31

2025

IL CAPITALE CULTURALE

Studies on the Value of Cultural Heritage

eum

Rivista fondata da Massimo Montella

Il capitale culturale
Studies on the Value of Cultural Heritage
n. 31, 2025

ISSN 2039-2362 (online)

Registrazione al Roc n. 735551 del 14/12/2010

Web http://riviste.unimc.it/index.php/cap-cult, email: icc@unimc.it

Editore / Publisher eum edizioni università di macerata, Corso della Repubblica 51 – 62100 Macerata, tel. (39) 733 258 6081, fax (39) 733 258 6086, http://eum.unimc.it, info.ceum@unimc.it

Layout editor Oltrepagina srl

Progetto grafico / Graphics +crocevia / studio grafico

Rivista accreditata AIDEA
Rivista riconosciuta CUNSTA
Rivista riconosciuta SISMED
Rivista indicizzata WOS
Rivista indicizzata SCOPUS
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Inclusa in ERIH-PLUS

Kutlu İ., Bekar İ., Digital perspectives of Sumela Monastery in the interaction of cultural heritage and technology
«Il capitale culturale», n. 31, 2025, pp. 415-437
ISSN 2039-2362 (online); DOI: 10.13138/2039-2362/3546

Digital perspectives of Sumela Monastery in the interaction of cultural heritage and technology

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Abstract

The rapid development of technology has a significant impact on the preservation and accessibility of cultural heritage. This study aimed to investigate the impact of technology on historical buildings through digital perspectives of Sumela Monastery in Trabzon (Turkey). The study consists of 4 stages: data collection, field study, photogrammetric modelling and evaluation process. A digital model of the Sumela Monastery was built, the place of digital documentation processes in conservation criteria was revealed, and the monastery model was introduced to a wide audience through the Sketchfab platform. Furthermore, sections from different programs that this digital model can be imported were presented. These digital perspectives provide new possibilities for the documentation, preservation and interactive exploration of heritage. This paper emphasises the role of technology in the field of cultural heritage and discusses the importance of the digitisation of the Sumela Monastery.

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Il rapido sviluppo della tecnologia ha un impatto significativo sulla conservazione e sull'accessibilità del patrimonio culturale. Questo studio si propone di indagare l'impatto della tecnologia sugli edifici storici attraverso prospettive digitali testate sul monastero di Sumela a Trabzon (Turchia). Lo studio si articola in quattro fasi: raccolta dati, studio sul campo, modellazione fotogrammetrica e processo di valutazione. È stato costruito un modello digitale del monastero di Sumela, è stato approfondito il ruolo dei processi di documentazione digitale nei criteri di conservazione e il modello del monastero è stato presentato a un vasto pubblico attraverso la piattaforma Sketchfab. Inoltre, sono state presentate le sezioni di diversi programmi in cui questo modello digitale può essere importato. Queste prospettive digitali offrono nuove possibilità per la documentazione, la conservazione e l'esplorazione interattiva del patrimonio. L'articolo sottolinea il ruolo della tecnologia nel campo dei beni culturali e discute l'importanza della digitalizzazione del Monastero di Sumela.

1. *Introduction*

Historical buildings represent the most significant assets embodying the economic power, knowledge, and sociocultural characteristics of a society.[1] These buildings provide essential insights into the identity of their respective locations.[2] These buildings bear the imprints of the cultural features of the geographical regions in which they are situated, thereby reinforcing local identities. The preservation and transmission of cultural heritage, a primary responsibility of contemporary societies, offer multifaceted contributions such as ensuring the continuity of historical buildings, establishing a connection with societies' pasts, understanding the socio-cultural structures of bygone eras, and drawing inspiration from construction techniques.[3]

The preservation of cultural heritage, now recognized as a universal concern and a prominent research topic, is regulated by various laws and regulations.[4] International conservation criteria have evolved into a global policy framework aimed at conserving, preserving, and transmitting cultural heritage to future generations. In this context, conducting interventions in accordance with conservation criteria is a fundamental requirement. Equally significant is the documentation of changes and transformations in cultural heritage from the past to the present and its transmission to future generations, as emphasized in numerous national and international declarations. Over the centuries, a diverse array of methods for documenting cultural heritage has been applied and developed, with advancements in technology enabling the adoption of contemporary documentation techniques for more effective and practical conser-

[1] Drury, McPherson 2008; Taher Tolou Del *et al.* 2020; Mohamed, Marzouk 2023.
[2] Plevoets, Van Cleempoel 2011; Ashworth 2013; Takva *et al.* 2023.
[3] Mahgoub 2007; Okech 2010; Sürücü, Başar 2016; Guerrero Baca, Soria López 2018.
[4] Della Torre 2021; Haddad *et al.* 2021; Gharaati *et al.* 2023.

vation efforts.[5] In recent years, a plethora of processing and texture synthesis software have been employed in the domain of computer-based visualization research.[6] Since the inception of the Venice Charter in 1964, the International Council on Monuments and Sites (ICOMOS) has advocated for the utilization of all relevant sciences and techniques to support conservation. Similarly, in 1995, the Council of the European Union passed a draft resolution on culture and multimedia. As part of awareness-raising initiatives, ICOMOS published the Charter on the Perception and Presentation of Cultural Heritage Sites in 2008. These principles and resolutions collectively promote the integration of current technologies in conservation practices.

New techniques are developed almost every day to obtain accurate and reliable data in the documentation of cultural heritage. Documentation techniques using traditional methods have mostly been replaced by modern techniques with developing technology.[7] Today's technology allows for faster and more accurate recording of historical artefacts and buildings that require preservation, facilitating their passing on to future generations.[8] One of the main advantages of this process is that documentation studies can be archived in computer systems, documents can be presented digitally, and three-dimensional studies can be performed in addition to two-dimensional productions. Digital archiving allows documents to be passed on to future generations for longer and in a smaller format. However, by performing studies in a digital environment, it is possible to quickly access the data related to the building when it is needed.[9] The fact that the documentation process is no longer only two-dimensional allows researchers to easily obtain the data that needs to be monitored in three dimensions. Over time, as technology develops, the number of three-dimensional modelling techniques increases. Today, image-based techniques, including photogrammetry, are among the fundamental tools for 3D documentation of cultural heritage, often used in combination with range-based methods such as scanning systems.

Photogrammetric modelling techniques are used for rapid and reliable documentation of cultural assets.[10] Photogrammetric methods play an important role in the documentation, presentation, conservation and especially restoration processes of historical buildings and in the detection of potential deterioration that may occur during and after the works performed by experts.[11]

[5] Sampaio *et al*. 2021; Zhang *et al*. 2022.
[6] Hatıpoğlu, Çavuş 2024.
[7] Remondino, Rizzi 2010; Hassani 2015; Donato, Giuffrida 2019; Khalil *et al*. 2021; Li *et al*. 2023.
[8] Yılmaz *et al*. 2008; Chiabrando *et al*. 2018; Mendoza *et al*. 2023; Şimşek, Kutlu 2023.
[9] Argasiński, Kuroczyński 2023; Kong, Hucks 2023.
[10] Yakar, Yılmaz 2008; Uslu *et al*. 2016; Erenoğlu *et al*. 2017; Bekar, Kutlu 2024.
[11] Turan 2004.

Another unique advantage of photogrammetry is its ability to model objects according to their original shape and dimensions.[12] This feature enables detailed and accurate representation of cultural assets and supports restoration processes, especially with three-dimensional (3D) representations. Due to the limitations of traditional documentation methods and technological advancements, photogrammetry has become an effective tool for rapid and detailed documentation of cultural heritage. This method creates three-dimensional models of objects by using geometric relationships between photographic images that can be obtained using different techniques. Yakar et al.[13] used photogrammetric modelling techniques for the Emir Saltuk Kümbeti and generated data for the maintenance and repair processes of the building. Ulvi and Yiğit[14] created digital documentation of the Taşkent Sultan Fountain using the photogrammetric modeling technique. Polat et al.[15] discussed photogrammetric modelling processes in archaeological excavation areas. Ulvi et al.[16] addressed the photogrammetric modelling process of a historical building using unmanned aerial vehicles. Alshawabkeh et al.[17] present a fusion-based workflow using photogrammetry and TLS to optimize point cloud data for accurate heritage BIM (HBIM) creation, demonstrating its effectiveness through case studies of the Matbouli House Museum and Asfan Castle. Kutlu et al.[18] included the photogrammetric modelling process of the Artuqid Mosque in Mardin. De Fino et al.[19] provide a comprehensive literature review demonstrating the advantages of photogrammetric methods in diagnostic processes for architectural heritage conservation. Mohareb et al.[20] use low-cost photogrammetry to document and analyze arched and vaulted entrances of historic buildings in Old Tripoli, Lebanon, demonstrating how affordable methods can support the safeguarding of endangered monuments through detailed 3D modeling of architectural elements at both micro and macro scales. Aylar et al.[21] conducted a significant field study on producing a photogrammetric model of the 4.7 km long Diş Rocks using photogrammetric methods, highlighting how such production can be achieved in challenging geographical terrains using photogrammetry. These studies highlight the increasing role of digital photogrammetric techniques in the documentation and conservation of heritage buildings, reflecting a wider shift toward high-precision, non-invasive methods in

[12] Doğan, Yakar 2018.
[13] Yakar *et al*. 2016.
[14] Ulvi, Yiğit 2019.
[15] Polat *et al*. 2020.
[16] Ulvi *et al*. 2020.
[17] Alshawabkeh *et al*. 2021.
[18] Kutlu *et al*. 2022.
[19] De Fino *et al*. 2023.
[20] Mohareb *et al*. 2023.
[21] Aylar *et al*. 2024.

preservation of historical heritage. The referenced case studies from Türkiye illustrate the successful application of photogrammetry in a variety of environments, highlighting its adaptability and effectiveness in capturing complex architectural details under varied environmental conditions. This approach underpins the methodology for Sumela Monastery, where photogrammetric modeling is utilized to achieve a detailed, scalable, and accessible record of the structure, essential for both current and future conservation needs.

Throughout history, Anatolian regions have served as the beginnings of different civilizations and cultures, creating an extensive cultural heritage that continues to this day. Achieving sustained conservation of this cultural asset involves the use of advanced technical approaches and scientific research. As a result, it is critical to disseminate scientific studies and technical approaches used to conserve cultural assets on both national and international levels. This dissemination intends to promote the development of more effective long-term policies for the preservation of both cultural and natural assets, as well as to increase the volume of research in this area. This study focuses on the Sümela Monastery, a notable cultural and historical site in Trabzon, Turkey, and one of the city's significant cultural symbols. The study aims to generate a photogrammetric model depicting the current state of the monastery and present this model to users through an interactive environment via QR code integration. Furthermore, cross-sections illustrating the interfaces between different programs are provided to demonstrate the potential benefits offered by the digital photogrammetric model to researchers. Sümela Monastery is situated in a mountainous, rugged, rocky, and challenging-to-access terrain. Therefore, employing alternative measurement methods rather than traditional ones can yield less cumbersome and more practical outcomes. In this regard, the utilization of unmanned aerial vehicles (UAVs) for measurements, data transfer to digital platforms, and the creation of three-dimensional models greatly facilitate the documentation of structures in hard-to-reach areas like Sümela Monastery. This study represents a significant step forward in the efforts to preserve the invaluable cultural heritage of Sümela Monastery by generating a digital model, documenting it and passing it on to future generations, contributing to the ongoing efforts to preserve this historical treasure.

2. *Method*

Trabzon, a city with a thousand-year history, has held the world's interest at every stage of history because of its location. It has hosted numerous civilizations throughout its history, and many historical monuments from these civilizations remain. Sümela Monastery is one of the most important of these monuments. Sümela Monastery, which has great potential in terms of religious tourism, is also an important building in terms of cultural tourism. Sümela Monastery is located on a steep cliff on the slope of Karadağ in the Altındere Valley in the Trabzon Maçka district (fig. 1). Sümela Monastery, which appears as a structure stuck to the mountain, spreads over a very large area and includes the main rock church, chapels, student rooms, kitchen, library, guest house and the holy ayazma.[22]

Sumela Monastery's unique topographical challenges, such as its steep cliffs and remote access routes, pose significant obstacles to conventional documentation methods. This study leverages photogrammetric techniques specifically adapted to these orographic conditions, enhancing both the accuracy and feasibility of documentation in challenging terrains. The study, reflecting the important cultural and historical heritage of Trabzon and revealing the digital perspectives of the current situation of the Sumela Monastery, which has come to the present day, was organised in 4 stages. The first stage was data collection, the second stage was field survey, the third stage was photogrammetric modelling and the fourth stage was evaluation and recommendations (fig. 2).

The first stage is data collection. At this stage, the conservation criteria related to the building were examined and the criteria for documentation and digital inventory were investigated. Additionally, the history of the building, its location and the changes it has experienced over time were identified through literature research.

The second stage consists of fieldwork, in which the building was observed and analysed on site. In addition to collecting information, fieldwork provides an opportunity to understand and analyse events, objects and actors through direct observation.[23] During the visit to Trabzon in 2023, buildings were investigated on site, visual and technical information was obtained, and inferences were made. In this study, high-resolution images were obtained using a drone to document the current condition of the site during field observations. The images were captured at a resolution of 2560 × 1440 pixels and 144 dpi, a level chosen to balance field conditions with processing efficiency. Although higher resolutions can yield more detailed models, studies by Maharani et al.[24], Tinkham and Swayze[25] and Ulusoy and Sevim[26], emphasize that excessively high resolutions can significantly increase processing time without necessarily enhancing model quality. Accordingly, the flight plan and shooting pattern were optimized to ensure the necessary clarity and overlap for an accurate model, with coverage of both horizontal and vertical surfaces designed to achieve the ideal strip overlap ratios. This approach balances the need for high-quality 3D modeling with efficient data processing.

[22] Kaya, Kaya 2022.
[23] Aydın 2018.
[24] Maharani *et al.* 2020.
[25] Tinkham, Swayze 2021.
[26] Ulusoy, Sevim 2024.

In the third stage of the study, a digital three-dimensional model of the building was generated using the photogrammetric modelling technique. A digital model is a computer-based representation of real-world objects or systems and can be created using various techniques.[27] The digital photogrammetric model used in this study is a process that uses the analysis of photographic images and measurements to create a three-dimensional geometric model of an object. This process is usually performed using computer algorithms. In this study, the Metashape program developed by Agisoft was used. Depth-sensing algorithms can be used to generate a measured model from photographs. The photogrammetric modelling process, starting with imaging and data collection, is completed with the creation of 3D point clouds, extraction of 3D models from point clouds, optimisation, processing and verification. The data produced at this stage provides a digital environment for the preservation of cultural heritage.

The fourth stage of the study involved the evaluation of the digital modelling process of the building, based on all the research and analysis performed, which can be transferred to future generations. This stage was divided into two steps. In the first step, the role of digital modeling and documentation in international conservation standards was examined, focusing on its strengths and limitations. In the second step, in order to provide the user with an interactive experience through the digital model, a QR code was created that can be accessed easily by the user. Thus, the user was able to access the photogrammetric model of Sumela Monastery in the Sketchfab environment by scanning the QR code. It was also emphasised in this step that the model generated can be exported to different programs, thus encouraging interdisciplinary collaboration and application. Considering the program used in the study, together with Metashape used for the photogrammetric model production, the digital model produced was exported to 6 different program, Rhinoceros 3D, 3DS Max, Revit, AutoCAD, Geomagic Wrap and Sketchfab, and extracts from the program interfaces were presented.

3. *Findings*

Documentation of historic buildings, containing many important cultural and social data, is very important in terms of conservation practice. In this study, a digital three-dimensional photogrammetric model of Trabzon Sumela Monastery was created. In the process of photogrammetric modelling, it is necessary to take photographs that can be identified with each other for

[27] Evens, Hauttekeete 2011; Gomes *et al*. 2014.

the depth sensing algorithm of the program. Each photo frame is defined by containing approximately 30% of the previous photo frame. In this way, the program creates a model by aligning the photographs.

In this study, Agisoft Metashape was used to generate 3D models and textures using photogrammetry-based depth-sensing algorithms.[28] Specific parameters were set to optimise model accuracy and detail. Image alignment was set to 'High' to increase spatial accuracy, and dense cloud quality was also set to 'High' to capture intricate architectural elements. For texturing, the Generic Mapping method was used to ensure a consistent representation of surface textures across complex geometries. These parameter settings were carefully chosen to balance the processing requirements with the level of detail needed to comprehensively document the heritage structure. Photographs were taken during the field survey for Trabzon Sumela Monastery in 2023 and were added to the program as the first phase of the model creation process. The 71 photographs taken using unmanned aerial vehicles were added to the Metashape program and the alignment process was started. At the end of the alignment process, the program defined and aligned all the photographs (fig. 3). The result was a three-dimensional model consisting of a point cloud of aligned camera angles (blue frames).

The second phase of the process is the generation of the dense point cloud. When the camera angles and point cloud were aligned, the dense point cloud was created (fig. 4). The dense point cloud model of the building was created using the automatically defined 'build dense cloud' command in Metashape. The quality of the dense point cloud usually depends on the resolution of the photographs and the number of defined photographs. It can be observed that the dense point cloud model of the Trabzon Sumela Monastery has sufficient quality to provide data such as facade and architectural element dimensions and topographic features.

After obtaining the dense point cloud model, the mesh model of the building can be created. The process of creating the mesh model includes a critical process of transferring the data obtained from the photographs to the mesh surfaces and creating realistic models. Before creating the photogrammetric mesh model of the building, the unnecessary points appearing in the dense point cloud model should be selected and cleaned using the quick selection command. The unnecessary data in the photo angles can also be modelled by the program. Various structures, trees, cars, roads, etc. that are far away from the building and not required in the process can be removed from the model. Since the mesh generation process is generated depending on the number of points in the point cloud model, the mesh generation process can be performed faster and healthier after removing unnecessary data. Due to the location of

[28] Agisoft 2023.

the Sumela Monastery in Trabzon, models of trees that were not required in the surrounding area were also obtained. After a quick cleaning process of the dense point cloud of trees not related to the building, the mesh model was created. A solid mass model of the structures can also be created at the same time as the mesh model. This solid mass model can be used in three-dimensional printers or solid element modelling processes with the developing technology. For Trabzon Sumela Monastery, a solid mass model was created together with the mesh model (fig. 5).

After the mesh and solid model were created, the textures in the photographs could be defined on the model. The automatic texture recognition command of the program applied the textures in the photographs to the meshes. After completing the mesh model for Sumela Monastery, the textures on the photos were assigned to the model and a model of its current state was created (fig. 6).

When the model was finalised and the numerical data presented, the faulty or missing points of the meshes on the model could be checked. The accuracy and reliability status of the photogrammetric model created for Sumela Monastery can be examined using the reliability map (fig. 7). The regions shown in green represent the regions where the meshes are accurate and complete, while the regions shown in red represent the regions where the meshes are defective. In the case of Sumela Monastery, the photogrammetric model primarily exhibits green confidence values across the building, indicating a generally high reliability in the 3D reconstruction. Metashape calculates these values based on several factors, including the number of image projections, convergence angle, image quality, and calibration accuracy, each contributing to the overall confidence level for each point. Naturally, areas within the building that are more concealed or shaded present lower confidence values, reflecting the inherent limitations in these less accessible regions. This confidence map provides a nuanced understanding of the model's reliability across different architectural sections.

The model created in this study provides the necessary data to obtain the actual dimensions of Sumela Monastery and the survey drawings of its building. At the same time, it provides an important three-dimensional digital basis for conservation and restoration works. Furthermore, the photogrammetric model of Sumela Monastery represents a digital record of the building according to the data of 2023, providing an archive that will contribute to intergenerational interaction.

4. *Evaluations*

Preserving and documenting cultural history allows us to better understand how societies' past, present and future interact. Evaluating both the past and present of cultural heritage and addressing the requirements of sustainable conservation provides a more-in-depth understanding of society roots and identity. The integration of digital technologies into documentation procedures has become a critical instrument for preservation and communication of historical buildings. Digital modelling tools, in particular, contribute significantly to conservation efforts by allowing for the detailed and precise recording of historical buildings. The digital model of Sümela Monastery is a significant example of how these technologies can be integrated in restoration and conservation processes. The preservation and passing on of historical buildings to future generations improves the identity of societies, and plays an important role in ensuring cultural continuity.

The sustainable conservation and continuity of cultural heritage is also emphasised in many international conservation criteria. In this regard, the necessity to integrate the proposed and developed digital modelling processes and the use of evolving technological tools and equipment in the documentation processes is also included in the international conservation criteria and detailed information is provided in tab. 1.

The flexible and versatile use of digital models is not limited to conservation and documentation activities, but also offers a wide range of applications by integrating them into various programm in different disciplines. In this regard, the photogrammetric model of the Sumela Monastery was imported to the Sketchfab platform to enable a virtual experience for readers. Sketchfab is a 3D modelling platform website for publishing, sharing, buying and selling three-dimensional (3D), virtual reality (VR) and augmented reality (AR) content (Sketchfab). It offers a viewer based on WebGL and WebXR technologies that allows users to view 3D models on the web using any mobile browser, desktop browser or virtual reality headset. The import of the Sumela Monastery model into Sketchfab allows the reader or user to have prior knowledge before experiencing the monastery. Providing interactive experiences through the three dimensional model with the information obtained by examining only two dimensional photographs can have an impact on the user in different dimensions. In order to provide quick access to the model created as part of the study, a QR code specific to the study was created, and by scanning the QR code, access was provided to the photogrammetric model of Sumela Monastery in the Sketchfab environment (fig. 8). The QR code makes it possible to access the model from both the computer environment and mobile phones. This facilitates quick access to the model for the reader and the user. During the upload process to this platform, the resolution of the realistic image of the photogrammetric model may decrease. However, it is considered that the model in the virtual environment is sufficient for this purpose in line with the aim of providing a preliminary experience with the user. Providing access to the photogrammetric model of Sumela Monastery has increased the accessibility and usability of digital archives. As a result, historical and cultural heritage can be supported to reach a wider audience.

ICOMOS (1990) Article 4: *"The compilation of inventories should therefore be regarded as a continuous, dynamic process."*	Digital modelling of the building at specific times creates an environment that allows the building to be tracked between the past and the future. This facilitates the documentation and monitoring of the changes and transformations that the building has undergone over the years..
ICOMOS (1990) Article 5: *"…Non-destructive techniques, aerial and ground survey, and sampling should therefore be encouraged wherever possible, in preference to total excavation.."*	Photogrammetric modelling and unmanned aerial vehicles were used to capture images of the entire building. This provided a better and more holistic view of the building's massing relationships. In photogrammetric modelling, unmanned aerial vehicles can be used in hard-to-reach and rugged terrain, such as Sümela Monastery, to make measurements much easier and more practical than traditional techniques.
THE NARA DOCUMENT ON AUTHENTICITY (1994) *"…efforts to document clearly the particular nature of authenticity for monuments and sites as a practical guide to future treatment and monitoring …"*	Digital modelling techniques form the basis of conservation projects, besides determining the current condition of the historical building. This enables survey and restoration projects to be practical in terms of both accuracy of information and time.
ICOMOS (1999b) Article 1: *"The condition of the structure and its components should be carefully recorded before any intervention, as well as all materials used in treatments."*	Another advantage of digital modelling is the ease with which complex parts of buildings can be surveyed and a three-dimensional model produced. At this point it can be said that the parts of the buildings with carvings, ornaments and decorations, which are very difficult to measure manually with the traditional method, can be obtained easier and more practical results through photogrammetric modelling.
ICOMOS (1999a) *"Changes over time should be appreciated and understood as important aspects of vernacular architecture.."*	The process of generating a digital inventory creates an effective, updatable and shareable way of intervening and recording changes.
ICOMOS (2017) *"…information about relevant traditional skills and technologies, should be collected, catalogued, securely stored and made accessible as appropriate…"*	Digital modelling allows accurate measurements of sections with complex geometry. Considering that the survey and evaluation of high scaffolded buildings requires long and difficult measurements, it is advantageous to use photogrammetric methods instead of traditional methods. Building texture data can be provided by photogrammetric methods. As these data are obtained from images of the building itself, more realistic models are presented. At this point, digital modelling techniques provide results that are close to the actual appearance and make it easier for the user to understand the building.
ICOMOS (2017) *"All the above documentation must be retained both for future maintenance of the building and as an historical record."*	Digital documentation methods make information more accessible and provide a more practical environment than traditional methods. The QR code can be used to access the photogrammetric model of the building. This provides an interactive platform where users can easily access the three-dimensional model of the Sumela Monastery.

Tab. 1. Evaluation of digital modelling in line with conservation criteria (by authors)

The photogrammetric model produced with Metashape program has significant data development and export potential, going beyond the basic digital modelling discipline. The export capabilities of this program not only transcend the boundaries of digital modelling, but can also encourage interdisciplinary collaboration and application. Metashape allows seamless export in a variety of formats including Autodesk DXF Polyline (.dxf), Wavefront OBJ (.obj), 3D models (.3ds), VRML models (.wrl), COLLADA (.dae), Stanford PLY (.ply), X3D models (.x3d) and STL models (.stl). This versatility enables researchers and practitioners in various fields to benefit from the model's features and representations. It can contribute to a variety of disciplines, from design initiatives to architectural conservation studies, and allow for the efficient migration of processes. Together, these opportunities underline the important role of advanced modelling techniques in promoting interdisciplinary studies and once again demonstrate the impact of digital modelling. The photogrammetric model of the Sumela Monastery generated within the scope of the study was exported in ".3ds" format and imported into 6 different programs.

The models imported into program widely used in the design discipline such as Rhinoceros 3D (fig. 9a) and 3DS Max (fig. 9b) provide the opportunity to pre-design the interventions to be made on the building and visualise them realistically. This can contribute significantly to conservation studies. One of the greatest debates in heritage conservation today is the appropriateness and reversibility of interventions. This program can support conservation efforts by providing realistic visualisations prior to intervention, allowing assessment of potential impacts and aiding the decision-making process. AutoCAD is extensively utilized for vector-based drawing, whereas Revit (fig. 9c) serves a critical role in Building Information Modeling (BIM) and Heritage Building Information Modeling (HBIM). Revit's capabilities extend beyond simple vector drawing by facilitating comprehensive digital modeling and management processes essential for documenting and preserving architectural heritage. Importing digital models of historical buildings into this program facilitates survey studies based on three-dimensional modelling. Photogrammetric models are generally quicker to produce and require less intervention than traditional surveying techniques. These models can then be used in two-dimensional vector drawing processes through various programs, as well as allowing three-dimensional documentation of historical buildings. Geogmagic Wrap (fig. 9e) is commonly used to identify and correct mesh defects in the generated models. This program helps to detect and correct surface defects or gaps prior to 3D printing. Therefore, the import of photogrammetric models into such a program shows that 3D printing processes can also be performed, especially for historical buildings. Considering the process of producing the photogrammetric model, it is clear that this technology can also be improved. Modelling, documentation and archiving processes can thus be conducted not only in virtual and digital environments, but also in printed and physical environments. Finally, the photogrammetric model is released to the SketchFab platform for online accessibility and interactive visualisation (fig. 9f). In order to increase the dissemination of the model of Sumela Monastery to a wider audience, an account of the monastery was created and the model was uploaded to this platform. A QR code was created to provide quick access to readers. The model was displayed in a three-dimensional environment that could be moved around and studied more easily.

Photogrammetric modeling provides advanced visualization capabilities for cultural heritage conservation projects when combined with programs such as Rhino. Rhino can use a tool to assist in the analysis of architectural features and structural details by allowing users to obtain precise cross-sections from complex photogrammetric models. In the context of Sumela Monastery, this approach allows for the creation of cross-sections, providing insights into the topographic features of the site. Additionally, Rhino's rendering tools enable pre-intervention visualizations where proposed changes or interventions to historical buildings can be virtually implemented and reviewed in a 3D environment. This use facilitates to assessment of potential impacts on the site before any physical intervention occurs, supporting a more controlled and reversible conservation process (fig. 10). By leveraging these capabilities, the model allows stakeholders to make data-driven decisions, ultimately enhancing the accuracy and effectiveness of conservation efforts.

The processes in which the model is imported and advanced operations applies are not limited to the Rhino program. As mentioned, after determining the program needed in the studies, the photogrammetric model can also be imported on various programs. Models imported to programs are sometimes used directly, and sometimes they require some edits to the model. Therefore, it is necessary to select the appropriate program taking into account the modelling requirements and the characteristics of the field study. This selection process should take into account factors such as user needs, level and speed of use, data processing requirements and intended use of the results. Some program focuses on specific tasks, while others are more suitable for general use. For example, in AutoCAD, additional work may be required to obtain 2D data from 3D data. However, photogrammetric modeling can definitely help in the process of obtaining 2D data. User experience and preferences may also influence the choice of program. Therefore, careful consideration of different programs and techniques will ensure that the most appropriate choice can be made. This process will ensure that modelling is carried out efficiently and that the results obtained are used effectively.

5. *Conclusions*

The photogrammetric modelling and archiving of Sumela Monastery is an impressive example of the beneficial and useful combination of technology, heritage conservation and scientific techniques. The application of photogrammetric techniques has allowed this historical building, located between the rugged and sharp lines of the Pontic Mountains, to be immortalised in the digital world with accuracy and precision. The significance of this study is not limited to technological innovation, it also provides an important reflection on the preservation and documentation of our common cultural heritage, to be passed on to future generations. The study also presented that digital documentation processes are recommended and should be widely adopted as a sustainable approach to the preservation of historical buildings and international conservation criteria.

Photogrammetric modelling allows different disciplines to come together to conduct in-depth studies. The photogrammetric modelling of the Sumela Monastery allows not only the architectural evolution and spatial organisation, but also the study of the artistic ornamentation of the building. These models, produced at different time intervals, will make it possible to document the architectural, spatial and structural changes in the building. This will allow a better understanding of the evolution of changes over time and their impact on the building. Furthermore, the comparison of models from different periods provides a valuable cultural and historical perspective by highlighting the extent and significance of changes to the building. The archiving of the generated model in interactive platforms will help to preserve the historical narratives and cultural significance inherent in this architectural landmark. This model contains data that can be used as a reference for future studies of the monastery. Another important advantage of photogrammetry is that the model can be exported to different program and research can be conducted on it. In future studies, models will be created that include interior models and frescoes that represent important stories of the building, and users will be able to experience them remotely with augmented reality applications. The digital model of the Sumela Monastery focused specifically on the building's facades and immediate surroundings, but excluded interior spaces. This situation can be considered a technical limitation of the photogrammetric model. It arises from the difficulties of using drone technology in indoor environments that require professional piloting skills.

This study of Sumela Monastery contributes to the literature by creating an archive of the current state of the building against a potential disaster that could occur at any time. The preservation and conservation processes of such important historical buildings should be approached with a holistic and interdisciplinary approach. Data on the building should not only be produced using traditional techniques, but a multidisciplinary study should be carried out using digital and technological data. Within this framework, a collaborative model should be established between institutions, organisations and non-governmental organisations, and the process should be conducted by sharing the necessary studies. These processes should also develop the data that will form the basis of conservation work to a level that will allow users to have an interactive technological experience. To enhance the effectiveness of preliminary monitoring in photogrammetric models, it is essential to conduct visualization studies before any interventions. This proactive approach allows for an assessment of the compatibility of proposed modifications with the building's original design and historical context. By leveraging photogrammetric technologies, various aspects of compatibility – including structural integrity, aesthetic coherence, and preservation of historical elements – can be systematically evaluated before implementing solutions to potential issues that may arise in the building. It is expected that this research will provide different perspectives on the use of digital technologies in documentation and inventory and pave the way for future studies.

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Appendix

Fig. 1. Location and surroundings of Sumela Monastery (by authors)

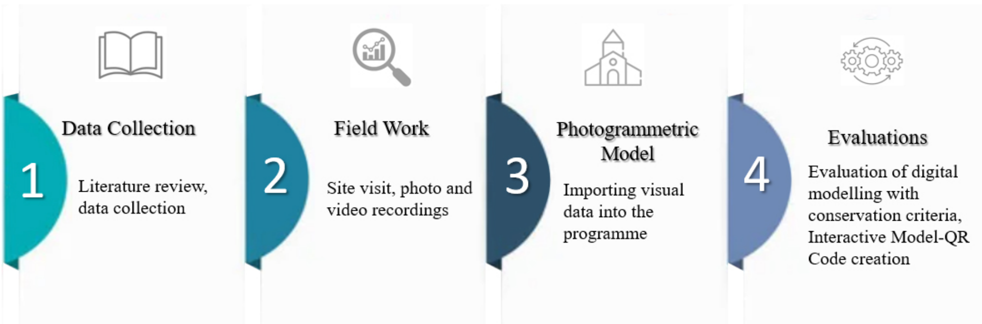

Fig. 2. Representation of the stages of the study (by authors)

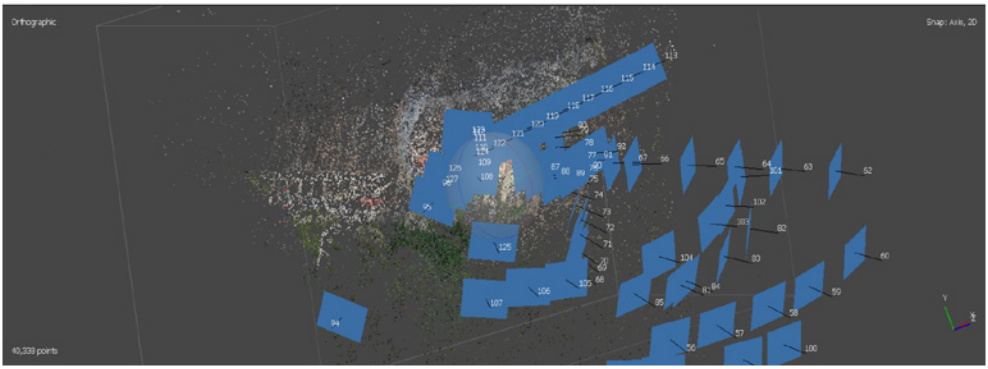

Fig. 3. Sumela Monastery – 71 photo angles (by authors)

Fig. 4. Sumela Monastery – Dense cloud model with 5.640.326,00 points (by authors)

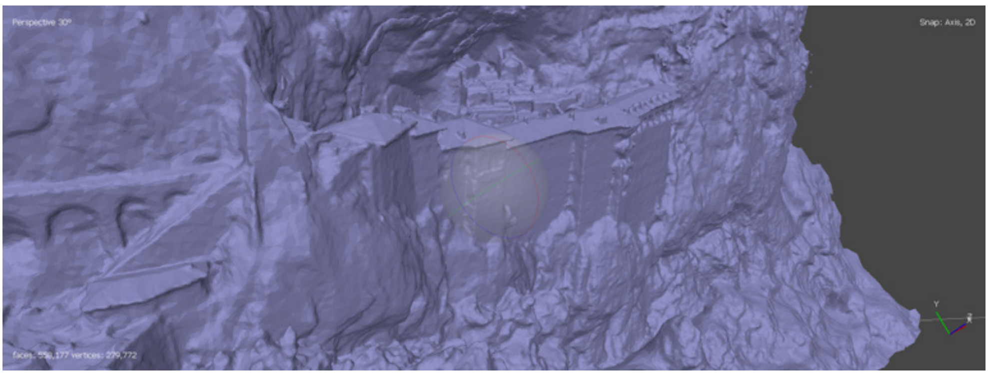

Fig. 5. Sumela Monastery – Solid model with 279.772,00 edges (by authors)

Fig. 6. Sumela Monastery – Photogrammetric model (by authors)

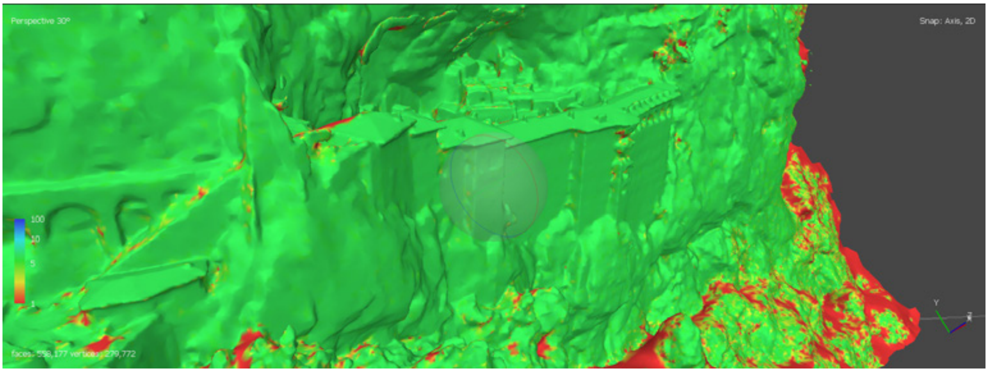

Fig. 7. Sumela Monastery – Confidence map (by authors)

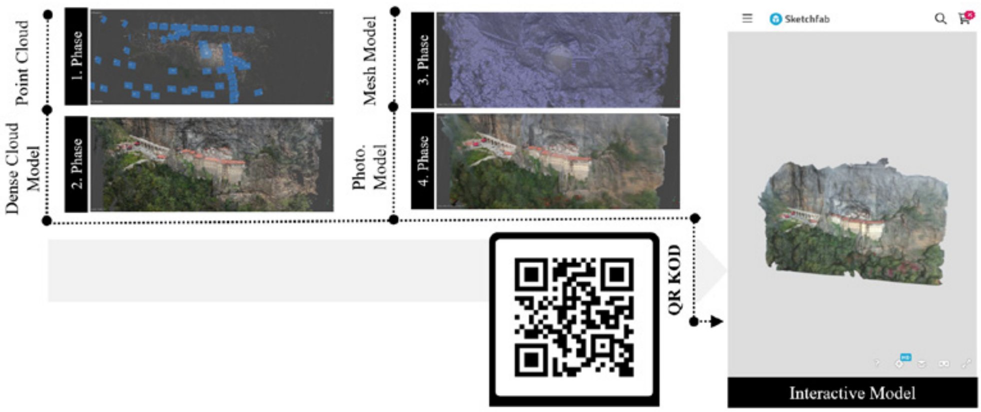

Fig. 8. Photogrammetric model stages of Sumela Monastery and QR code providing access to the model in virtual environment (by authors)

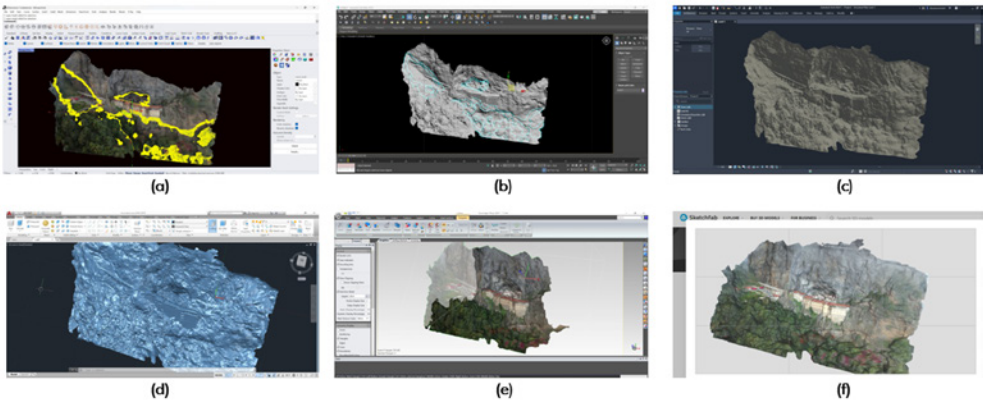

Fig. 9. The photogrammetric model of the Sumela Monastery exported to various programs – (a) Rhinoceros 3D, (b) 3DS Max, (c) Revit, (d) AutoCAD, (e) Geomagic Wrap, (f) SketchFab online platform (by authors)

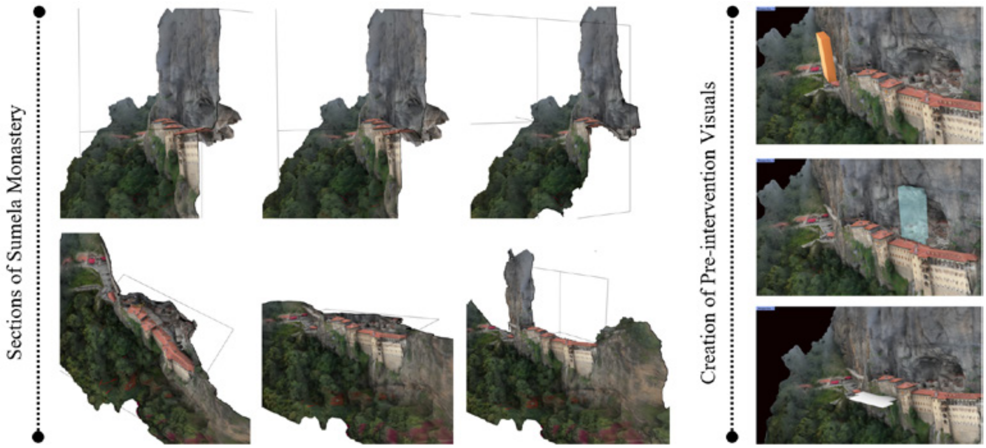

Fig. 10. Monastery cross-sections and pre-intervention potential visualizations obtained by integrating the photogrammetric model into the program in Rhino (by authors)

JOURNAL OF THE DIVISION OF CULTURAL HERITAGE
Department of Education, Cultural Heritage and Tourism
University of Macerata

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ISSN 2039-2362