

Exploring Photogrammetry for Documentation and Conservation

Fatih Uzun
Sevgi Altun
Sena Kayasü
Berkay Öztürk
Mine Özkar

33–42

Photogrammetry, the process of producing detailed 3D models using photographs, is an indispensable tool in heritage conservation and construction due to its capacity for documentation. It can benefit professionals across various fields of design and computation to efficiently generate digital renditions that can be used for documentation, dissemination, education and entertainment. This paper describes a feasible and cost-effective workflow for creating and processing high-quality photogrammetry-based models and a series of workshops that introduce architecture students and researchers to it. The proposed framework strives to document objects and spatial elements by streamlining the terrestrial photogrammetry process in the face of modern challenges, focusing on the necessity of model optimisation for the longevity of documentation. In this spirit, the workshop seeks to empower participants to actively engage in the preservation of cultural heritage.

#photogrammetry

#architectural documentation

#3D model optimisation

#UV mapping

#physically based rendering

Introduction

Photogrammetry, a method for quickly and reliably generating detailed 3D models using only photographs, is a vital tool in heritage conservation. Photogrammetric documentation can precede singular restoration projects and contribute to the efficient generation of data/model repositories. The widespread availability of digital cameras and user-friendly software with automated workflows enables individuals with varying levels of expertise and resources to generate three-dimensional models using photogrammetry (Sapirstein 2014). The method is also flexible and efficient in capturing colour and texture (Pepe et al. 2017) to provide realistic outputs (Baskar et al. 2023). However, the resulting models consume significant digital storage space and require processing to reduce their size and increase their operability (Figure 1). The heritage field draws on optimisation methods developed for game design and virtual reality applications to resolve these issues. Optimisation improves efficiency, which in turn further promotes the use of photogrammetry for documentation. These issues, and the optimisation necessary to resolve them, have been essential for game-design applications, in which developments such as level of detail and mesh-map baking (e.g. normal map and height map) are employed to balance computational efficiency with visual fidelity (Ferdani et al. 2020). As a result, it is essential to create and disseminate a framework for photogrammetry that encompasses the basics of heritage documentation, as well as data processing and optimisation, to encourage greater numbers of professionals to use this technique (Figure 2).

In this research, we define a framework for employing photogrammetry to meet the urgent need for architectural documentation and to create resilient archives of built heritage against the complex challenges of our time. The workshop series emphasises the importance of proactive

preservation strategies while discussing the basics of photogrammetry-based 3D modelling in a user-friendly and efficient workflow. This workflow is designed to be applicable across various scales to encourage users to actively engage in the documentation of visually accessible surfaces. Following the fundamental photogrammetry-based modelling workflow, from photographing objects to optimising models, we define steps to generate efficient and sustainable models and discuss the implications for application and dissemination. The models have the potential to store important information on the built environment, and optimisation increases their performance and usability across various platforms to maximise the dissemination potential of the models and the resulting archives. Once optimised, digital representations can also be imported into game engines, allowing for immersive experiences through virtual reality and augmented reality. This technology facilitates the creation of virtual museums and serious games that display physical artefacts and convey comprehensive information about cultural heritage, blending archiving with dissemination.

Objectives

1. Outline the need for architectural documentation and the importance of accessible methods.
2. Develop a comprehensive understanding of the basics of photogrammetry-based 3D modelling.
3. Explore methods to optimise photogrammetry-based models.
4. Explore the potential applications and utilisation of collected data for further analysis and preservation efforts.
5. Engage in discussions on ethical considerations in architectural docu-

mentation, including obtaining consent, data management practices, ownership and authorship of models and cultural sensitivities.

Workshop Series' Structure

To meet these objectives and empower professionals to use photogrammetry widely, we designed a workshop series to provide insights throughout a typical photogrammetric workflow. These are first framed through a series of theoretical presentations and then demonstrated through guided, hands-on practice. The presentations begin with the introduction of conceptual information about terrestrial photogrammetry-based modelling, its stages and its most commonly used tools. They continue with a discussion of the suitability of various surfaces for photogrammetry applications. Subsequently, there is a theoretical presentation of photography techniques for objects, surfaces and buildings that are optimal for modelling. The final stage of the theoretical portion is an explanation of the minimum requirements for digital phones and DSLR cameras used in photogrammetry applications, as well as camera settings (aperture, shutter speed and ISO) to optimise the photo set (white balance, base curve and colour calibration) in Darktable.

In the practical portion, the participants model small objects as examples (Figure 4). Photogrammetry typically involves several key steps: camera calibration, image acquisition, image preprocessing, alignment in sparse point clouds, the building of dense point clouds, three-dimensional mesh generation and texture map generation. The participants collect data using a DSLR camera, Gretag-Macbeth ColorChecker and a polarising filter. Then, they create a model using Agisoft Metashape. The presenters provide information on handling the source model's topology optimisation (retopology) in ZBrush, resulting in a representative model.

The represented model with a regulated UV map provides surfaces to 'bake' the mesh-map data of the source model using Adobe Substance Designer. Presentations regarding key points and concerns for heritage documentation and the introduction of neural network applications with photogrammetry-based digital models support the discussions through workshops. This comprehensive structure covers fundamental information for professionals from either a computational or heritage background, encouraging various disciplines to engage in digital documentation.

Workshops

Workshops 1 and 2: Photogrammetry and Augmented Reality

In the context of converting cultural heritage assets into 3D digital models and then into augmented reality experiences for mobile devices by performing topology optimisation, we held two local workshops: one at Istanbul University's Department of Architecture and the other at Sakarya University's Department of Landscape Architecture (Figure 3). The main purpose of these workshops was to provide architecture and landscape architecture students with basic skills in photogrammetry, increase awareness regarding cultural heritage documentation and encourage the preparation of digital models for virtual museums and educational games using AR models (Video 1, Figure 4).

Workshop 3: Resilient Heritage: Exploring Photogrammetry for Documentation and Preservation

This international workshop was held at Singapore University of Technology and Design as part of the 'Utilising UV-Mapping for the 3D-Point Cloud Segmentation of Architectural Heritage' study, which was presented at the CAADRIA 2024 symposium (Uzun et al. 2024).

The workshop aimed to inform computational specialists about built-heritage considerations and to encourage the use of more particular optimisation methods. During the practical component, the participants transferred the base colour map and height map textures of digital models obtained from heritage works to a representative model with a regular UV map (Video 2).

Conclusion

The primary objective of the workshop series is to encourage participants to take an active part in documenting and disseminating cultural heritage by familiarising them with photogrammetry-based modelling and model optimisation. We aim to help participants gain confidence in documenting their environment, sharing their models and applying the workshop techniques to their projects. While demonstrating with selected software, we also discuss the underlying logic behind the workflow and provide alternatives. We have found across the workshops that our workflow is highly adaptable with regard to the target audience and time availability. In all the workshops, the participants attain a basic grasp of photogrammetric modelling and optimisation where they have none before. The feedback from participants has been overwhelmingly positive, leading to valuable knowledge-sharing sessions and potential collaborations in the future.

Acknowledgements

We sincerely thank Instructor Sümeyye Ta delen (Department of Architecture, Istanbul University) and Assistant Professor Dr. Ömer Faruk Uzun (Department of Landscape Architecture, Sakarya University) for providing the venue and support for our workshops. We also appreciate the CAADRIA 2024 Organisation Committee (Singapore University of Technology and Design) for hosting our international workshop and offering a platform for sharing our research.



Figure 1. Example output from the workshops: High-poly model polycount: 44338 (this page). Low-poly model count: 2594 (next page).
Source: Authors.



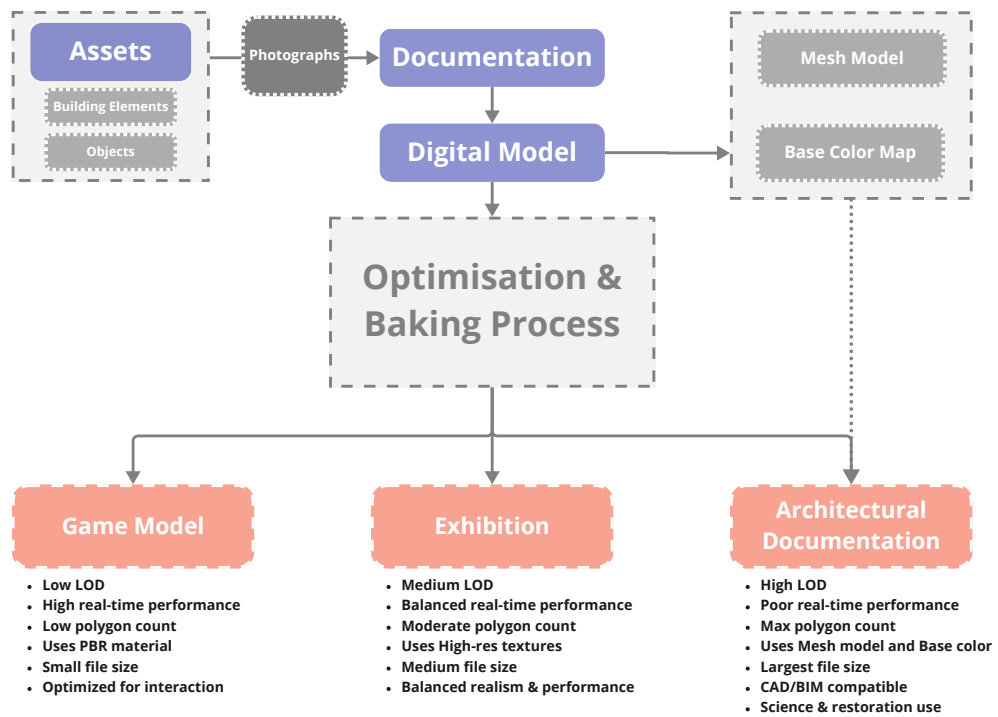


Figure 2. Digital model optimisation workflow for different applications.

Source: Authors.



Figure 3. Photographs from the workshops: Temporary documentation setup.
Source: Authors.



Figure 4. Alternative reality-based visualisation of architectural elements in a physical space. *Source: Authors.*



Video 1: Workshops 1 and 2: Photogrammetry and Augmented Reality. *Source: Authors.*



Video 2: Resilient Heritage: Exploring Photogrammetry for Documentation and Preservation. *Source: Authors.*

Bibliography

Baskar, Radhika, P. Muthu Krishnammal, Anurag Aeron, Syed Sumera Ali, T. Thomas Leonid, and M. R. Arun. 2023. "3D Image Reconstruction and Processing for Augmented and Virtual Reality Applications: A Computer Generated Environment." *2023 International Conference on Communication, Security and Artificial Intelligence (ICCSAI)* (Greater Noida, India). IEEE.

Ferdani, D., B. Fanini, M. C. Piccioli, F. Carboni, and P. Vigiariolo. 2020. "3D Reconstruction and Validation of Historical Background for Immersive VR Applications and Games: The Case Study of the Forum of Augustus in Rome." *Journal of Cultural Heritage* 43: 129–43.

Pepe, Massimiliano, Sebastiano Ackermann, Luigi Fregonese, and Cristiana Achille. 2017. "New Perspectives of Point Clouds Color Management – The Development of Tool in Matlab for Application in Cultural Heritage." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLII-2/W3*: 567–71. <https://doi.org/https://doi.org/10.5194/isprs-archives-XLII-2-W3-567-2017>.

Sapirstein, Philip. 2014. "Photogrammetry as a Tool for Architectural Analysis: The Digital Architecture Project at Olympia." In *Archaeological Research in the Digital Age. Proceedings of the 1st Conference on Computer Applications and Quantitative Methods in Archaeology Conference - Greek Chapter (CAA-GR)* (Rethymno, Crete). Institute for Mediterranean Studies – Foundation of Research and Technology (IMS-FORTH).

Uzun, Fatih, Sevgi Altun, Sena Kayasü, Berkay Öztürk, Yusuf Sahin, Gozde Unal, and Mine Ozkar. 2024. "Utilising UV-Mapping for the 3D-Point Cloud Segmentation of Architectural Heritage." *Accelerated Design – 29th International Conference on Computer-Aided Architectural Design Research in Asia, CAADRIA 2024* (Singapore). The Association for Computer-Aided Architectural Design Research in Asia.

Bio

Fatih Uzun works as a Research Assistant at the Faculty of Architecture, Istanbul Technical University. He earned his undergraduate degree in Architecture from Süleyman Demirel University and a master's in Computational Design in Architecture from Istanbul Technical University. Currently pursuing his Ph.D. at Istanbul Technical University, Fatih has actively contributed to various research projects. His academic research areas include serious games, gamification, photogrammetry, and HBIM.

Sevgi Altun is a doctoral researcher at Università della Svizzera italiana (USI), within the Fabrication and Material Aware Architecture group at the Accademia di Architettura. At the Chinese University of Hong Kong (CUHK), she contributed to the AI for the Future project supported by The Hong Kong Jockey Club. She holds an MSc in Architectural Design Computing from Istanbul Technical University (2023). Her research interests lie at the intersection of digital fabrication and sustainability in architecture.

Sena Kayasü is a PhD candidate in the Architectural Design Computing program at Istanbul Technical University. She holds an MA in Historic Preservation planning from Cornell University (2018). As a conservation specialist, she is currently researching methods to utilize photogrammetry and object-oriented modeling in the documentation of architectural heritage.

Berkay Öztürk is a Technical Artist at QReal, where he focuses on the integration of artificial intelligence and augmented reality in creative digital experiences. He holds a bachelor's degree in Architecture from Izmir Institute of Technology and earned his master's degree in Computational Design in Architecture from Istanbul Technical University. His academic research centered on the use of photogrammetry tools within HBIM and the computational documentation of historical structures.

Mine Özkar is a Professor of Architecture at Istanbul Technical University. Her research focuses on visual, spatial and material aspects of design computation, and more recently on their integration to heritage studies. She has interpreted the history and theory of progressive pedagogy in art and design from a computational perspective. She led interdisciplinary research on medieval Anatolian architecture, using geometric analysis, machine learning, and robotic reconstruction to interpret and recreate historical craft techniques. Mine currently serves on the Editorial Boards of Nexus Network Journal and A|Z ITU Journal of the Faculty of Architecture as well as the Board of the CAADFutures Foundation.