Images extrapolated from the laser scanner RGB point cloud (top) and reality-based 3D modeling phase (bottom) of Palazzo Bellisomi Vistarino, Pavia

Documentation, conservation, and reuse planning activities for disused cultural heritage

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Abstract: The present contribution illustrates the documentation and setting up of a digital database of a portion of Bellisomi-Vistarino Palace in Pavia (Italy), a relevant historical asset due to its artistic value. Despite recent restoration work, there are still disused portions of the complex, including the garden, the loggia and the rooms on the ground floor that overlook it. These portions are the elements this paper deals with. The approach to a small portion of the building is a pilot case from the perspective of a broader work of integral documentation of the whole complex. The aim is to define digital support for diagnostic and restoration planning activities from the perspective to enhance and create a new cultural attraction for the city, using the Foundation of the University of Pavia, already settled in the Palace and their organizational skills and networks. This is achieved by structuring a tridimensional digital twin and database connected to it to monitor the assets and generate digital environments for cultural and touristic valorisation.

Keywords: cultural heritage; conservation project; documentation; information system; 3D Model, Pavia.

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1. Introduction

Bellisomi-Vistarino Palace was built from the aggregation of several buildings arranged in a single block and is one of the examples of Lombard *Barocchetto's architectural style.* The Palace occupies about 5600 square meters and is extended over an entire urban block enclosed by the ancient Bellisomi and San Simone districts. The Palace is listed according to Legislative Decree 42/04 and L. 1089/1939, art. 21. Bellisomi-Vistarino Palace is based on the *Villa di Delizia* Renaissance archetype and the renovation that characterizes it occurred through the design of architect Francesco Croce. Restoration works followed one after another until the considerable impetus given in 1726 by Marquis Gaetano Annibale Bellisomi, who expanded the Palace with the construction of a new wing towards the east linked to the historic nucleus. Today Palace Bellisomi-Vistarino is defined as a court of honour, a service court, a large garden with a boundary wall and Belvedere, an important grand staircase and a noble floor with mezzanines and service rooms (Fig. 1). The Palace is described as one of the most significant examples of Lombard *Barocchetto* for its harmony between architecture, decoration, and furnishings (Forni, 1989; Vicini, 1978). From research conducted in Pavia's archives and libraries, the bibliography, and historical and critical notions about the Palace in question are particularly lacking (Erba, 2000). The richest documentation is in the Historical Civic Archives of Pavia, of the Bonetta Civic Library, where the private archives of the Bellisomi family have been checked and reorganized by Prof. M. Vicini. The Palace nowadays hosts the *Alma Mater Ticinensis Foundation* and *EDiSU Pavia.*[1] The latest restoration of the building was completed in 2013, financed by the Fondazione Banca del Monte di Lombardia, and conducted by the studio of Arch. Marco Chiolini and Arch. Enrico Sacchi, focuses on the main floor and allows the reuse of many rooms (Forni, 2020).

However, the Palazzo's garden and ground floor rooms facing the loggia remained excluded from this intervention and are still in a state of disuse with degradation and critical issues (Fig. 2). The contribution proposes a preliminary analysis of the survey and documentation of the Palace garden as a starting point for developing an intervention proposal for reusing the still unused rooms. It is about reconnecting the Palace garden and the Palace itself to the citizenship, generating, as was the case until the 1950s, an identity place for the city of Pavia.[2]

2. Garden historical function

The Palace garden is characterized by perimeter walls that, by their morphology, do not determine the overall boundary of the property but contribute to the renewal of the 18th century design of the archetypal park of the *Villa di Delizia.*[3] Similarly, the garden emphasizes the 18th century reform of the Palace with the front facing the park modelled about the size of the park and richly decorated concerning the main entrance front. The loggia on the ground floor and the terrace above, with the portion of the facade corresponding to them, form a scenic backdrop from the central perspective of the garden, leaving in a state of apparent and incongruent separation a part of the Palace, outside the boundary of the park itself. On the axis with the staircase leading to the loggia, at the opposite end of the garden, is the Belvedere with pair of flights of stairs leading to the elevated terrace. The garden of the 18th century Bellisomi-Vistarino Palace originated as a *Hortus conclusus,* almost abutting the Ticino River. No graphic documentation has been found on the original design of the garden but, some formal features suggest elements typical of the time.

The Palace garden is coherent with the layout of the *Villa di Delizia* open to the landscape, codified by Jacques-François Blondel. Even on the original essences of the garden design, there is no certain information, although in 1830 Elia Giardini reports the presence of greenhouses (Giardini, 1839). At the behest of Marquis Pio Bellisomi, son of Gaetano Annibale, in 1776 the garden was enlarged towards the Ticino. The phases of use and abandonment of the garden followed the fate of the entire Palace, first inherited by the Giorgi counts of Vistarino and then sold in 1889 to Antonio Bottoni (Fig. 3). In the 1930s the garden was neglected, as appears from photos of the time. In the late 1950s, the green space became the site of Corsino Park, a summer dance hall with a dance floor in the centre of the garden and entrance from Porta Damiani Street (Fig. 4). The portico on the ground floor is raised from the level of the park like a stage about the stalls, as the central staircase that allows communication between the two spaces. It plays the symbolic role of a proscenium, bringing the architecture of the building to the level of the green and marking the full formal and functional integration of the loggia within the park itself.

After a series of changes of ownership, in 1980 the Palace was purchased by the University of Pavia and nowadays houses the *Alma Mater Ticinensis* Foundation and the offices of *EDiSU Pavia*. The process described is part of a more ambitious goal of the Foundation and the University for the enhancement of the Palace and its use through cultural offerings. This process had already begun in the past with the survey and proposed redevelopment of other abandoned portions, in particular, the 18th century stables and the palace's private chapel, which in the 19th century also served as a place of worship for the faithful of the San Simone district (Doria *et al.,* 2018).

Figure 1 | Location of the Palace in the city of Pavia and images of the interior rooms restored since 2007 and the exterior.

Figure 2 | Top: The main access courtyard to the Palace. Bottom: front of the Palace facing the garden with loggia on the ground floor and balcony on the main floor.

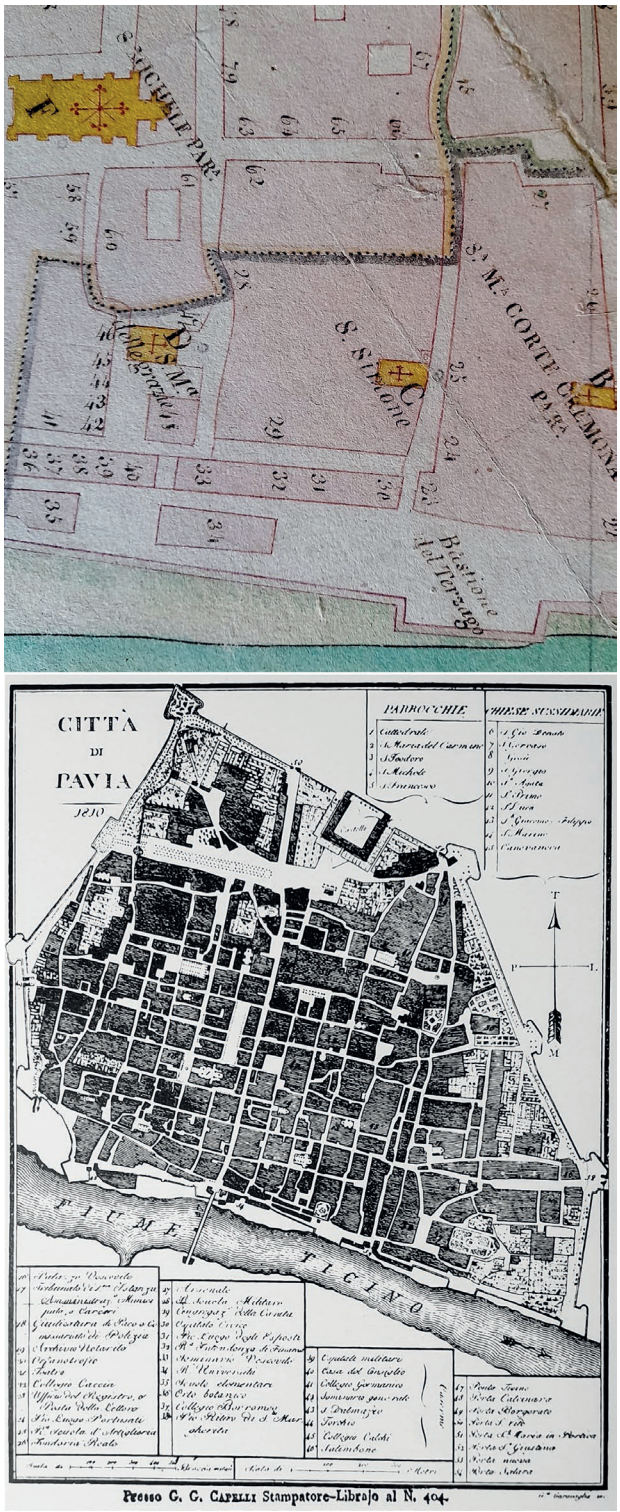

Figure 3 | Historical maps to understand the evolution of the Palace. Top: excerpt from the 1757 cadastral plan of Pavia showing the Contrada of San Simone. Bottom: planimetry from 1810 showing the Palace garden with an evident drawing of the greenery.

Figure 4 | Corsino Park dancing hall in the garden of the Palace: view of the dance hall in the Palace garden with the dance floor and tables; along the boundary wall, there were the musicians, illuminated fountains and sculptures. For more information see Pavia (PV), Musei Civici di Pavia, Guglielmo Chiolini Fund.

3. Related research: state of art

The process of documenting the architectural cultural heritage is used in the context of the research to represent the material conservation of the Palace and to emphasise its intangible value, understood as the value of the place that is identifiable and identifying for Pavia (Besana, 2018; Gasparoli, 2012; Morandotti *et al.*, 2014; Niglio, 2017; Samol, 2023). This conception is essential to structure interventions capable of preserving and managing the historical context. The research field of heritage protection underlines how the preliminary investigation and digital documentation

Figure 5 | Photographs of the Palace garden, in particular: the balcony of the second floor with the Belvedere in the distance; Loggia of the ground floor with the Belvedere in the distance; Interior of the Belvedere with the double staircase made of masonry and wrought iron that is now unsafe and uninhabitable.

are fundamental aspects from which to start the activity (Balzani and Maietti, 2017; D'Urso, 2018; Parrinello and De Marco, 2021), together with the elaboration of digital models and virtual simulations. The contribution aims to define a process of cognitive actions basic to the design of planned conservation interventions (Della Torre, 2021). The actions that were carried out took place in different phases following the methodologies currently used: an indirect digital non-invasive survey to acquire morphology, volumetry and colorimetric aspects (Parrinello and Picchio, 2019; Santagati and Lo Turco, 2016); analysis of the state of conservation of materials, pathologies and alterations; modelling of the three-dimensional model (Centofanti, 2022; Croce, 2021; De Marco, 2021); integration of data for an information system (Malinveni *et al.* 2020; Sangiorgio, 2017). Developing digital twins (Grives, 2015) for Cultural Heritage management and conservation requires an integrated and multidisciplinary cognitive approach, a method recommended and already widely applied in the field of heritage conservation (Bruno *et al.* 2022; Jouan and Hallot, 2020). The GIS Georeferenced Information Tool represents a solution to extend, as a future project, the documentation to other buildings of the University of Pavia and connect them into a single system, which can be integrated with BIM and H-BIM detailed modelling (Giannattasio *et al.*, 2020; Batarin *et al.*, 2014; Dell'Amico, 2021; Pocobelli *et al.*, 2018; Ruffino *et al.*, 2019).

4. Documentation actions

The garden is the core of a larger project that reconnects the built architecture of the Palace with the surrounding landscape. Architecture and nature find in this enclosed space- the garden – a testimony of the past that is now forgotten and almost unknown to citizens due to the prolonged period of disuse (Fig. 5). To pursue this idea of reconnection, it is necessary to establish a process of reliable documentation and survey to guarantee an initial dataset of information from which to develop a proposal for intervention. The garden and façade had never been digitally documented through detailed analysis and a three-dimensional digital survey. The digital surveying process and pathologies analysis were carried out in May 2022 with the collaboration of the DAda-LAB, PLAY and STEP research laboratories of the University of Pavia as part of the training activity - Seminar on Architectural Survey and Representation - dedicated to the students of the degree course in Building Engineering and Architecture at the University of Pavia (Fig. 6).

The intent to proceed with a documentation activity conducted in the field stemmed from the idea of bringing students closer to the issues of documentation and enhancement of cultural heritage. The integral survey involved the use of digital instrumentation such as Terrestrial Laser Scanner - TLS - for metric reliability,

Figure 6 | Seminar activities for surveying and documenting the garden, trees and arboreal essences and architectural front of the Palace. Students involved in the seminar: Bassini S., Bianchi A., Daccò F., Ienco R., Mancini N., Masella M., Messa I., Montagner L., Sanmartino S.

Mobile Laser Scanner – MLS – for the survey of the trees and green area, Unmanned Aerial Vehicle - UAV - instruments for the close-range acquisition of the roof and the upper parts of the front and the garden, and Structure from Motion – SfM – photogrammetry for generating metrically reliable orthophoto and models. To enable the highest possible reliability all the data acquired were registered together to reduce possible accidental errors and the TLS digital survey was conducted with active RGB camera acquisition to obtain a point cloud that returned the colorimetric appearance of the front and garden.

The overall TLS point cloud consists of 82 RGB scans each composed of several points varying between 7 to 10 million with a maximum registration error of 3.1 mm (Fig. 7). The photogrammetric model of the roofs and facade of the garden was made with DJI Mavic Mini UAV, close-range SfM photogrammetry technique, and has an alignment, verified by having the TLS point cloud as a reference, of 1.7 cm (Fig. 8). The different point clouds were registered with each other through the use of black and white targets recognizable by each instrument. The use of targets made it possible to proceed with automatic recognition during the registration phase; the targets were used as checkpoints for error management. The elements analysed, such as columns, capitals, decorations, mouldings, and balustrades, were also hand-drawn and surveyed in detail to identify components and special features, creating an abacus of the elements.

Starting from the survey and the detailed analysis of architectural decorative elements, reliable bidimensional drawings of the facade and garden were developed to describe the architecture. The bidimensional vectorial drawings were used also as a basis for the analysis of existing pathologies. In addition to the digital survey, a detailed analysis was also conducted on the architectural elements that make up the architecture of the Palace (Fig. 9). The final products are processed to enable the documentation of critical issues prior to future restoration work, and as a history of the evolution of the pathologies found on the surfaces. The analysis has been conducted according to the Italian and European reference regulations: UNI 11182/2006 standard (ex Nor.Ma.L. 1/88) and Illustrated Glossary on Stone Deterioration Patterns ICOMOS 2008.

Figure 7 | Images of the TLS point cloud integrated with the point cloud generated by close-range aerial photogrammetry. The point cloud was created by paying attention to fully document the architecture but at the same time to detect the tree species. Numerous scans were taken from high points on the façade and Belvedere to obtain data on the summit portions of the garden as well.

5. New function and restoration

With careful restoration and enhancement, the Palace lends itself to triggering a regeneration and identity reappropriation. Indeed, the integration of the park with the cultural functions, which have long been active at the *Alma Mater Ticinensis* Foundation, will be a reason for mutual interaction.

On the one hand, the cultural functions already carried out by the Foundation will be able to take advantage of the open and redeveloped space of the park for cultural events. Such events concern concerts performances temporary exhibitions; on the other hand, the public opening of the park to a wider user base than the one that could benefit from the services of the Foundation itself will constitute an element of social rapprochement to a space that is now forgotten

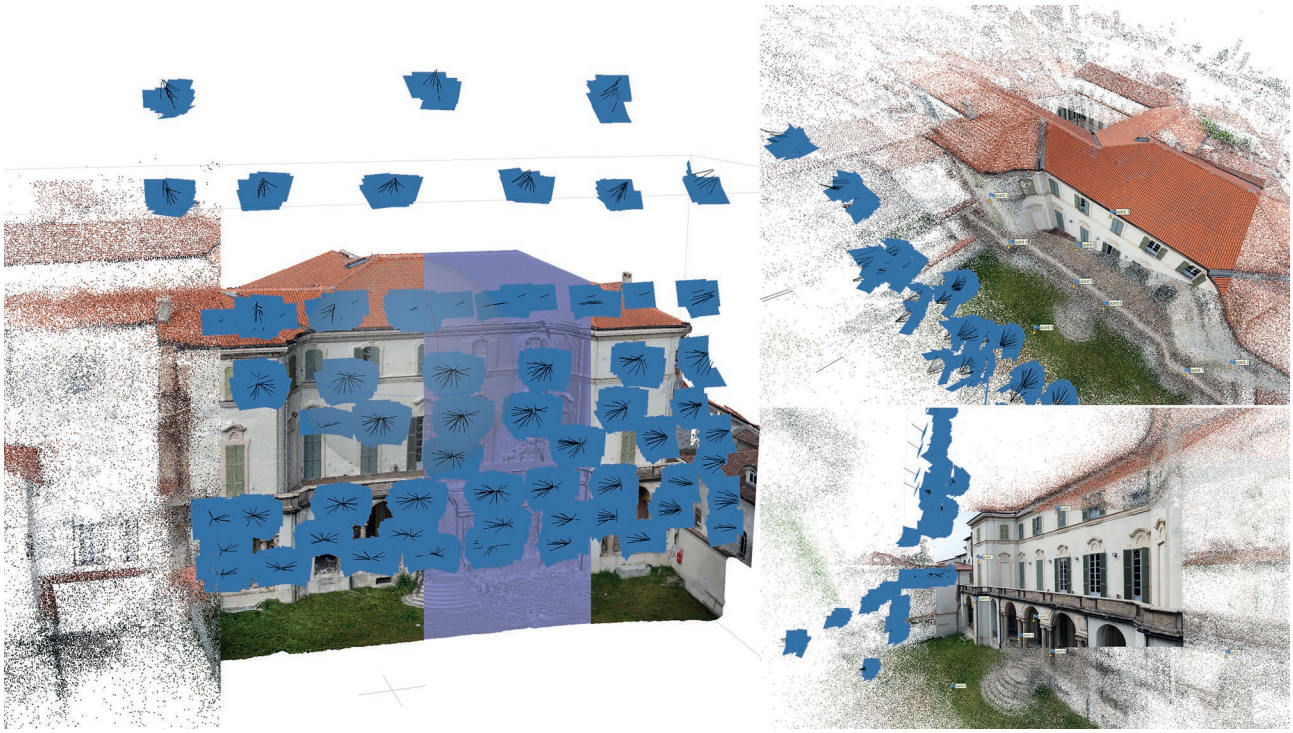

Figure 8 | Close-range photogrammetry of the facade on the Palace garden performed with DJI Mavic mini. Left: the evolution of processes from point cloud to textured model. Right: images of the sparse point cloud highlighting the location of acquired photographs and targets used for model alignment. The UAV acquisition was conducted with the support of licensed pilot R. De Marco.

and therefore of cultural reinforcement and possible synergy with other ambitious operations underway in the city along the same axis given by the avenue along Ticino. The morphology of the park and the connections that already exist today will provide a series of differentiated accesses that will ensure its enhancement while allowing for the necessary and adequate separation of user distribution flows (Fig. 10). It will be possible to make the park accessible to users outside of the spaces in use by the foundation by reactivating an existing gateway on Berengario square. This will exploit a natural diaphragm created by an open space pertaining to the Foundation but outside the garden where the core of service toilets will be installed. The appropriate closure on the opposite side of the park will likewise allow for the containment of visitor flows within the green area without functional interference with the contiguous spaces of the Foundation. The goals of the restoration and enhancement proposal focus on the following issues:

- Giving back to Bellisomi-Vistarino Palace and to the city a place enriched with a new cultural interest and included in the path of the redevelopment of the river already being developed by the Municipality;

- Guarantee high management and maintenance standards ensured by the presence of the Foundation, which would manage directly at the different scales of users: citizens, groups of researchers, and city; the existing organizational structure remains at the service of the park itself;

- Ability to manage over time following the rapid evolution of scientific research topics by adapting them to the specific dissemination; the educational and cultural activities already present structure the cultural path of events that quickly change to the rapidly evolving in-depth study in the form close to the most common knowledge, touching the artistic, literary, and close to music areas;

- Possibility of strengthening the identity of the places of the building and the city by opening the space to urban usability and generating a strong interaction between the public and associated spaces of the university as elements of cultural interaction;

Figure 9 | Two-dimensional representations of the building to understand the relationships between the volumes and between the architecture and the garden. The drawings were produced during an MSc thesis dissertation in 2018 and during May 2022 Architectural Survey and Representation seminar.

- Study applied to landscape regeneration promotes sustainability seen in the regeneration of a multipurpose space open to the recovery of environmental issues, with a view to a landscape sensitivity applied to the use of the existing space enhanced with its cultural values and potential (Morandotti, 2018; Picchio, 2016).

5.1. Architectural and sculptural components

The project involves the conservative restoration and securing of two architectural elements tightly integrated with the park and previously mentioned: the loggia, an architectural element mediating between the interior and exterior of the Palace, and on the opposite front of the park the Belvedere. Regarding the loggia, it is visible

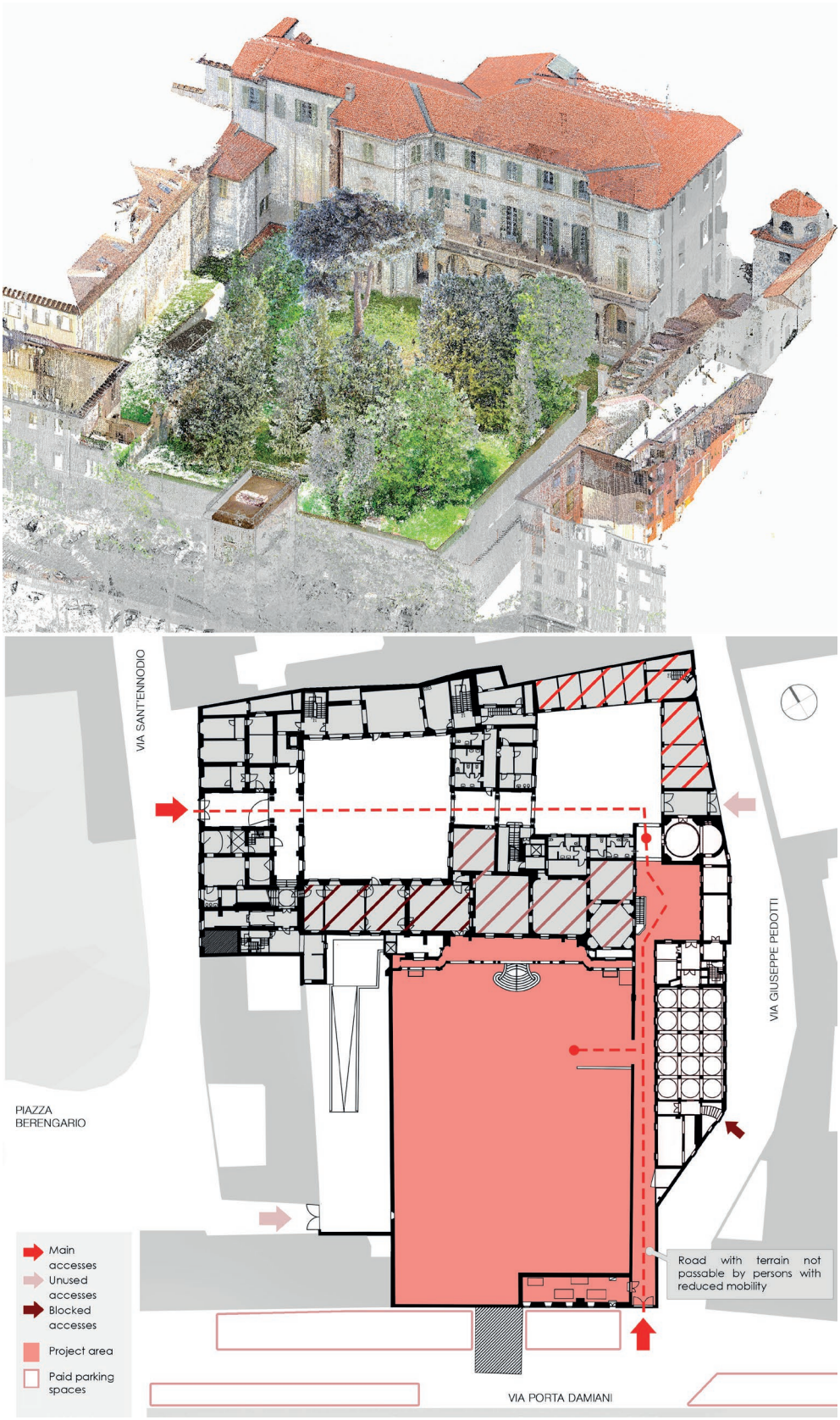

Figure 10 | Viability and main accesses to the Palace. The garden can once again become a usable space in synergy with the Palace and at the same time a stand-alone element with possibilities to isolate the accesses and functional flows of people in it.

Figure 11 | Decorative elements and portions of architecture have been surveyed and catalogued. Through querying the three-dimensional model of the researched area, it is possible to have specific references to the observed object. These data converge in the database that constitutes the backbone of the 3D information system.

that the current state of preservation is compromised by the presence of widespread paintings of damp pathologies due in part to infiltration from the terrace above and widespread deterioration of the plastered surfaces. Similarly, there is a clear need to restore the balustrade that separates the loggia from the park; the architectural elements that make up the balustrade are largely present *in situ,* although removed from their original position and therefore repositionable by anastylosis (Fig. 11). Cracks are evident on the intrados of the loggia vaults, which must be the subject of localised stylistic interventions. In addition to this, an analysis system should be activated in connection with the mapping of deterioration in the interior rooms, scheduled as a STEP Laboratory activity for November 2022.[4]

Regarding the Belvedere at the end of the garden, structural interventions are largely necessary; in addition to the maintenance of the plastered surfaces that show swelling, surface deposits, efflorescence, partial lack of plasters and the presence of biological colonization, the intervention has to include the securing of the stairs. The twin staircases are partly made of stone and partly of partially rusted wrought iron. The structural stability of the walking components and parapets should be analysed in the restoration project, as well as an inspection of the upstairs terrace currently in a state of abandonment (Fig. 5). Access to the highest elevation of the Belvedere may be provided only when the roof parapet has been secured.

5.2. Information systems

The experimentation involved modelling the portions surveyed and documented during this project phase. The model was obtained from the mutually recorded data of the different point clouds of the survey phase. Having the detailed drawings available, the model was made NURBS, Non-Uniform Rational Basis-Splines, and is composed of curves and surfaces. The model was made only for the portions for which we currently have the detailed digital survey, thus only for the pilot case that includes the facade and garden. Using modelling software plug-ins, it was possible to verify the reliability between the model and the point cloud on time, displaying both as different layers in overlapping. Once

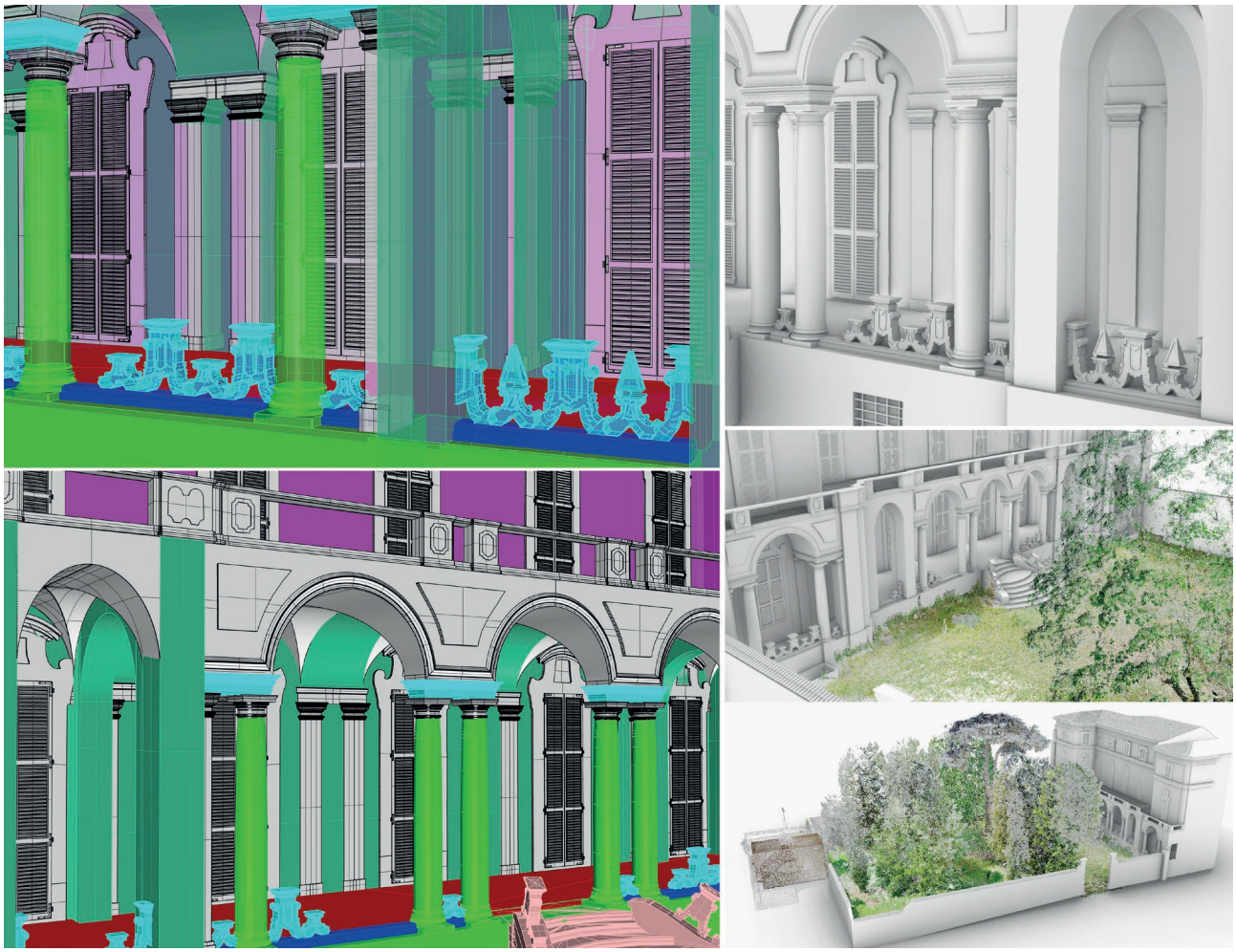

Figure 12 | Images of the three-dimensional model made with different classes of elements highlighted and union between the model and point cloud to verify the reliability and integrate different data. Two-dimensional drawings and models are partly supplemented by the work produced by students of the didactic seminar.

the point cloud is loaded into the 3D modelling environment, the plug-in offers powerful point cloud manipulation tools and uses the cloud to store and transmit point cloud data without loss of quality.

Documentation and enhancement can be conducted using 3D digital models enriched with metadata as tools, expanding the scope of application of an information system either for specific technical uses-restorations, maintenance, preservation-or as a tool for remote use or augmented reality and musealisation. Digital technologies applied to cultural heritage are the platforms where models and metadata can be linked in interoperable and interactive formats (Brusaporci, 2010). In the field of Cultural Heritage, they include 3D models and GIS data viewers, such as ArcSCENE or QGIS software,[5] which support a mesh model of the façade with a representation of the decorations and selectable surface overlay of the architectural elements or pathologies analysed. All mesh models are exported from the modelling software -.3ds - and imported into the computer platform as shapefiles. Related textual data can be entered by uploading textual.csv files or external images or pdfs as hyperlinks.

5.3. Enhancement and communication

The enhancement actions that can be activated on the park are many and range from its opening to the public to its use for Foundation initiatives that can also be carried out for a wider public. Along with an enhancement related to the use of the physical spaces, of the

Figure 13 | Starting from the 2D drawings was modelled a 3D digital environment. The modelling was structured via Mc Neel Rhinoceros software. Based on the model and augmented reality applications that will be developed in the next phases of the project, the research wants to focus on two main aspects such as the inclusion of additional information related to diagnostics and the development of a musealisation application.

park, a broader action of enhancement can be envisaged through the implementation of useful supports to promote accessibility. The digital and tridimensional digital model of the park is aimed not only to be the tool for the design of garden and building restoration interventions but as a structuring element for subsequent communication actions. It is intended to create, from the virtual three-dimensional model of the current state of the park, a digital reproduction showing the historical conformation of the garden, starting from the 18th-century one, through modelling of period images, the 20th-century transformative state and its future design projection. In this way, such a model of the park would take on a role not only as a digital twin but also as an evolutionary testimony to the transformations undergone by this green space over time. The virtual reconstruction can be enjoyed through a layering of content at different degrees of interactivity and users, differentiated and comprehensible not only by specialists' architectural historians, landscape architects, and restorers, but also by a wider audience, schoolchildren, and others, connected to a cultural dimension related to education and training (Doria *et al.*, 2022). Virtual enjoyment of the park will be able to take place through the in-site use of visors that will facilitate guided tours and take visitors on a sensory, as well as the virtual spatio-temporal journey of time.

6. Results and conclusions

The informative digital three-dimensional model of the portion of the Palace built starting from the point cloud can be used as digital support for intervention and enhancement planning. The three-dimensional model can be used not only as a support for the creation of navigable virtual environments but also as a structure of an information system enriched with information and data on the state of conservation of materials, architecture, vegetation, and with the abacuses of the elements surveyed during the documentation phase. The stages of the process described in this contribution included: Historical archival surveys aimed at understanding the property and its evolution; Survey and digital documentation of the state of the sites; Implementation of an information system aimed at the management of the asset; Support to the identification of architectural restoration strategies; Support to the definition of intervention techniques; Support in defining actions to enhance the value of the asset. Among future goals, it will certainly be useful to extend the survey and digital documentation to the entire Palace to obtain a comprehensive model that can be used for conservation action planning. In addition to the practical activity of documentation, desirable long-term goals appear to be to contribute to the improvement of cultural and service

offerings as well as the quality of life of citizens, to foster the development of ecosystem functions with direct and positive environmental impacts, and to strengthen and disseminate scientific, technical, environmental, and architectural sustainability knowledge.

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Notes

[1] The Foundation was established in 2007 and has two founding members: the University of Pavia and the Fondazione Banca del Monte di Lombardia. Its mission is to promote, enhance and make use of the University's knowledge and to foster collaboration between the University and the economic and social community,

[2] The scientific group set up to develop this research includes Prof. Marco Morandotti, Prof. Olimpia Niglio, Prof. Sandro Parrinello and Prof. Massimiliano Savorra of the Department of Civil Engineering and Architecture of the University of Pavia.

[3] The definition is the one assigned by Marc'Antonio Dal Re to his collection of engravings depicting various Milanese suburban villas. The garden is an element that characterises this typology, with which the palace is built in close relation. For more information, see: Castellaneta C. (1993) Villa di Delizia, Bestsellers, n. 363, Milano, Mondadori.

[4] The surveying phase of alterations and pathologies of the rooms on the ground floor of the Palace is being carried out and reviewed by the authors and is being conducted as part of an experimental master's thesis in the Building Engineering and Architecture degree program.

[5] ArcScene is software from the ESRI group and allows data layers to be overlaid in a 3D environment with attributes and properties, and each layer can be managed differently. QGIS is an Open-Source Geospatial Foundation Open-Source Geospatial Information System (OSGeo) released under the GNU General Public License. They are brought as examples of georeferenced information systems used in the experimentation because of their different characters from the point of view of cost and source files

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