Information system as tool for Cultural Heritage documentation and preservation. Protocol structuring and testing on a case study.

M. Morandotti [1], E. Doria [2]*

[1] DICAr, Department of Civil Engineering and Architecture, University of Pavia – Pavia, Italy – marco.morandotti@unipv.it
[2] DICAr, Department of Civil Engineering and Architecture, University of Pavia – Pavia, Italy – elisabetta.doria@unipv.it

KEY WORDS: Information System, valorisation project, Cultural Heritage, heritage database, heritage documentation, 3D modelling, GIS.

ABSTRACT:

This contribution presents a process of documentation and conservation of the built Cultural Heritage, tested on a partially disused case study located in the urban fabric of the city of Pavia. The actions defined led to the design and implementation of a tridimensional Information System obtained integrating data collected across different research areas, reality-based models and with the goal of enriching a tool for the documentation and management historical buildings owned by the University of Pavia. The process of documentation, three-dimensional digitisation, and census of the architectural elements on an urban and-architectural scale defines a tool for standardised analyses on building complexes of the same property and for large-scale planning of monitoring and valorisation activities. The research is based on the use of tridimensional Information System, as one of the indicators of the 2030 Agenda, in line with target 11/11.4, to activate a process of reuse and sustainable management of urban heritage.

1. INTRODUCTION

The implementation of tools for the protection of tangible cultural heritage is based on the diagnosis of the conservation status of the property and its context (d. Lgs. 42, 2004). Enforcing a set of scheduled protective actions limits extraordinary intervention, facilitating punctual actions and maintaining an analytical approach for effective long-term interventions (Cardaci, 2023; Della Torre, 2015). When intervening on historic city centres, the complexity of the urban fabric implies additional layers of complexity. The most critical issues arise when designing and implementing general control tools for the elaboration of effective responses within the time limits of ordinary maintenance interventions (Gasparoli, 2011; 2012). A reliable and updatable system can be an effective representation of the built heritage, being integrated with the major planning tools at various scales, ranging from territorial to technological, with architectural detailing supporting analytics. Maintenance and monitoring actions are to be identified in the Italian context with the introduction of the Legislative Decree 50/2016 "*Codice Appalti*" and described as all "activities aimed at the maximum safeguard of the asset through the monitoring of its conservation conditions". Predictive maintenance can be described as maintenance based on observed conditions at the current state and performed according to repeated and recurrent analyses. All actions referring to such decree are described in the 2001 UNI 10951 standard: "SIGeM. *Sistemi Informativi per la Gestione della Manutenzione dei patrimoni immobiliare* - Information Systems for Property Maintenance Management". The standard provides methodological-operational guidelines for the design, implementation, use and updating of information systems and for the related digitisation of environments and construction of databases. To enable the drafting of tools for the management of assets, additional standards have been added (UNI 11257, 2007) but, despite the standards being kept up to date, the subject of maintenance planning in the digital age is not standardised. The standardisation of actions is particularly complex in the context of historic urban built heritage assets since there is no unambiguous methodology for the implementation of processes. Although regulations for information platforms are being updated, the topic of integrating data ingested from different data is still under development.

Systems such as the GIS Geographic Information System (Bocconcino, 2023; Doria, 2022), H-BIM Heritage Building Information Model (Sanseverino, 2022; Parrinello, 2019; Chiabrando, 2017) and AR/VR Augmented/Virtual Reality (Sangiorgio, 2021; De Fino, 2020; De Marco, 2023) for the facility management of the historic built environment represent the integrated interdisciplinary approach suggested for the optimisation of processes for the use and data management gathered in the data acquisition and asset documentation phase (Besana, 2019; Miceli, 2020). The aim of such process is to structure a single tool fulfilling objectives such as facilitating the overall vision for long-term sustainable management, informing stakeholders of current needs, and providing guidance on how to enhance the site. Sustainable management of the built heritage is a priority that cannot be postponed and is subject to Italian and international regulatory standards. In this framework, United Nations Sustainable Development Goals (UNSDG) 11 "Sustainable Cities and Communities" is approached as a guideline for the development of appropriate national and supranational policies, including the use of built heritage information systems.

2. SCOPE OF THE RESEARCH

This contribution presents a process of documentation and conservation of the built cultural heritage, tested on a partially disused case study located in the Italian urban fabric. The actions defined led to the design and implementation of an information system, integrating data collected across different research areas, enriching a tool for the documentation and management of Palace Vistarino in Pavia, an historical building from 1700 owned by the University of Pavia and the *Alma Mater Ticinensis* foundation. The case study is a portion of the

* Corresponding author

Palazzo, displaying the characteristic alterations and pathologies of a disused place lacking ordinary monitoring and maintenance. Being this article more focused on the processes and methodologies, the following paragraphs will focus on the actions and the development phases rather than on the historical notions of the specific built heritage, for which reference is made in previous publications (Vicini, 1978; Forni, 1989; Erba, 2000; Doria, 2018; Forni, 2020; Doria, 2023).

2.1 Information systems for Cultural Heritage preservation

Information models for cultural heritage (CH) preservation can include information layers providing a cohesive overview of the environment (Batty, 2018; Bocconcino, 2022). Digital technologies are used extensively for the study and analysis of multiple aspects (Balzani, 2017; De Marco, 2021) among which: digital surveying with laser tools for 3D scanning, photogrammetric, colorimetric and textural surveys (Parrinello, 2019, 2021; Picchio, 2022; Volzone, 2022) three-dimensional modelling (Croce, 2021; Parrinello, 2022; Brumana 2020), dissemination through Virtual Reality (VR) and Augmented Reality (AR) integrated with virtual fruition systems of the products obtained in 3D and 4D platforms and information systems (Bocconcino, 2021; Trizio, 2021). Previous research and experiences suggest basing actions and strategies for the preservation of CH on a thorough knowledge of both the CH itself and the intervention technologies used nationally and internationally, to reduce the risk of heritage loss. Among the measures currently indicated at national level for the prevention of CH the notable ones upon which this work builds are monitoring and planned maintenance of the historical heritage; spatial planning and management; awareness-raising campaigns and training of technical staff; cooperation of institutions and availability of economic resources (Chiabrando, 2018).
Conservation of Cultural heritage relies on a specific set of principles to guide operators towards appropriate interventions (ICOMOS 1998; UNESCO 2010) and, in this scenario, the objectives of documentation can be found in the realm of conservation resilience processes (Morandotti, 2017). The interrogability of information systems, describing the complexity of the heritage, and the readability of the information are key elements for proper operability of the acquired information. The structuring of the information system and the management of the complexity of Cultural Heritage represents an archive of information from which specific analyses can be activated based on the data present. Querying integrated digital archives using different combinations of keywords and values, guarantees consistent and multi-variable data extraction within a multi-scalar approach. Queryable and integrated information systems enable a higher degree of cognitive value when compared to isolated and non-interoperable individual information units.

3. DATA ACQUISITION AND POST-PRODUCTION

The contribution describes the actions carried out for the generation of a georeferenced GIS information system, managed with the ESRI platform. The research processes for the structuring of such tool concern: 1. acquisition of the morphological data of the architecture by means of digital survey integrating LiDAR (Light Detection and Ranging), Terrestrial Laser Scanner (TLS) instruments and Structure From Motion (SfM) photogrammetric techniques both from flat and spherical photographs; 2. collection of material and technological data with census sheets and population of the database; 3. reality-based three-dimensional modelling starting from the survey data with integrated mesh and NURBS (Non-Uniform Rational B-Spline) models; 4. import of models and census data into the GIS platform, querying of the three-dimensional data with the information data for the extraction of intervention priority levels and historical comparison; 5. access to the locations and 3D models through Application Programming Interfaces (APIs); 6. management of Identity Access Management with diversified access according to user categories with web-map tools. The process was focused on the portion of the palazzo relating to the south façade, the internal rooms on the ground floor, now in a state of disuse, and the palazzo's private garden. The south façade, the garden and the internal rooms on the ground floor overlooking the garden had never been fully documented beforehand with a TLS and photogrammetric survey. The digital documentation phase was conducted from May to December 2022; the succession of seasons, even within a short time lapse, allowed the alterations of the materials on the surfaces to be observed under different conditions. The survey was conducted in collaboration with the STEP, DAda-LAB and PLAY research laboratories of the University of Pavia, Department of Civil Engineering and Architecture - DICAr. The integral survey involved the use of digital instrumentation such as TLS for metric reliability, UAV instruments for the acquisition of roofs, and Structure from Motion - SfM - photogrammetry for the generation of orthophotos and metrically reliable models of the lower portion of the front and detailed architectural elements. In addition, fast LiDAR surveys were tested to make comparisons and evaluations based on the relationship between data reliability and acquisition time. The functionality of the Apple iPad Pro (3rd generation) LiDAR sensor was tested using a 3D survey app. The Polycam app, currently being tested in the field of CH documentation, (Luetzenburg, 2021; Eker, 2022; Vacca, 2023) allowed the scanning of objects and architectural elements by exporting the acquired data in different formats including .obj, .dae, .ply, .laz, and .pts. The point cloud processing phase allows the customisation of values, such as the depth interval (from 0.1 to 6 m), voxel size (from 3 mm to 27 mm) and the mesh simplification to be applied to the surveyed data (in a progressive fashion).

Clusters/scans	Connessions	Point error iterations [mm]	Average point error [mm]	Minimum overlap
Scan_271	4	1.1	0.8	31.9 %
Scan_272	11	2.7	1.3	30.5 %
Scan_273	11	2.0	1.3	36.9 %
Scan_274	13	3.0	1.4	45.7 %
Scan_275	15	3.2	1.5	31.9 %
Scan_283	17	4.8	2.1	15.2 %
Scan_284	15	1.9	1.3	35.7 %
Scan_285	13	1.8	1.3	35.4 %
Scan_286	12	2.1	1.4	38.1 %
Scan_287	11	1.8	1.2	30.2 %
Scan_288	13	2.2	1.2	31.5 %
Scan_289	6	1.5	1.0	27.8 %
Scan_290	4	1.9	1.2	15.2 %
Scan_291	4	3.9	1.7	29.5 %
Scan_292	4	1.1	1.0	31.2 %
Scan_293	5	4.8	1.9	37.8 %
Scan_294	2	4.0	2.1	33.6 %
Scan_299	11	3.2	1.6	38.0 %
Scan_300	11	3.0	1.5	28.9 %
Scan_301	12	2.7	1.5	30.5 %
Scan_302	12	2.1	1.3	32.4 %
Scan_303	15	1.9	1.3	33.9 %
Porticato_DX	9	2.1	1.2	33.6 %

Figure 1. Data from outdoor scans recording report acquired with TLS FARO CAM2 S150 and recorded with CAM2 SCENE software. The main iteration errors correspond to scans made in the garden of the palace closer to the trees and grass.

Figure 2. Top: Images from LiDAR models acquired with PolyCam tablet and app; The application allows the acquired model to be viewed in augmented reality, navigating the room or around the object by moving the tablet. Bottom: images acquired using TLS FARO CAM2 S150. Registration was performed using visual alignment of the proprietary software and the targets positioned during the survey for areas of the garden away from architectural elements.

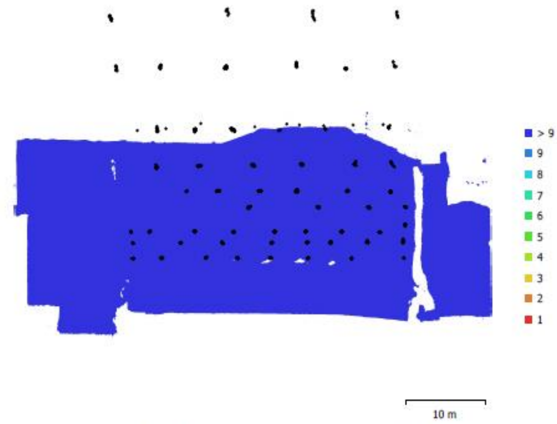

Fig. 1. Camera locations and image overlap.

Number of images:	770	Camera stations:	770
Flying altitude:	16.3 m	Tie points:	1,768,617
Ground resolution:	4.92 mm/pix	Projections:	6,409,329
Coverage area:	1.17e+003 m²	Reprojection error:	1.15 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC7203 (4.49mm)	4000 x 2250	4.49 mm	1.76 x 1.76 μm	No

Figure 3. Top: Report of the process followed to generate three-dimensional models from Structure from Motion photographic technique via a DJI Mavic Mini UAV. Bottom: image composition describing the processing steps of the photographic data, from sparse point cloud to textured model.

The test phase was performed on small portions of the colonnade and some of the interior rooms. The total TLS point cloud consists of 82 RGB scans, each on comprised of between 7 and 10 million points. The photogrammetric model of the roofs and the garden façade was surveyed with a DJI Mavic Mini UAV and validated using the TLS point cloud as reference with an alignment error of 1.7 cm. The point cloud obtained allowed both to perform the modelling phase and to obtain reliable drawings for the description of the architecture, acting as the foundation for the analysis of surveyed pathologies. The final products elaborated allow for a process of documentation of the critical issues prior to future restoration work, documenting the evolution of the observed pathologies. The modelling phase was conducted by integrating vector drawing and reality-based point cloud modelling, with the use of software plug-ins. The Veesus Point Clouds for Rhino plug-in uses Zappcha's Cloud support for storing and visualising point clouds in Rhino software.

4. THREE-DIMENSIONAL INFORMATION SYSTEM

High usability, geo-location of data and the possibility of including temporal references in addition to static data are among the most strengths of GIS and web-map information systems in the dissemination and online representation of cultural heritage; the case presented in this contribution focuses on the integration of data from the census and the cataloguing of elements, materials, and architectural data. The latter data, combined with the potential of GIS tools, was the basis of the dataset populating a multifunctional tool, usable as an integrated and queryable repository of multi-scalar data belonging to different layers of knowledge (Campanaro, 2016; Apollonio, 2018; Coluccio, 2018; Ruffino, 2019; Sánchez-Aparicio, 2020; Porcheddu, 2022). The long-term archiving of Cultural Heritage models and data is an essential requirement to enable digital preservation planning, while the dissemination and use of these tools is essential to reach the widest possible audience.

The filing of the garden façade had the dual purpose of collecting data on material pathologies (ICOMOS-ISCS, 2008) and analysing the remains of the decorative elements that still exist even though they are in a poor state of conservation. An example of the latter case is represented by the stone balustrades separating the portico from the garden, whose overall decorative design was lost, and could only be inferred from historical photos and historical reconstructions, relying on the existing remains (Guglielmo Chiolini Photographic Archive, Civic Museums, Pavia; Figure 4). The census was carried out with the use of a structured database with a usable front end to facilitate data entry tasks. The census cards were filed both remotely and on site with the use of hand-held tablets, allowing for a quick survey of the elements and reducing the post-production phase (Munro, 2017; Parrinello, 2023).

Multiple GIS platforms allow the management of three-dimensional models, which can be exported and imported across different platforms with shapefiles packages (QGIS, ESRI GIS). The different surfaces and volumes of the model were divided into layers according to the classification criteria of the project (e.g., technology packages, surfaces, volumes, structural elements) to be linked to the census sheets and data surveyed during the different phases. Each architectural element shows additional layers of information hotspots overlaid onto it, via applied textures, representing the diagnostic information. The model includes the integration of multiple information sets updated according to phases of analysis in progress that may be improved and extended as the research is further developed, working towards a multidimensional model.

Figure 4. Photographic images from the Pavia Civic Museums, Guglielmo Chiolini Fund, Pavia (PV). Top and centre: images from 1934. Bottom: image from 1977.

https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1081-2023

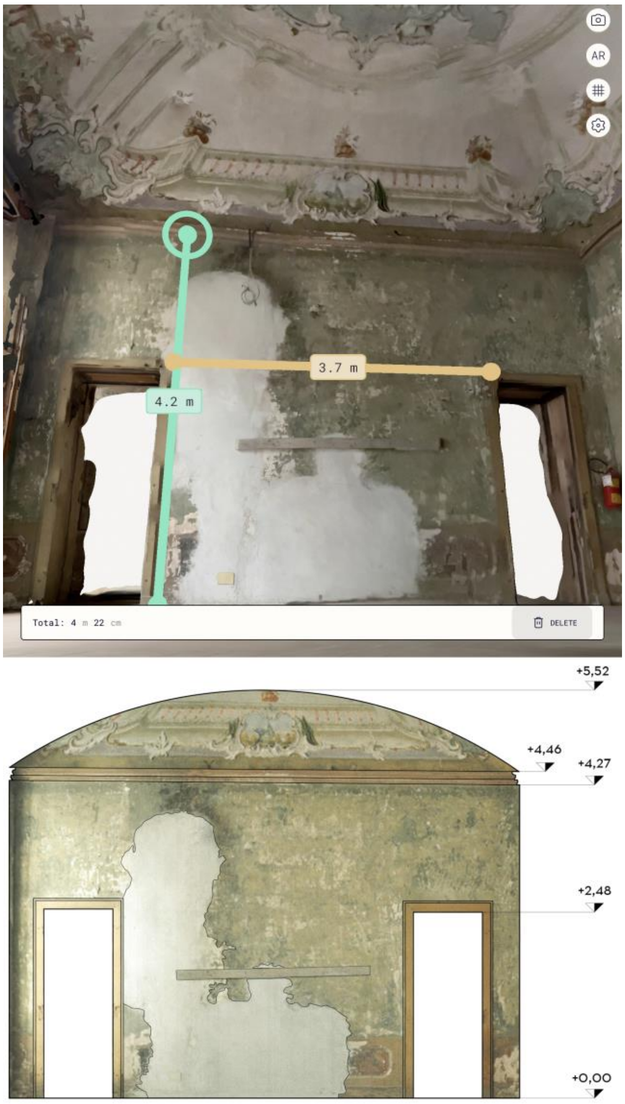

Figure 5. Comparison of fast survey with tablet (LiDAR acquisition) with TLS point cloud and photogrammetry. The reliability of LiDAR data compared to TLS depends on the way the data is acquired and processed. The LiDAR tests carried out saw acquisitions varying between 1 and 5 minutes per room, obtaining satisfactory results for a fast documentation process for non-structural monitoring.

The first integration is that of the fourth dimension, the temporal dimension. There is a vast scientific literature concerning 4D GIS models, identifying as the fourth dimension the temporal one (UNI 11337-6, 2017; Charef, 2018) by layering structured information. Such representation allows to keep track, within the model, of the temporal sequence of card loading and census information both in terms of updates and new entries into the IS. The development of a dynamic system allows the tracking and querying of the transformation processes underway, and thus an effective monitoring of the management actions of the mapped CH. The database, in its final implementation, serves different purposes: collecting data to build a digitised historical memory of the asset; managing the extraction of the data entered according to multi-variable queries to obtain indications on the elements and criticalities with the necessary intervention priorities; usage of the three-dimensional model remotely with accessible and filterable information according to the users with whom it is shared.

Figure 6. Top: Modelling phase from vector drawings. Centre: Modelling phase from the point cloud and integration with the garden. Bottom: three-dimensional model of the palace front on the garden with thematic classification of decorative and functional architectural elements.

5. FUTURE ACTIONS

The process described was developed on a portion of the case study currently in disuse, but the full potential of the information system could be achieved by extending the application to the entire complex. The choice of implementing a GIS platform as the information tool stemmed from the requirement of replicability of the protocol on different buildings owned by the University. The process of documentation, three-dimensional digitisation, and census of the architectural elements on an urban and non-architectural scale defines a tool for standardised analyses on building complexes of the same property and for large-scale planning of monitoring and valorisation activities. Future developments of the process follow UNESCO's Agenda 2030. The lack of reliable data collection, measurement and monitoring processes is a significant and critical obstacle in promoting the importance of cultural heritage and creativity (United Nations, Sustainable development goals). Information systems for culture are one of the indicators of the 2030 Agenda, in line with target 11/11.4, to activate a process of reuse and sustainable management of urban heritage.

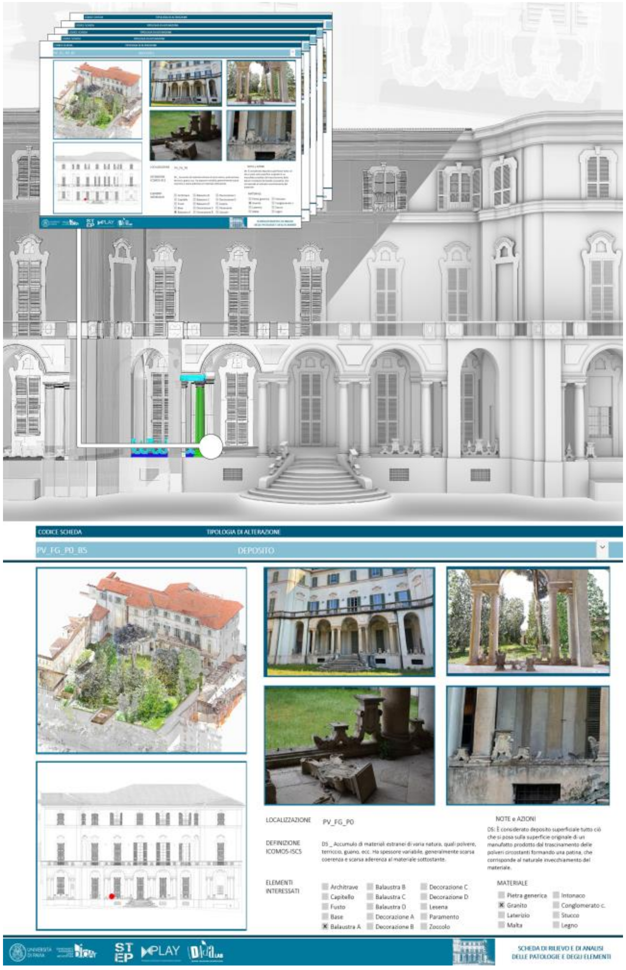

Figure 7. In the image: census cards of the architectural elements that make up the balustrade separating the loggia from the garden. Each element is characterised by a unique code on both the card and the model enforcing a relation between the three-dimensional data and the census data.

ACKNOWLEDGEMENTS

The authors of the contribution would like to thank the *Alma Mater Ticinensis* foundation for the promotion of research activities and cooperation. The three-dimensional model before being validated and divided in thematic layers by the authors was first initialised within the course of Prof. S. Parrinello “Survey and Representation”, in the academic year 2021-2022, aimed at students of the degree course in Building Engineering and Architecture at the University of Pavia. The authors would also like to thank R. De Marco PhD from University di Pavia for the support in the acquisition phase via UAVs. The figures were realised by the authors of the submitted paper.

REFERENCES

Apollonio, I.F., Basilissi, V., Callieri, M., Dellepiane, M., Gaiani, M., Ponchio, F., Rizzo, F., Rubino, A.R., Scopigno, R., Sobra’, G., 2018: A 3D-centered information system for the documentation of a complex restoration intervention. *Journal of Cultural Heritage*, Volume 29: 89-99, 2018. https://doi.org/10.1016/j.culher.2017.07.010

Balzani, M., Maietti, F., 2018: Architectural Space in a Protocol for an Integrated 3D survey aimed at the documentation, representation and conservation of cultural heritage. *Diségno*. 1: 113-122, 2017. https://doi.org/10.26375/disegno.1.2017.13

Batty, M., 2018: Digital Twins. *Environment and Planning B-Urban Analytics and City Science*, 45(5): 817-820, 2018

Besana, D., 2019: Cultural heritage design: theories and methods for the project complexity management. *EGE Revista de Expresión Gráfica en la Edificación*. Nº 11, 2019. https://doi.org/10.4995/ege.2019.12864

Bocconcino, M.M., Lo Turco, M., Vozzola, M., Rabbia, A., 2021: Intelligent Information Systems for the representation and management of the city. Urban survey and design for resilience. In: Sposito, C. (eds) *Possible and Preferable scenarios of a sustainable future TowardS 2030 and beyond*. 90-107, 2021. 107. 10.19229/978-88-5509-232-6/562021

Bocconcino, M.M., 2022: Mappe “nd” che mostrano ciò che non si vede, per un’immaginazione del concreto - Sistemi informativi e prospettive future che già sono il presente | “nD” maps that show what cannot be seen, for an imagination of the concrete - Information systems and future perspectives that are already the present. In Parrinello S. (ed.). *3D Bethlehem - Gestione e controllo della crescita urbana per lo sviluppo del patrimonio e miglioramento della vita nella città di Betlemme | Management and control of urban growth for the development of heritage and improvement of life in the city of Bethlehem*. pp. 173-189, Vol. 3, Edifir Edizioni Firenze, Firenze, 2022.

Bocconcino, M., 2023: Information Systems and Models for Territorial and Cultural Heritage. In: Parrinello, S., De Marco, R. (eds) *Digital Strategies for Endangered Cultural Heritage (forthcoming INTERSPECIES)-Handbook of Research on Strategies and Creative Interdisciplinarity for the Digitization and Safeguard of Endangered Heritage*, pp. 52-63. Milano, Pavia university Press.

Brumana, R., Oreni, D., Barazzetti, L., Cuca, B., Previtali, M., Banfi, F., 2020: Survey and Scan to BIM Model for the Knowledge of Built Heritage and the Management of Conservation Activities. In: Daniotti B., Gianinetto M., Della Torre S. (eds) *Digital Transformation of the Design, Construction and Management Processes of the Built Environment. Research for Development*. Springer, Cham. https://doi.org/10.1007/978-3-030-33570-0_35

Campanaro, D. M., Landeschi, G., Unto, N. D., Touati, A. L., 2016: 3D GIS for cultural heritage restoration: A ‘white box’ workflow. *Journal of Cultural Heritage*, 18, 321-332. https://doi.org/10.1016/j.culher.2015.09.006

Cardaci, A., Versaci, A., Azzola, P., 2023: I Torresini da Polvere di Bergamo: prospettive di conoscenza conservazione e valorizzazione. *I Torresini da Polvere di Bergamo: prospettive di conoscenza conservazione e valorizzazione*, Pisa: Pisa University Press, pp. 479-486. 10.12871/978883339794861

Charef, R., Alaka, H., Emmitt, S., 2018: Beyond the third dimension of BIM: A systematic review of literature and assessment of professional views. *Journal of Building Engineering*, 19, 242–257. https://doi.org/10.1016/j.jobe.2018.04.028

Chiabrando, F., Lo Turco, M., Rinaudo, F., 2017: Modeling the decay in an HBIM starting from 3D point clouds. A followed approach for cultural heritage knowledge. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W5, 605–612, https://doi.org/10.5194/isprs-archives-XLII-2-W5-605-2017

Chiabrando, F., Colucci, E., Lingua, A., Matrone, F., Noardo, F., Spanò, A., 2018: A european interoperable database (EID) to increase resilience of cultural heritage. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-3/W4, 151–158, 2018. https://doi.org/10.5194/isprs-archives-XLII-3-W4-151-2018

Coluccia, E., Noardob, F., Matrone, F., Spanò, A., Lingua, A., 2018: High-level-of-detail semantic 3D gis for risk and damage representation of architectural heritage. High-level-of-detail semantic 3D GIS for risk and damage representation of architectural heritage. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XLII-4, 107–114, 2018. https://doi.org/10.5194/isprs-archives-XLII-4-107-2018

Croce, V., Caroti, G., Piemonte, A., Bevilacqua, M.G., 2021: From survey to semantic representation for Cultural Heritage: the 3D modeling of recurring architectural elements. *ACTA IMEKO*, 03 2021, 10 (1): 98-108, 2021. https://doi.org/10.21014/acta_imeko.v10i1.842

Decreto Legislativo 22 gennaio 2004, n. 42. Codice dei beni culturali e del paesaggio, ai sensi dell'articolo 10 della legge 6 luglio 2002, n. 137 (G.U. n. 45 del 24 febbraio 2004, s.o. n. 28)

De Fino, M., Ceppi, C., and Fatiguso, F., 2020: virtual tours and informational models for improving territorial attractiveness and the smart management of architectural heritage: the 3d-imp-act project, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLIV-M-1-2020, 473–480, https://doi.org/10.5194/isprs-archives-XLIV-M-1-2020-473-2020

De Marco, R., Galasso, F., 2023: Digital survey and 3D virtual reconstruction for mapping historical phases and urban integration of the fortified gates in the city of Pavia, Italy. In: *Defensive architecture of the mediterranean: vol. XV* – Pisa: Pisa University Press, pp. 1029-1036. DOI: 10.12871/9788833397948130

De Marco, R., Parrinello, S., 2021: Management of mesh features in 3D reality-based polygonal models to support non-invasive structural diagnosis and emergency analysis in the context of earthquake heritage in Italy. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLVI-M-1-2021, 173–180, 2021. https://doi.org/10.5194/isprs-archives-XLVI-M-1-2021-173-2021

Della Torre, S., 2015: *La conservazione programmata del patrimonio storico-architettonico. Linee guida per il piano di manutenzione e consuntivo scientifico*. Guerini e Associati. Collana: Ricerche e strumenti. Gennaio 2015.

Doria, E., Morandotti, M., Venini, P., 2018. Conoscenza e progetto per il riuso di spazi esistenti: un caso di studio. In: Minutoli, F. (eds.) *ReUSO 2018. L'intreccio dei saperi per rispettare il passato interpretare il presente salvaguardare il futuro*, Vol. 2, pp. 1549-1560. Roma: Gangemi Editore spa.

Doria, E., La Placa, S., Miceli, A., 2022: Il GIS come strumento di analisi urbana per la gestione del Life Cycle della città - GIS as an urban analysis tool for the management of the city's Life Cycle. In: Parrinello, S. (eds.): *3D Bethlehem - Gestione e controllo della crescita urbana per lo sviluppo del patrimonio e miglioramento della vita nella città di Betlemme | Management and control of urban growth for the development of heritage and improvement of life in the city of Bethlehem*. pp. 139-165. Firenze: Edifir Edizioni Firenze. ISBN: 9788892800960

Doria, E., Morandotti, M., 2023: Documentation, conservation, and reuse planning activities for disused cultural heritage. *VITRUVIO - International Journal of Architectural Technology and Sustainability*. Vol. 8 (2023): Special Issue: Restoration and reuse of heritage - REUSO 2023. Pp. 30-47. doi.org/10.4995/vitruvioijats.2023.18814.

Eker, R., Elvanoglu, N., Ucar, Z., Bilici, E., and Aydın, A., 2022: 3D modelling of a historic windmill: ppk-aided terrestrial photogrammetry vs smartphone app, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XLIII-B2-2022, 787–792, https://doi.org/10.5194/isprs-archives-XLIII-B2-2022-787-2022

Erba, L., 2000: Spunti per una storia del giardino a Pavia. *Annali di Storia Pavese*, n° 28, Pavia.

ESRI GIS. https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview Ultimo accesso: 13 Gen 2023.

Forni, M., 1989: *Cultura e residenza aristocratica a Pavia tra '600 e '700*. Milano: FrancoAngeli.

Forni, M., 2020: Palazzo Bellisomi Vistarino, Almum Studium Papiense. *Storia dell'Università di Pavia*. Vol. 3, II. Milano: Monduzzi Editoriale srl.

Gasparoli, P., 2011: La manutenzione preventiva e programmata. In: Cecchi, R. (eds) *Roma archeologia. Interventi per la tutela e la fruizione del patrimonio archeologico*. III Rapporto. Milano: Electa.

Gasparoli, P., 2012: La manutenzione preventiva e programmata del patrimonio storico tutelato come prima forma di valorizzazione. *TECHNE*, Vol. 02/2012. Firenze: Firenze University Press. ISSN: 2239-0243

ICOMOS, 1998: *International Charters for conservation and restoration. Stockholm*, September 11th, 1998.

ICOMOS-ISCS, 2008: *Illustrated glossary on stone deterioration patterns Manual*. ICOMOS, Paris, 78p. Monuments & Sites, Vol. XV. ISBN 978-2-918086-00-0

Luetzenburg, G., Kroon, A. Bjørk, A.A., 2021: Evaluation of the Apple iPhone 12 Pro LiDAR for an Application in Geosciences. *Sci Rep*, 11, 22221 (2021). https://doi.org/10.1038/s41598-021-01763-9

Miceli, A., Morandotti, M., Parrinello, S., 2020: 3D survey and semantic analysis for the documentation of built heritage. The case study of Palazzo Centrale of Pavia University. *VITRUVIO - International Journal of Architectural Technology and Sustainability*. 5(1): 65-80, 2020. https://doi.org/10.4995/vitruvio-ijats.2020.13634

Morandotti, M., 2017: Planning the re-use: Sustainability through resilience evaluation. In: Van Balen, K., Vandesande, A. (eds) *Innovative Built Heritage Models. Edited contributions to the International Conference on Innovative Built Heritage*

Models and Preventive Systems (CHANGES 2017), February 6-8, 2017. DOI: 10.1201/9781351014793-3

Munro, M.C., 2017: Introducing FileMaker. In: *Learn FileMaker Pro 16*. Apress, Berkeley, 2017. https://doi.org/10.1007/978-1-4842-2863-0

Parrinello, S., Picchio, F., 2019: Integration and comparison of close-range SfM methodologies for the analysis and the development of the historical city center of Bethlehem. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W9: 589–595, 2019. https://doi.org/10.5194/isprs-archives-XLII-2-W9-589-2019

Parrinello, S., Picchio, F., De Marco, R., Dell'Amico, A., 2019: Documenting The Cultural Heritage Routes. The Creation Of Informative Models Of Historical Russian Churches On Upper Kama Region. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W15, 887–894, https://doi.org/10.5194/isprs-archives-XLII-2-W15-887-2019

Parrinello, S., De Marco, R., 2021: Digital surveying and 3D modelling structural shape pipelines for instability monitoring in historical buildings: a strategy of versatile mesh models for ruined and endangered heritage. *ACTA IMEKO*, Vol. 10, Number 1: 84-97, https://doi.org/10.21014/acta_imeko.v10i1.895

Parrinello, S., Picchio, F., La Placa, S., 2022: From Model to Model. The narrative between drawing and digital reproduction of Donatello's Pulpit. Architectus, Nr 4 (72), pp. 71-82. DOI: 10.37190/arc220407

Parrinello, S., De Marco, R., Doria, E., 2023: Analysis and definition of intervention strategies for the conservation of the boundary walls in Verona. In: Bevilacqua, G., Ulivieri, D. (eds). *Defensive architecture of the Mediterranean*. Pisa University Press, Pisa. 1113-1121. DOI: 10.12871/9788833397948140

United Nations, 2023: *Transforming our world: the 2030 Agenda for Sustainable Development, su United Nations – Sustainable Development knowledge platform*. https://sdgs.un.org/2030agenda (23/04/2023)

Picchio, F., Parrinello, S., Barba, S., 2022: Drones and Drawings-methods of data acquisition, management, and representation. DISEGNARECON, 15(29), pp. 1-7. https://doi.org/10.20365/disegnarecon.29.2022.ed

Porcheddu, G., Picchio, F., 2022: Close-range photogrammetry for the production of models and 3D GIS platforms for archaeological rescue excavations. In: Barba S, Parrinello S, Limongiello M, Dell'Amico A. (eds) *Drones-Drones - Systems of Information on Cultural Heritage for a spatial and social investigation*. vol. 2: 112-121, Milano: Pavia University Press.

QGIS - The Leading Open Source Desktop GIS. https://www.qgis.org/it/site/about/index.html (18/01/2023)

Ruffino, P.A., Bocconcino, M.M., Del Giudice, M., Osello, A.. 2019: From The Elaboration Process Of Point Cloud To Information Systems Both For Planning And Design Management Of Cultural Heritage. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XLII-2/W11, 2019, 1031–1038, https://doi.org/10.5194/isprs-archives-XLII-2-W11-1031-2019.

Sangiorgio, V., Martiradonna, S., Fatiguso, F., Lombillo, I., 2021: Augmented reality based-decision making (AR-DM) to support multi-criteria analysis in constructions. Automation in construction. *Automation in Construction*, Volume 124, 103567. https://doi.org/10.1016/j.autcon.2021.103567

Sánchez-Aparicio, L. J., Masciotta, M., García-alvarez, J., Ramos, L. F., Oliveira, D. V, Martín-jiménez, J. A., González-aguilera, D., Monteiro, P., 2020: Web-GIS approach to preventive conservation of heritage buildings. *Automation in Construction*, Volume 118, 103304. https://doi.org/10.1016/j.autcon.2020.103304

Sanseverino, A., Messina, B., Limongiello, M., Guida, C. G., 2022: An HBIM Methodology for the Accurate and Georeferenced Reconstruction of Urban Contexts Surveyed by UAV: The Case of the Castle of Charles V. *Remote Sens*. 2022, 14(15), 3688. https://doi.org/10.3390/rs14153688

UNESCO, ICCROM, ICOMOS IUCN, 2010: *Managing Disaster Risks for World Heritage*. United Nations Educational, Scientific and Cultural Organization.

UNI 11337-6, 2017: *Building and civil engineering works—Digital management of the informative processes—Part 6: Guidance to redaction the informative specific information*. Italy regulation.

Vacca, G., 2023: 3D Survey with Apple LiDAR Sensor—Test and Assessment for Architectural and Cultural Heritage. *Heritage*, 6(2), 1476–1501. MDPI AG. Retrieved from http://dx.doi.org/10.3390/heritage6020080

Vicini, D., 1978: Per l'architettura pavese del Settecento: palazzo Bellisomi-Vistarino, note preliminari. *Bollettino della Società Pavese di storia Patria*. Pavia: Tipografia del Libro.

Volzone, R., Niglio, O., Becherini, P., 2022: Integration of knowledge-based documentation methodologies and digital information for the study of religious complex heritage sites in the south of Portugal. *Digital Applications in Archaeology and Cultural Heritage*, 24. https://doi.org/10.1016/j.daach.2021.e00208