INTERNATIONAL JOURNAL OF TECHNOLOGY AND ACADEMIC RESEARCH

ISSN: 2224-6878 | Pakistan Volume 6, No. 10.

IF: 14.91 | 2026 http://waerasia.org/index.php/ijtar

# FROM DIGITAL DOCUMENTATION TO IMMERSIVE HERITAGE: INTEGRATING CLOSE-RANGE PHOTOGRAMMETRY, LASER SCANNING, AND VIRTUAL REALITY FOR THE PRESERVATION AND ACCESSIBILITY OF THE AK-SARAY MAUSOLEUM IN SAMARKAND

**Saida Yunusova**
Lecturer Bucheon University in Tashkent
Tashkent, Uzbekistan
E-mail: yunusova.saida93@gmail.com
doi:https://doi.org/10.5281/zenodo.23308949

**Abstract.** This article presents a methodological case study of the digital documentation, reconstruction, and immersive presentation of the Ak-Saray Mausoleum in Samarkand. The workflow combines terrestrial laser scanning, close-range photogrammetry, architectural CAD documentation, three-dimensional modelling, and virtual reality. The field survey used a FARO Focus M 70 terrestrial laser scanner from 48 positions; the resulting point-cloud data were processed in Autodesk ReCap Pro, while plans and sections were developed in AutoCAD. Close-range photogrammetry and documentary evidence were then used to reconstruct damaged and incomplete decorative elements. The reconstructed heritage model was developed in Autodesk 3ds Max and integrated into Unreal Engine to create an immersive virtual environment. The study demonstrates how a continuous digital workflow can connect measured architectural evidence with carefully distinguished interpretive reconstruction and public-oriented visualization. The approach has particular relevance for cultural heritage sites that are difficult to access, physically vulnerable, or incomplete. Rather than claiming experimentally demonstrated educational or accessibility outcomes, the article identifies virtual reality as a platform with clear potential for heritage interpretation, remote access, and future user-centred research.

**Keywords:** cultural heritage; close-range photogrammetry; terrestrial laser scanning; 3D reconstruction; virtual reality; digital heritage; Ak-Saray Mausoleum; Samarkand.

## Introduction

Digital technologies are increasingly used to document, analyse, reconstruct, and communicate cultural heritage. For architectural monuments, the combination of three-dimensional survey techniques and digital modelling makes it possible to preserve geometric information while also creating new forms of interpretation and access. This is especially important for historic structures whose fabric is exposed to deterioration, whose decorative elements are incomplete, or whose physical accessibility is limited.

The Ak-Saray Mausoleum in Samarkand provides a relevant case for such an integrated approach. The monument contains architectural and decorative information that must be understood in relation to its existing geometry, material condition, and surviving visual evidence. A single recording technique cannot adequately address all of these requirements. Laser scanning provides dense geometric documentation, while close-range photogrammetry can support the recording and reconstruction of surface and ornamental information. CAD and 3D modelling then provide a structured environment in which the documented evidence can be interpreted and represented.

The principal contribution of the present study is methodological: it demonstrates a continuous workflow from on-site documentation to a virtual heritage environment. The workflow is designed to preserve a clear distinction between what is directly measured and what

ISSN: 2224-6878 | Pakistan Volume 6, No. 10.

IF: 14.91 | 2026 http://waerasia.org/index.php/ijtar

is reconstructed or interpreted. This distinction is essential for scholarly transparency in digital heritage projects.

**Research Gap and Objectives**

Existing digital-heritage workflows frequently emphasize acquisition technologies and visual quality. Less attention is sometimes given to the continuity between documentation, reconstruction, interpretation, and public presentation. A further challenge is that a visually convincing virtual reconstruction may unintentionally blur the boundary between surviving evidence and hypothetical restoration.

The study addresses this gap by treating the digital model not simply as a visualization product but as the outcome of a documented sequence of survey, processing, reconstruction, modelling, and immersive presentation. The objectives are: (1) to document the monument using terrestrial laser scanning; (2) to complement geometric documentation with close-range photogrammetry and documentary evidence; (3) to develop a coherent three-dimensional reconstruction; (4) to transfer the model to an immersive virtual-reality environment; and (5) to discuss the potential of this workflow for preservation, interpretation, education, and remote access without overstating outcomes that were not experimentally measured.

**Materials and Methods**

The methodological workflow was developed around the Ak-Saray Mausoleum in Samarkand. The principal stages were: field survey; point-cloud processing; architectural documentation; close-range photogrammetric recording and reconstruction of decorative elements; three-dimensional modelling; and immersive presentation.

| Stage | Main technique | Primary output |
|---|---|---|
| 1. Survey | Terrestrial laser scanning; 48 scanner positions; RG | BR/HegDisRtecraepdtuproeint-cloud dataset |
| 2. Documentation | ReCap Pro processing; AutoCAD plans and sections | Architectural survey drawings |
| 3. Reconstruction | Close-range photogrammetry; documentary interpre | tRaeticoonnstructed decorative elements |
| 4. 3D modelling | Autodesk 3ds Max; geometry and texture developme | nTtextured digital heritage model |
| 5. Immersive pres | eUnntraetaiolnEngine; interactive scene integration | VR-ready digital heritage environment |

**Terrestrial laser scanning**

The monument was surveyed from 48 scanner positions using a FARO Focus M 70 terrestrial laser scanner. The purpose of the survey was to capture the existing spatial configuration with sufficient density to support subsequent architectural documentation and three-dimensional reconstruction. The resulting scans were processed and registered in Autodesk ReCap Pro.

ISSN: 2224-6878 | Pakistan Volume 6, No. 10.

IF: 14.91 | 2026 http://waerasia.org/index.php/ijtar

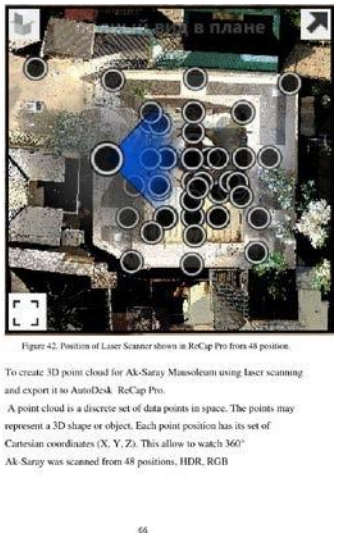



Figure 42. Position of Laser Scanner shown in ReCap Pro from 48 position.

- To create 3D point cloud for Ak-Saray Mausoleum using laser scanning and export it to AutoDesk ReCap Pro.
- A point cloud is a discrete set of data points in space. The points may represent a 3D shape or object. Each point position has its set of Cartesian coordinates (X, Y, Z). This allow to watch 360°
- Ak-Saray was scanned from 48 positions, HDR, RGB

66

Figure 1. Terrestrial laser scanning survey and scanner positions.

**Architectural documentation and photogrammetric evidence**

The processed point cloud was used as the geometric basis for plans and sections prepared in AutoCAD. Because geometric data alone do not fully describe ornamental surfaces or missing decorative components, close-range photogrammetry and available documentary evidence were used to investigate and reconstruct selected elements.

Findings from ReCAP Pro



Figure 48. Findings of the old texture of the wall

73

Figure 2. Architectural and decorative evidence used for reconstruction.

**Reconstruction and three-dimensional modelling**

Reconstruction was performed by interpreting the available visual and documentary evidence against the measured geometry. The measured point cloud provides the spatial reference, while reconstructed ornament represents an interpretive layer.

ISSN: 2224-6878 | Pakistan Volume 6, No. 10.

IF: 14.91 | 2026 http://waerasia.org/index.php/ijtar



Figure 52. Restorate Ornaments.

78

Figure 3. Reconstructed decorative ornament based on documented evidence.

The reconstructed elements were subsequently incorporated into a three-dimensional model in Autodesk 3ds Max.

3D Max

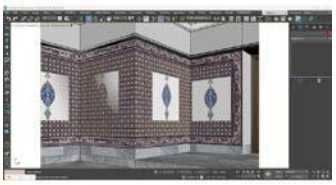


Figure 53. Viewport view

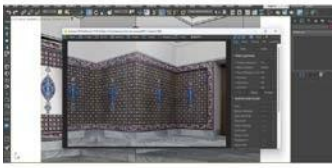


Figure 54. Render frame

78

Figure 4. Three-dimensional reconstruction developed in Autodesk 3ds Max.

**Virtual-reality integration**

The final model was transferred to Unreal Engine to create an immersive environment. The objective was to establish a spatially navigable representation in which users can experience the monument from different viewpoints. Such an environment can potentially support remote interpretation and educational presentation while reducing dependence on physical access to the site.

ISSN: 2224-6878 | Pakistan Volume 6, No. 10.

IF: 14.91 | 2026 http://waerasia.org/index.php/ijtar

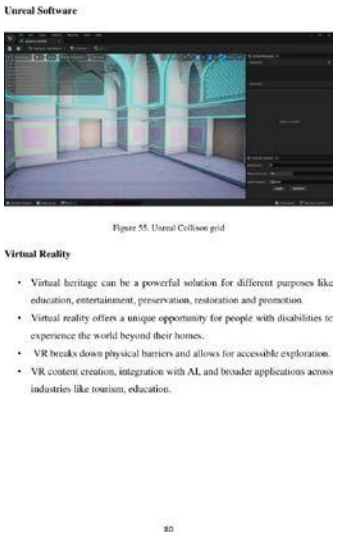



Figure 5. Integration of the reconstructed model into Unreal Engine for immersive presentation.

**Results**

The principal result is an integrated digital representation of the Ak-Saray Mausoleum linking measured survey data, architectural documentation, reconstructed decorative elements, three-dimensional modelling, and immersive presentation. The workflow demonstrates that the outputs of one stage can serve as inputs for the next, reducing fragmentation between surveying, modelling, and visualization.

The laser-scanning stage produced a detailed geometric record of the existing monument. ReCap Pro processing organized the survey data into a usable point-cloud dataset, while AutoCAD supported the extraction of architectural drawings. Photogrammetric and documentary analysis supplemented the geometric record by providing evidence for decorative reconstruction.

The final 3D model and Unreal Engine environment transformed the documented information into an immersive heritage representation. The virtual scene can be understood as an additional layer of access: instead of replacing the physical monument, it provides another means through which its spatial and architectural characteristics can be examined.



ISSN: 2224-6878 | Pakistan Volume 6, No. 10.

IF: 14.91 | 2026 http://waerasia.org/index.php/ijtar

Figure 6. Virtual-reality presentation of the Ak-Saray digital heritage model.

**Discussion**

The significance of the workflow lies less in any individual technology than in the continuity established among technologies. Terrestrial laser scanning addresses existing geometry; close-range photogrammetry and documentary analysis address surface and ornamental information; 3D modelling organizes the evidence; and virtual reality converts that object into an experiential environment.

A critical methodological issue is the relationship between documentation and interpretation. A point cloud records an observed state of the monument, whereas a reconstructed ornament may represent an informed interpretation based on surviving evidence. Keeping these categories conceptually separate improves the scholarly value of the resulting model and allows future researchers to revise interpretive components without losing the original survey record.

The VR stage changes the role of the digital model. It can function as a platform for interpretation, public engagement, and remote viewing. However, the present study does not include a controlled user experiment measuring learning outcomes, usability, accessibility, or sense of presence. These dimensions should therefore be treated as potential applications rather than demonstrated empirical effects.

**Practical and Research Implications**

For heritage documentation, the workflow provides a repeatable structure in which raw survey information can remain connected to later modelling decisions. For conservation practice, the point cloud can serve as a spatial reference for monitoring and future comparison. For education and public interpretation, the virtual model offers an opportunity to present architectural space without requiring every user to be physically present at the monument.

The workflow may also be adapted to other historic monuments with complex geometry, incomplete ornament, or restricted access. Its wider value depends on maintaining metadata, documenting reconstruction assumptions, and preserving both original survey data and derived models so that future users can distinguish primary evidence from subsequent interpretation.

**Limitations and Future Research**

The study is primarily a methodological and applied case study. It does not provide a controlled comparison of alternative survey workflows, an independent accuracy assessment of every reconstructed element, or quantitative evaluation of the VR environment with representative users.

These limitations restrict claims about efficiency, usability, learning, and accessibility.

Future research should investigate independent geometric accuracy assessment; comparative evaluation of photogrammetric and scanning workflows; systematic documentation of uncertainty in reconstructed ornament; usability, accessibility, presence, and learning studies with representative users; and long-term digital preservation strategies for point clouds, models, textures, metadata, and immersive environments.

**Conclusion**

The Ak-Saray case demonstrates how terrestrial laser scanning, close-range photogrammetry, architectural CAD, 3D modelling, and virtual reality can be organized as a continuous digital heritage workflow. The approach produces a detailed spatial record while also enabling the reconstruction and immersive presentation of selected architectural and decorative information.

The main methodological principle is to connect immersive visualization with a transparent evidentiary structure. Measured information should remain identifiable as such, while reconstructed components should be understood as interpretations supported by available

ISSN: 2224-6878 | Pakistan Volume 6, No. 10.

IF: 14.91 | 2026 http://waerasia.org/index.php/ijtar

evidence. Within these limits, virtual reality can extend the reach of digital heritage documentation and create new opportunities for remote interpretation and future user-centred research.

**Acknowledgements**

The article is based on research and documentation developed in the dissertation project of Saida Yunusova at Turin Polytechnic University in Tashkent. The present article reorganizes that work into a concise scientific case-study format.

## References

1. Wolf, Paul R., and Bon A. Dewitt. Elements of Photogrammetry: With Application in GIS. 3rd ed.
2. Linder, Wilfried. Digital Photogrammetry: A Practical Course. Berlin: Springer, 2009.
3. Historic England. 3D Laser Scanning for Heritage. Guidance on the use of terrestrial laser scanning for historic environments.
4. Wang, Guanghui, Zhanyi Hu, Fuchao Wu, and Hung-Tat Tsui. "Single View Metrology from Scene Constraints." Image and Vision Computing 23, no. 9 (2005): 831–840.
5. Shih, T. Y., and W. Faig. "A Solution for Space Resection in Closed Form." Photogrammetric Engineering and Remote Sensing 27, no. 5 (1988): 547–556.
6. Spiegel, Michael. "Improvement of Interior and Exterior Orientation of the Three Line Camera HRSC with a Simultaneous Adjustment." Remote Sensing and Spatial Information Sciences 36, no. 3/W49B (2007): 161–166.
7. Kenefic, John F. "Ultra-Precise Analytics." Photogrammetric Engineering (1971): 1167–1187.
8. Mildenberger, S. J., R. E. Kelly, and P. R. H. McConnell. "The Gestalt Photomapping System." Photogrammetric Engineering and Remote Sensing 43, no. 11 (1977): 1407–1417.
9. LexUZ. National Legal Information Database of the Republic of Uzbekistan.
10. Yunusova, Saida. 3D Modeling of Historical Monument Using Close-Range Photogrammetry. Dissertation, Turin Polytechnic University in Tashkent, 2024.