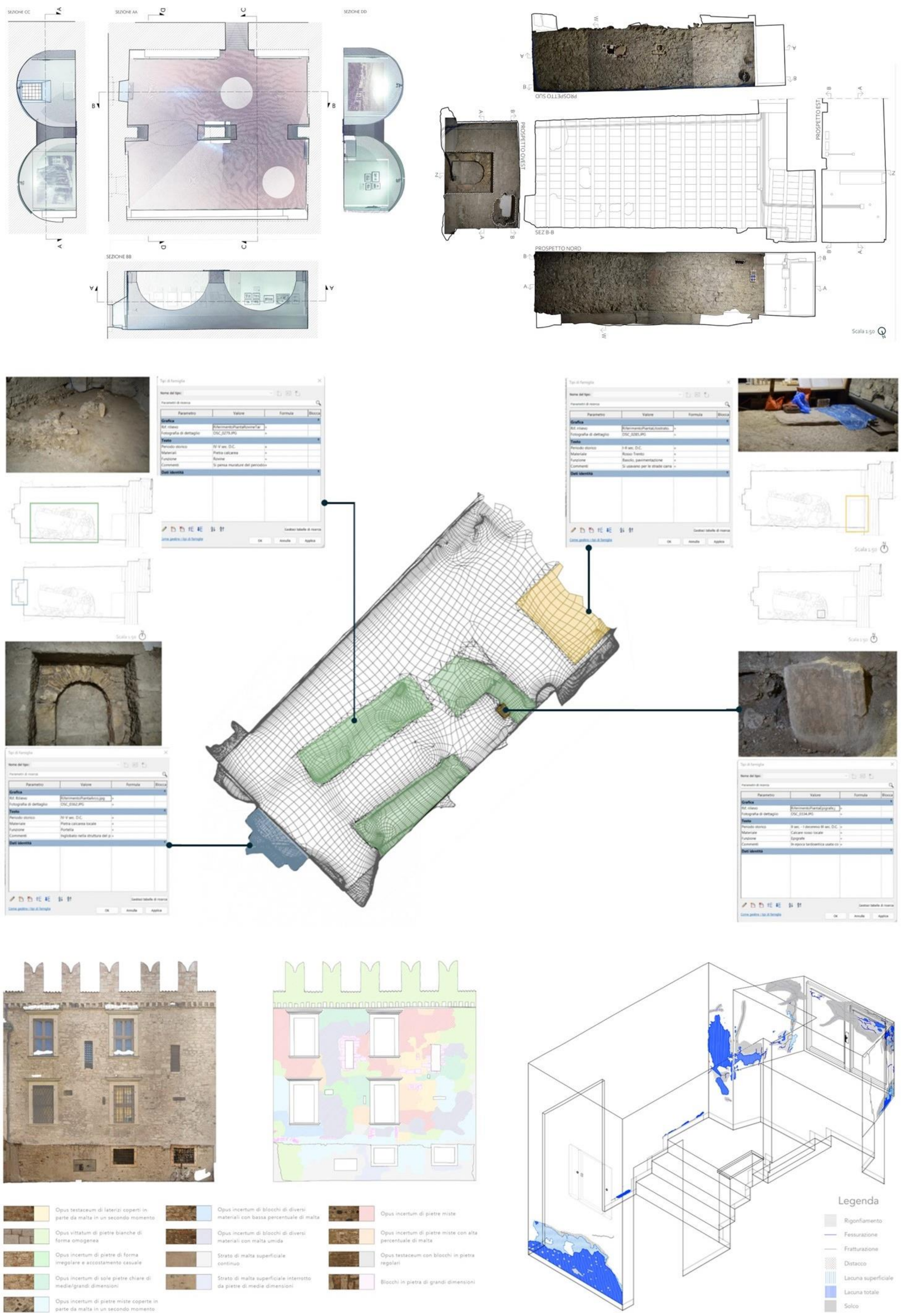

Fig. 10: Students' elaborations displaying the development of geometric models based on point clouds (top left) and photoplanes (top right) and used to develop an informative 3D model within a BIM environment (centre) and thematic analysis on wall texture (bottom left) and on degradation phenomena (bottom right).

detailed database useful to complement the 3D digital survey conducted by the research team. Especially with the acquisition of detailed geometric and metric data and specific analyses related to materials, construction technologies, state of preservation, traditional methods and techniques have proven the value of an integrated approach to architectural surveying and the contribution that traditional surveying can provide to more advanced 3D digital techniques. Moreover, this experience confirms the importance of selecting methods and techniques according to knowledge objectives and objects of investigation.

4. A necessary symbiosis: model, image, drawing

The applied techniques and analytical processes, described up to here, have produced processed data which combine to constitute two distinct models, the 3D restitution model by planes and the semantic 3D HBIM model. Both are places in which analyses become coherent and knowledge becomes structured, thus redelivering the visible and hidden geometry of the studied architecture. Both models, according to different procedures and with several purposes, intend to allow the use of information for design purposes, but in the first case, communication is implemented mainly through graphics.

The 3D digital model by planes of Pretorio Palace was built in a CAD environment (Autodesk AutoCad 2023) verifying the coherence of all the acquired information, both obtained with the aid of advanced technologies and with consolidated techniques, comparing and relating the collected and processed data (Pellegatta & Luce, 2015). This model formalises, in digital space, the project of description and interpretation of the analysed area and is structured according to the horizontal and vertical planes of discretization of the architecture. Such planes tell of a 3D modelling *ante litteram* precisely because, despite their two-dimensional development, preserve the spatial and relational logic of a three-dimensional model. The foundation of the model and its supporting structure is the set of points defined topographically by triples of Cartesian coordinates, the true connecting fabric of the restitution operations on whose plot the history of the form of Pretorio Palace is woven.

The first operation carried out on the model's embryonic frame is precisely the construction of the horizontal and vertical synthesis planes of the architecture; they structure the digital model, reassemble the acquired data, and identify plans, sections, and elevations i.e. the graphic results of the survey operations. The positions of these planes guide the reconstruction of the 'drawn' geometries by simultaneously managing metric information of different origins: point clouds produced directly by laser scanners and indirectly by multi-image photogrammetry, orthophotos from point clouds, photo-plans and longimetry. Thereby the model takes shape and becomes the place of the project, where measurement and representation merge (Massari, Luce, & Pellegatta, 2011).

The 3D model by planes has a dual value. In addition to the overall consistency, implicitly it shows the main result of the restitution phase, that is, the drawing. The information reprocessing operation involves the definition of the digital objects constituting the drawn architectural elements, such for example the profiles of sectioned and projected walls, internal and external doors and windows, sectioned and projected, and so on, according to consolidated graphic codes. We can therefore speak of graphic communication as 'prefiguration', upstream linked to the choice of the final documents' printing scale, a real guide to the survey as it helps to establish both the acquisition detail and the restitution one, therefore the degree of 'synthesis' in the representation. The 3D model by planes is built on a 1:1 scale but the deriving graphic documents apply the codes of graphic communication specific to the different scales (Fig. 11).

Therefore, the architectural line drawing is the synthesis of the studies and operations carried out and shows, *super partes*, the shape/figure of the represented object; it does not favour one procedure and does not take advantage of one technique or tool over another. There is no distinction between a survey drawing obtained from an acquisition with advanced techniques and one with 'traditional' techniques; the information and communication objectives are identical and subject to the same coding; the differences remain in the history of the model but not in its final identity.

The survey graphic work is a drawing, according to the words of Vittorio Ugo (1994, p. 39), which "implies an intentional renunciation of the practical implementation of the graphic model in a material outcome"; but the same 'suspension' of intentionality becomes a way of verifying the representation and its 'scientificity', i.e. the

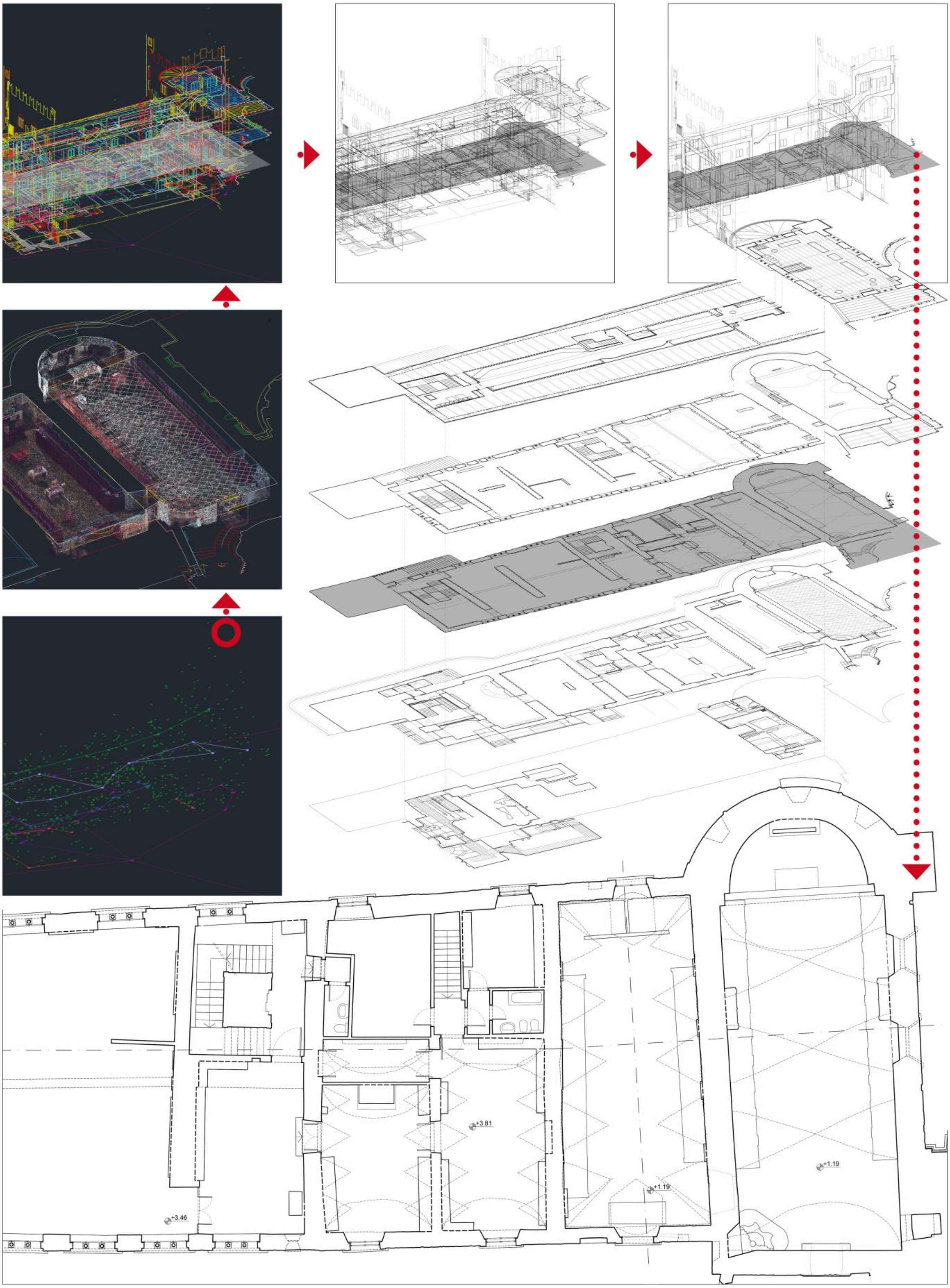

Fig. 11: The construction process of the 3D digital model by planes: from the topographical points to the line drawing.

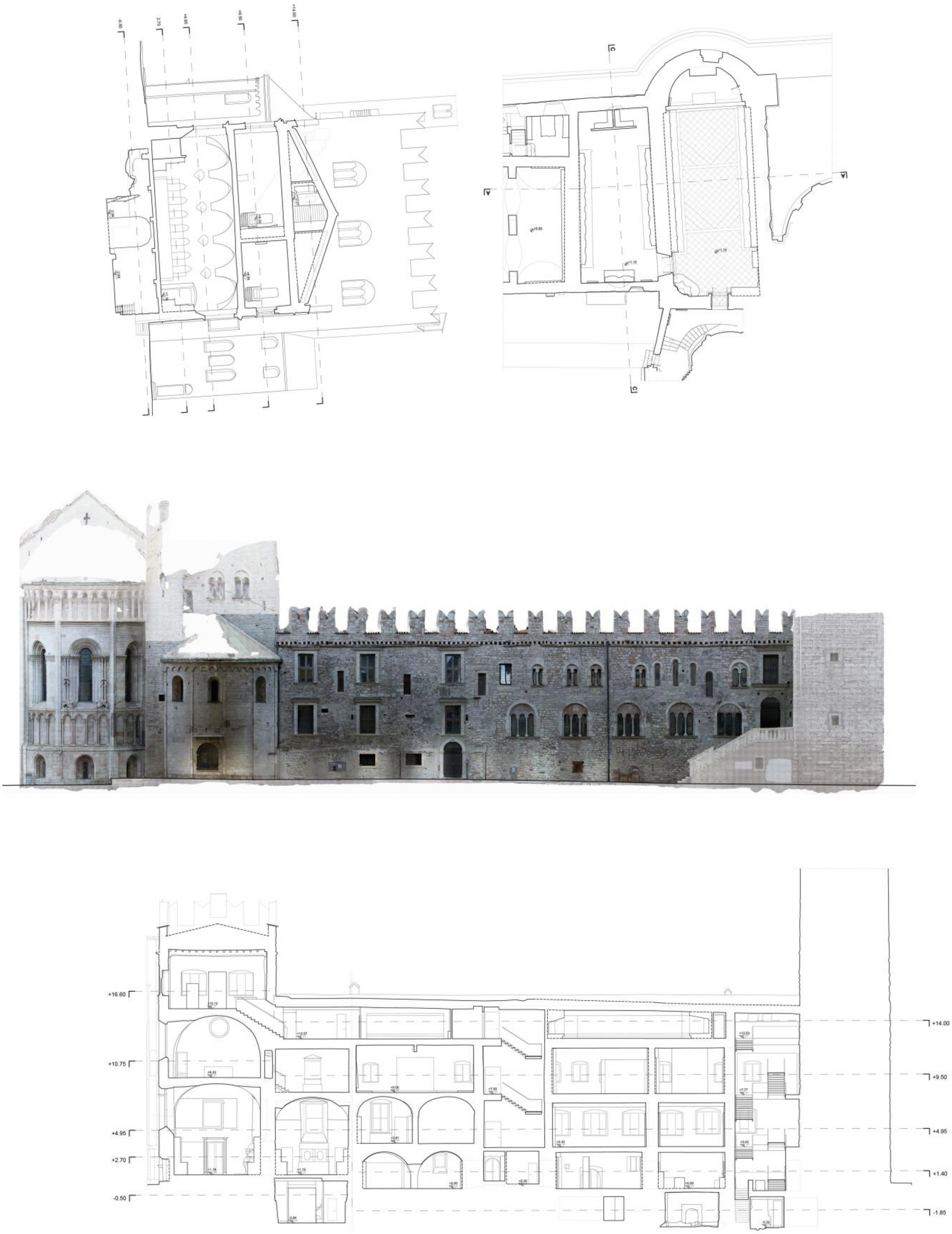

Fig. 12: Pretorio Palace, drawing in 1:100 scale. From top to bottom: vertical transversal section and detail of the ground floor plan; front along via Giuseppe Garibaldi and longitudinal section.

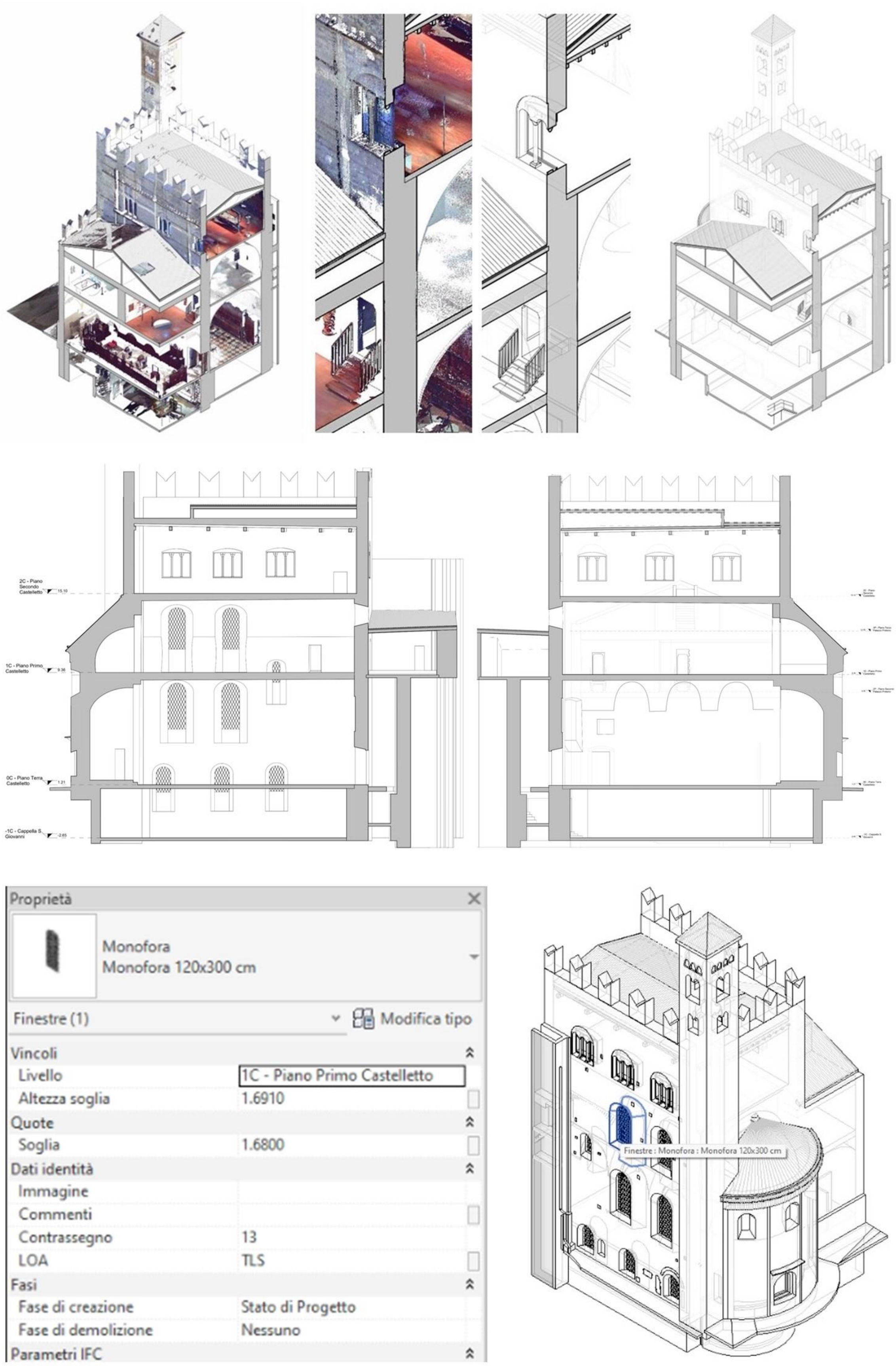

Fig. 13: From top to bottom: Heritage Building Information Model development based on the point cloud from digital 3D survey, extraction of vertical section and visualisation of information associated with single components, such as windows.

confirmation that a survey is a way of knowledge and not a simple instrument, and in this sense, it transmits sets of information through drawing (Fig. 12).

On the other hand, the second 3D model aims to experiment with the processing of semantic contents, according to the HBIM (Heritage Building Information Modelling) methodology and starting from the same point clouds obtained from the 3D image and range-based surveys. Built with the Autodesk Revit software, the model focuses on a portion of the building, called 'Castelletto', located between the Cathedral of St. Vigilio and the Pretorio Palace, which now houses the Diocesan Museum. The ground floor and basement respectively hosting the Presbyterian Sacristy and the Chapel of St. Giovanni, are only accessible from the Cathedral, while the first and second floors are used as exhibition rooms of the Diocesan Museum. To develop the model, this portion of the building was decomposed in its construction elements, such as walls, floors, ceilings, windows, doors, and roofs (Attenni, Griffo, Inglese, & Ippolito, 2019). The point cloud was used as a reference for the definition of the floor levels and the positioning of the above-mentioned elements and all the other component parts.

More complex architectural details such as triforas, biforas and niches, were modelled starting from profiles, obtained from horizontal and vertical sections of the point cloud (Rafeiro & Tomé, 2020), and further detailed with the support of hand drawings and photographs. To reach a higher correspondence between the geometries of the model and the point cloud, vaulted ceilings were modelled as loft surfaces in Autocad based on curves obtained by sectioning the point cloud and then imported in Revit. This portion of the building also included two apses, modelled as surfaces with a single parametric algorithm developed via VPL in Dynamo to better match the point cloud geometry (Fig. 13).

Each component of the model was integrated with a specific parameter MS (Modelling Source) declaring from which bases the component has been modelled (TLS - Terrestrial Laser Scanner scans; PH - Photomodelling, iP - iPad scans; HYP - Hypothesis; etc.). This parameter aims at facilitating a seamless and transparent sharing of the model among different users. Further implementations of the model in this direction could include a deviation map and other parameters such as the Level of Accuracy (Grahm, Chow, & Fai, 2018; Santagati, Lo Turco, & Garozzo, 2018; Brumana, Banfi, Cantini, Previtali, & Della Torre, 2019) or the Level of Reliability (Bianchini & Nicastro, 2018; Maiezza, 2019; Brusaporci, Maiezza, Marra, Tata, & Vespasiano, 2023). The components are represented graphically within the model as specific elements, in terms of quantity, size, shape, position and orientation (LOD 300). The 3D geometry of this model is conceived as a framework to enrich with further information as soon as the other research partners will finish the ongoing analysis of the history of the building.

Both 3D models synthesise and discretize the architecture at the same time as they reconstruct its geometries, showing them both in overall, axonometric, and perspective images and reducing them to horizontal and vertical section planes. Although developed with different purposes from those of the 3D restitution model for planes, HBIM processing shows how graphic communication maintains its transversal identity and is always the final link of the investigation, regardless of the technologies that allowed us to build the information necessary for its construction.

It is therefore important to put architecture and its geometries, cognitive processes rather than operational techniques back at the centre of survey activities, as well as that indispensable critical spirit capable of relating the objectives to be pursued and the technical-instrumental procedures useful for achieving them. Not only that, the experience of Pretorio Palace underlines the sense of the graphic quality of the drawing as an attribution of meaning to the forms/geometries of the architecture.

5. *What is the future of the discipline of surveying?*

The replacement of physical reality with reality-based virtual models, generated by very dense point clouds, responds to the demand for exhaustive knowledge of the material world and to the human need to counteract the alterations caused by time, including disappearance, through a stable memory protected on the web (Fig. 14). On the other hand, first, the Renaissance lesson and subsequently the Galilean one teach us that the ‘intrinsic’ understanding of architecture cannot rely on the generic static and/or dynamic visualisation guaranteed by the availability of point clouds. Instead, it requires specific activities 'individually' oriented towards built geometries, along with the adoption of instrumental strategies capable of leading to discoveries not accessible with the capabilities of the senses alone.

Stereometric or not, every geometry can be investigated thanks to advanced automation and translated into triples of Cartesian coordinates. However, this is only one of the themes of the survey, whose soul is still linked to the historical origins according to which each visible part can be a clue to hidden facts.

The geometric models of Pretorio Palace are the spatial frame to which to anchor every discovery made through archival investigations and stratigraphic analyses of the surfaces.

The technological solutions for the accurate virtual duplication of physical spaces will most likely continue to improve, thanks to the contribution of artificial intelligence and the need to have 3D digital environments as part of digital twin projects. Architectural surveying is at a crossroads: it can progressively forget the centuries-old history of the discipline, its being an all-round knowledge project that legitimises interpretation and transformation and can accept being limited to a system suited to the production of a refined mathematical model of the building. Or it can remain firmly anchored to its theoretical foundations and persevere in recognising a philosophical meaning to measurement and representation, which places various declinations of the notion of 'model' at the centre. In the future, the challenges will not be posed by the data collection phases, but by the processing, management and transmission of information through multi-objective models, which include qualitative parameters and graphic communications not only linked to traditional forms of drawing.

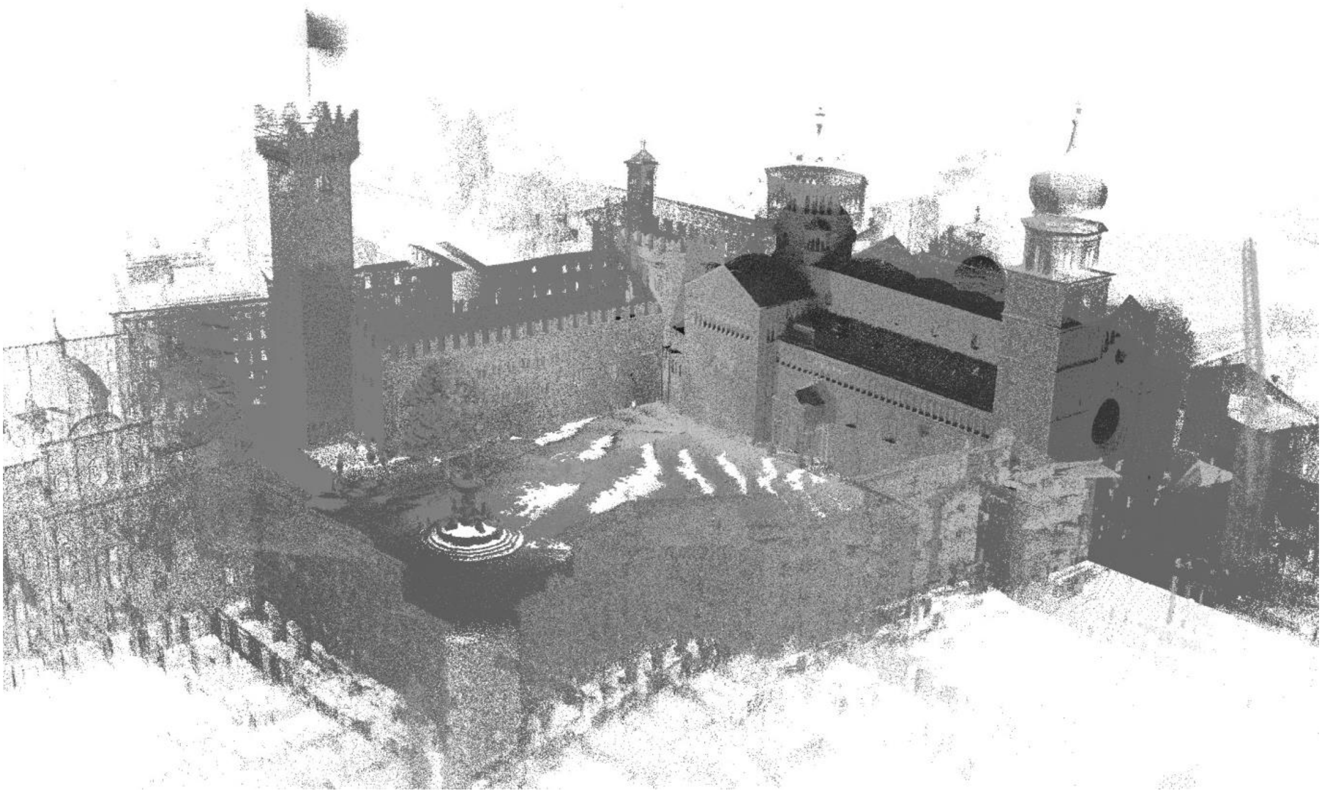

Fig. 14: Points clouds model of the Cathedral Square and Pretorio Palace.

References

Attenni, M., Griffo, M., Inglese, C., & Ippolito, A. (2019). Metodi e modelli per la rappresentazione: il Tempietto di San Pietro in Montorio. *Disegnare idee immagini, 59*, 82-93.

Bianchini, C. (2014). Survey, modeling, interpretation as multidisciplinary components of a knowledge system. *SCIRES-IT - SCIentific RESearch and Information Tecnology, 4*(1), 15-24. http://dx.doi.org/10.2423/i22394303v4n1p15

Bianchini, C., & Nicastro, S. (2018). La definizione del Level of Reliability. Un contributo alla trasparenza dei processi di Historic-BIM. *DN, 2*, 208-255.

Bitelli, G., Gatta, G., Guccini, A., & Zaffagnini, A. (2019). GIS and Geomatics for archive documentation of an architectural project: the case of the big Arc of entrance to the Vittorio Emanuele II Gallery of Milan, by Giuseppe Mengoni (1877). *Journal of Cultural Heritage, 38*, 204-212. https://dx.doi.org/10.1016/j.culher.2019.01.002

Brumana, R., Banfi, F., Cantini, L., Previtali, M., & Della Torre, S. (2019). HBIM level of letail-geometry-accuracy and survey analysis for architectural preservation. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W11*, 293-299. https://doi.org/10.5194/isprs-archives-XLII-2-W11-293-2019

Brusaporci, S., Maiezza, P., Marra, A., Tata, A., & Vespasiano, L. (2023). Scan-to-HBIM Reliability. *Drones, 7*(7), 426. https://doi.org/10.3390/drones7070426

Camagni, F., Colaceci, S., & Russo, M. (2019). Reverse modeling of Cultural Heritage: pipeline and bottlenecks. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W9*, 197-204. https://doi.org/10.5194/isprs-archives-XLII-2-W9-197-2019

Dallagiacoma, A., Maragno, A., & Massari, G.A. (2019). Projects to save the sites of salvation. *World heritage and legacy. Culture - Creativity - Contamination* (p. 705-714). Roma, Italy: Gangemi Editore.

Fiorillo, F., Remondino, F., Barba, S., Santoriello, A., De Vita, C., & Casellato, A. (2013). 3D digitization and mapping of heritage monuments and comparison with historical drawings. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, II-5/W1*, 133-138. https://isprs-annals.copernicus.org/articles/II-5-W1/133/2013/

Grahm, K., Chow, L., & Fai, S. (2018). Level of detail, information and accuracy in building information modelling of existing and heritage buildings. *Journal of Cultural Heritage Management and Sustainable Development, 8*(4), 495-507. https://doi.org/10.1108/JCHMSD-09-2018-0067

Heidegger, M. (1991). La questione della tecnica. In M. Heidegger, & G. Vattimo (Ed.), *Saggi e discorsi* (p. 5-27). Milano, Italy: Mursia.

Ippolito, A., Palmadessa, C., Nousrati Kordkandi, M., & Arias Tapiero, J. (2023). The Domus of the Calendar: a qualitative comparison analysis of digital data obtained from 3D laser scanners, SfM methodologies and portable devices. *Archeologia e Calcolatori, 34.2*, 247-262. https://doi.org/10.19282/ac.34.2.2023.13

Łabędź, P., Skabek, K., Ozimek, P., Rola, D., Ozimek, A., & Ostrowska, K. (2022). Accuracy verification of surface models of architectural objects from the iPad LiDAR in the context of photogrammetry methods. *Sensors, 22*(21), 8504. https://doi.org/10.3390/s22218504

Maiezza, P. (2019). As-built reliability in architectural HBIM modeling. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W9*, 461-466. https://doi.org/10.5194/isprs-archives-XLII-2-W9-461-2019

Maldonado, T. (2005). *Reale e virtuale.* Milano, Italy: Feltrinelli.

Masiero, R. (1988). Il vasaio e l'ingegnere: lineamenti per la disciplina del Rilievo. *XY Dimensioni del disegno, 6-7*, 61-72.

Massari, G.A. (2003). Outline/Interpretation. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, XXXIV-5/W12*, 225-230.

Massari, G.A., Bonora, M. C., & Svaldi, K. (2010). Spazi medievali scolpiti e dipinti: misura e rappresentazione. *Graphic Expression applied to Building International Conference* (p. 55-63). Alicante, Spain: Universidad de Alicante.

Massari, G.A., Luce, F., & Pellegatta, C. (2011). Multiscale Interactive Communication: inside and outside Thun Castle. *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXVIII-5/W16*, 311-318. https://doi.org/10.5194/isprsarchives-XXXVIII-5-W16-311-2011

Massari, G.A., Rolando, A., & Salerno, R. (2005). Metodologia di rilievo multiscala tra architettura e paesaggio: Arco di Trento. In *Il rilievo dei beni architettonici per la conservazione* (pp. 444-449). Roma, Italy: Edizioni Kappa.

Pellegatta, C., & Luce, F. (2015). Rilevare per la memoria della città: l'esperienza di via del Suffragio a Trento. In A. Marotta (Ed.), *Drawing & City. Cultura, Arte, Scienza, Informazione, Atti del XXXVII Convegno internazionale dei Docenti delle Discipline della Rappresentazione, XII Congresso della Unione Italiana del Disegno* (p. 763-770). Roma, Italy: Gangemi Editore.

Rafeiro, J., & Tomé, A. (2020). Adapting thet Tool: a historic Building Information Model (HBIM) of Senhora Da Piedade Da Caparica. In P. M. J., A. Aguiar Costa, & L. Sanhudo (Eds.), *Ptbim 3º Congresso Português de "Building Information Modelling"* (pp. 689-696). Porto, Portugal: U.Porto, Faculdade de Engenharia, Univeridade do Porto.

Russo, M., & Manfredini, A. M. (2014). Integration of image and range-based techniques for surveying complex architectures. In F. Remondino, & F. Menna (Eds.), *ISPRS Technical Commission V Symposium 2014. II-5*, p. 305-312. Riva del Garda: Copernicus GmbH. https://doi.org/10.5194/isprsannals-II-5-305-2014

Santagati, C., Lo Turco, M., & Garozzo, R. (2018). Reverse information modeling for historic artefacts: towards the definition of a level of accuracy for ruined heritage. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2*, 1007-1014. https://doi.org/10.5194/isprs-archives-XLII-2-1007-2018

Torsello, B. (1988). *La materia del Restauro. Tecniche e teorie analitiche.* Venezia, Italy: Marsilio Editori.

Ugo, V. (1994). *Fondamenti della rappresentazione architettonica.* Bologna, Italy: Esculapio.

Vacca, G. (2023). 3D Survey with Apple LiDAR sensor-Test and assessment for architectural and Cultural Heritage. *Heritage, 6*(2), 1476-1501. https://doi.org/10.3390/heritage6020080

Voltolini, F., El-Hakim, S., Remondino, F., Girardi, S., Rizzi, A., Pontin, M., & Gonzo, L. (2007). Digital documentation of complex architectures by integration of multiple techniques: the case study of Valer Castle. In J. Beraldin, F. Remondino, & M. Shortis (Eds.), *Videometrics IX. 6491.* SPIE Digital Library. https://doi.org/10.1117/12.702727