Photogrammetry-Based Monitoring for the Continuous Management of Cultural Heritage: A Case Study of the Petroglyphs of Cheonjeon-ri, Ulju

Hae Jun Park [1], Gyu Ri Choi[1], Jeong Yeon Kim[1], Sang Ok Lee [1*]

[1] Conservation Science Lab, Korea National University of Heritage, Buyeo, Republic of Korea
- (961126mrp, gyuri0803, gydid061, lso8675) @csllso.co.kr

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Abstract

The Petroglyphs of Cheonjeon-ri are a significant cultural heritage site that offers important insights into cultural developments from prehistoric times through ancient history. However, as an outdoor site, the Petroglyphs of Cheonjeon-ri are highly vulnerable to environmental hazards such as heavy rainfall, typhoons, and climate anomalies, which can lead to physical deterioration. Their location within an active watershed further increases their susceptibility to surface erosion, periodic flooding, and biological colonization, accelerating the weathering of the carvings. These factors underscore the urgent need for continuous and systematic monitoring, as well as early detection, to ensure their long-term preservation. This study applies photogrammetry as a digital documentation method to support the safeguarding of the Petroglyphs of Cheonjeon-ri. 3D models were produced by using photographs captured under varying working distances and camera angles and evaluated for realism and accuracy. Simulated damage conditions were also introduced to assess the effectiveness of photogrammetric change detection through Cloud-to-Mesh (C2M) distance analysis. The results demonstrate that multi-angle image acquisition at relatively close distances significantly improves model precision and enhances the detectability of surface deformations. Artificially damaged areas were clearly identified through color-mapped analysis, confirming the potential of photogrammetry-based 3D modeling as a practical tool for monitoring heritage sites at risk. This study provides foundational insights toward optimized acquisition strategies for photogrammetric monitoring and highlights its value as an accessible, repeatable, and sustainable method for the continuous preservation of outdoor cultural heritage.

1. Introduction

The Petroglyphs of Cheonjeon-ri, part of ‘Petroglyphs along the Bangucheon Stream Petroglyphs’, contain a wide range of carvings dating from the prehistoric to the historic periods. They serve as an important visual record linking ancient Korean pictographic traditions to the broader development of human civilization. In 2025, Petroglyphs along the Bangucheon Stream, including the Bangudae and Cheonjeon-ri sites, were inscribed on the UNESCO World Heritage List in recognition of their outstanding universal value.

However, the Petroglyphs of Cheonjeon-ri are highly vulnerable to physical deterioration due to their shallow engravings and exposure to an active watershed environment. Particularly, natural disasters such as typhoons and heavy rainfall can raise the water level of the nearby Daegokcheon stream, submerging the rock surface or subjecting it to impacts from floating debris such as stones and branches. Since the engraved surfaces themselves constitute the core heritage value of the site, even minor damage may result in serious and irreversible loss. Therefore, continuous and precise monitoring is essential to document physical changes and to formulate appropriate conservation strategies.

In Korea, heritage monitoring is currently conducted through periodic inspections led by the National Research Institute of Cultural Heritage. These inspections are typically carried out every three to five years, with high-risk sites receiving more detailed attention through terrestrial laser scanning (TLS) and other precision measurement tools. TLS offers high-resolution geometric documentation of heritage assets, but it requires expensive equipment, specialized software, and skilled personnel. In practice, many cultural heritage managers lack the technical background to process and interpret complex 3D datasets, making it difficult for them to fully utilize TLS outputs. Furthermore, the high cost and operational complexity of TLS limit its feasibility for routine and repeated monitoring, thereby hindering the sustainable accumulation of long-term 3D documentation.

As a more accessible and cost-effective alternative, photogrammetry has gained attention in recent years. This method leverages only a standard camera to acquire overlapping images from multiple viewpoints, enabling the precise reconstruction of an object’s three-dimensional geometry without the need for specialized equipment. In Korea, Oh and Kim (2017) demonstrated that photogrammetry applied to the Rock-carved Buddha in Singyeong-ri, Hongseong achieved a precision of approximately ±1 mm when compared to TLS results. Similarly, Jo and Kim (2019) integrated TLS and UAV-based photogrammetry at the Magoksa Temple region in Gongju, confirming the complementary potential of these technologies across complex terrain. Numerous other studies have compared the accuracy of 3D modeling methods—including TLS and UAV photogrammetry—at outdoor archaological and architectural heritage sites (Supaporn et al., 2019, Davis et al., 2017).

Meanwhile, efforts have been made to apply photogrammetry for monitoring changes in cultural heritage sites. One notable example is the Guidoiro Areoso archaeological site located along the coasts of Spain and France, where photogrammetric data were collected at six-month intervals and used to compare short-term (6 months to 1 year) and long-term (10 years) changes in erosion and sedimentation patterns (Juan et al., 2024). This case study demonstrated that high-precision monitoring is feasible in dynamic coastal environments using only low-cost equipment and software. Additionally, it has been shown that multitemporal photogrammetric models can be used to monitor and quantitatively visualize changes in sculptural works over time (López-Armenta and Nespeca, 2024).

These previous studies demonstrate that photogrammetry can serve as a viable alternative or complement to high-precision scanning technologies for documenting and monitoring heritage sites. However, most prior research has focused on architectural structures or large-scale sites, with few studies targeting objects with shallow engravings, particularly those like the Petroglyphs of Cheonjeon-ri, that face recurring environmental threats. Additionally, while some studies have investigated photogrammetry's applicability for monitoring purposes or in combination with other technologies, few have systematically analyzed the impact of image acquisition parameters on model accuracy—particularly in the context of long-term monitoring. Since the precision of photogrammetric models is highly dependent on image quality and capture methodology, it is crucial to identify standardized and reproducible acquisition strategies tailored to specific heritage characteristics.

This study applies photogrammetric techniques to the Petroglyphs of Cheonjeon-ri under various image acquisition conditions to build 3D models and evaluate their geometric accuracy, while also examining the practical viability of photogrammetry as a monitoring tool that can be efficiently implemented by on-site heritage personnel, with the objective of contributing to the development of sustainable and repeatable documentation methods for outdoor cultural heritage.

2. Object and Methodology

2.1. The Petroglyphs of Cheonjeon-ri

The petroglyphs of Cheonjeon-ri were engraved on rock surfaces situated along the mid-reaches of the Daegokcheon Stream, a tributary of the Taehwagang River. The site is composed of an upper and lower section, each distinguished by different engraving techniques and thematic content.
The upper section features chiselled engravings of geometric patterns, animals, and abstract human figures, such as solar symbols, deer, and semi-human forms, which are generally considered to originate from the Bronze Age based on their stylistic simplicity and symbolic motifs.
In contrast, the lower section consists of line-drawn imagery interspersed with over 800 Chinese characters. The pictorial scenes depict equestrian processions, dragons, and boats, with the procession of horse riders appearing in three distinct locations. The boat imagery offers valuable insights into maritime activities during the Silla period. The inscriptions state that this site was visited during the reign of King Beopheung of the Silla Dynasty. They also contain references to official titles and elements of the governmental system, making them valuable sources for the study of 6th-century Silla society.
Taken together, the petroglyphs of Cheonjeon-ri collectively serve as a vivid cultural archive, offering rich insights into the beliefs, social structures, and daily lives of people from prehistoric times through the early historical era of Korea.
However, the petroglyphs' proximity to the Daegokcheon stream exposes it to continuous risks of physical and biological deterioration. Especially, extreme weather events such as heavy rainfall and typhoons, exacerbated by climate change, have raised concerns regarding submersion and impact damage caused by floating debris, including rocks and wooden fragments. Additionally, the high-humidity environment promotes biological colonization by organisms such as lichens, accelerating surface erosion and diminishing the visibility of the petroglyphs.

Figure 1. The Petroglyphs of Cheonjeon-ri.

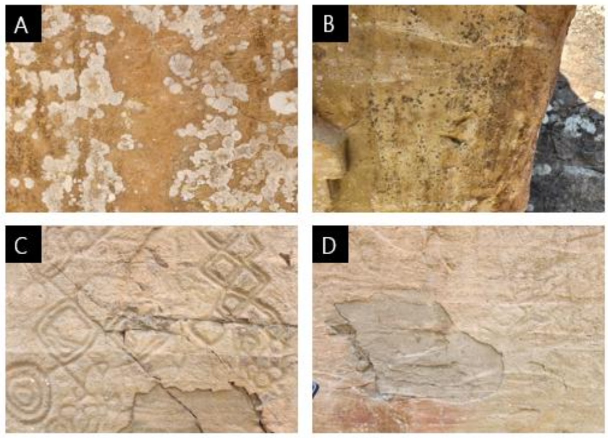

Figure 2. Current Damage Conditions of the Petroglyphs of Cheonjeon-ri A: White lichen colonization, B: Black lichen colonization, C: Cracks, D: Exfoliation.

2.2. Shooting Parameters Settings

To evaluate the effects of different image acquisition parameters on the resulting 3D photogrammetric models, a systematic acquisition process was implemented by varying both the shooting distance and angle. The working distances were set at 2 meters, 4 meters, and 6 meters from the main carved surface of the Petroglyphs of Cheonjeon-ri. For each distance, two perspectives were adopted: a frontal view (F) directly facing the surface and oblique views (S) captured from approximately ±30 ° to the left and right.
All images were captured with tripod support for stabilization, except at the 2 m working distance, where uneven ground made tripod use impractical. A consistent minimum image overlap of 70% was maintained to ensure data quality. Six reflective targets were affixed to the rock surface, measured in situ, and used as scale references for aligning and scaling the 3D models. Image capture was conducted twice, in March and April 2024, using a Nikon D7100 DSLR camera. The shutter speed was adjusted to account for fluctuations in ambient lighting and direct solar exposure on the petroglyph surface. Detailed acquisition parameters are presented in Table 1 and 2.

Camera Device	Nikon D7100
Resolution	6000 x 4000
Film Sensitivity (ISO)	500
Aperture	F=5.6
Overlap	Up to 70%

Table 1. Camera Settings.

Date	Working Distance	Camera Angle
2024.03.21	2m	Front
		Front, Side
	4m	Front

		Front, Side
2024.04.25	2m	Front
		Front, Side
	4m	Front
		Front, Side
	6m	Front
		Front, Side

Table 2. Shooting Parameters Settings.

2.3. 3D Model Reconstruction

3D models were generated using photographs acquired under each shooting parameter and the photogrammetry software Metashape. The modeling process proceeded sequentially through camera alignment, point cloud generation, mesh creation, and texture mapping, with the quality set to High at each step. Unnecessary surrounding areas outside the petroglyph surface were removed to ensure consistency during model comparison. The completed models were labelled according to the acquisition date (M: March, A: April), working distance (2, 4, or 6 meters), and camera angle (F: front, S: side). Additionally, hybrid models were generated by combining images acquired at different distances to evaluate the impact of mixed acquisition parameters on the quality and structural integrity of the resulting 3D models.

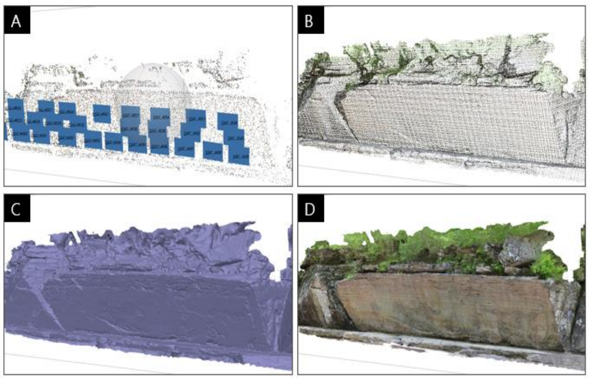

Figure 3. 3D Model Reconstruction Process with Agisoft Metashape.
A: Camera alignment B: Point cloud generation C: Solid mesh model D: Textured mesh model.

2.4. 3D Model Analysis

3D models were comparatively analyzed to evaluate their realism and accuracy under each shooting condition. Realism assessment focused on the effectiveness of representing fine carvings, surface textures, and spatial depth, particularly in terms of clarity and three-dimensional rendering. For accuracy evaluation, 3D models acquired in March and April under identical acquisition conditions were compared. Spatial alignment of the models was performed using the Iterative Closest Point (ICP) algorithm implemented in the open-source software CloudCompare, followed by Cloud-to-Mesh (C2M) distance analysis. Metrics such as mean distance and standard deviation were extracted as indicators of model consistency. A smaller mean distance indicated closer proximity between the compared and reference model surfaces, whereas negative values suggested that the compared model was positioned behind the reference surface. Lower standard deviation values reflected greater geometric similarity between the models (Jeon, 2019).

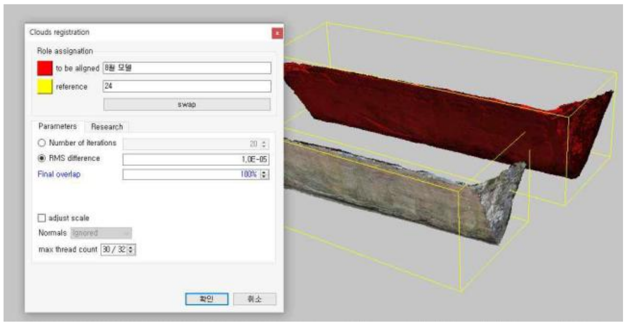

Figure 4. ICP algorithm registration.

Figure 5. Cloud to Mesh distance in CloudCompare.

2.5. Evaluation of Change Detection Capability

To assess the applicability of photogrammetry for detecting physical changes on the surface of cultural heritage sites, simulated damage conditions were created. To represent hypothetical damage zones, red-painted test patches of varying sizes and depths were fabricated and temporarily attached to the surface of the Petroglyphs of Cheonjeon-ri. New image sets were acquired under the same shooting parameters, and corresponding 3D models of the damaged state were subsequently generated. These models were compared with baseline models of the undamaged surface using CloudCompare. Differences between the models were visualized through color-scaled Cloud-to-Mesh (C2M) distance maps, enabling clear identification of the artificially introduced damage zones. The results demonstrate the potential of photogrammetric modeling to monitor surface changes and detect damage with high visual clarity. The overall workflow of the study is presented in Figure 7.

Figure 6. Attaching a test specimen for the assumption of damaged conditions.

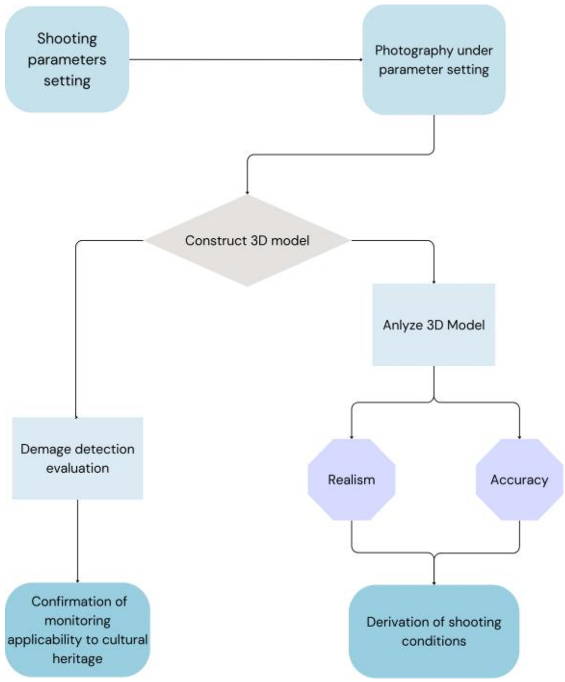

Figure 7. Overall Workflow.

3. Results

3.1. 3D Model Reconstruction Results

3D models were generated using photographs acquired under each shooting parameter. To analyze temporal changes or differences, 3D models were produced from images captured at two different time points (March and April) under identical shooting parameters, resulting in two models for each of the four shooting parameters. Additionally, two models were generated under the 6-meter distance parameter alone, and two mixed models were created by combining images acquired at different working distances. Consequently, a total of twelve models were produced, comprising two models for each of the six shooting parameters. Each model was labelled according to the corresponding shooting parameters and acquisition date. The detailed configuration of the models is summarized in Table 3.

Figure 8. Example of 3D model of the Petroglyphs of Cheonjeon-ri.

Model name	Aligned photos	poly vertex	poly faces
M2F	91	524373	1046111
M2FS	143	7718781	15430828
M4F	45	510479	1018512
M4FS	91	519985	1037317
A2F	97	7110263	14214377
A2FS	122	6019287	12029789
A4F	32	536457	1070101
A4FS	85	483261	96891
A6F	11	110428	55826
A6FS	30	188742	375131
A mixed	66	597103	1192085
F mixed	80	3010897	6011873

Table 3. Specification of 3D Model (M: March A: April, F: Front view S: Side view).

3.2. 3D Model Analysis Results

The comparison of model realism indicated that shorter working distances resulted in better representation of the carved features. At a working distance of 4 meters, the carvings of the Petroglyphs of Cheonjeon-ri were clearly identifiable, and at 2 meters the carvings were rendered with the highest level of clarity. When the working distance was held constant, models incorporating side-view images exhibited greater three-dimensional depth and higher resolution than those constructed using only frontal images. At a working distance of 6 meters, models created solely from frontal images failed to adequately reveal most of the engraved features; however, the inclusion of side-view images significantly improved the resolution, allowing the outlines of the carvings to be discerned.

Meanwhile, texture errors were observed in models constructed using images captured from 6 meters. This issue is presumed to have resulted from the increased distance, causing the photogrammetric software to misinterpret protective fences and informational signs surrounding the site as being on the same plane as the carvings. Additionally, when images captured at different distances were combined to produce a single model, surface continuity was disrupted, and noticeable noise appeared in the resulting mesh (Figure 11). These findings highlight the importance of maintaining controlled and consistent image acquisition parameters when documenting cultural heritage sites using photogrammetry.

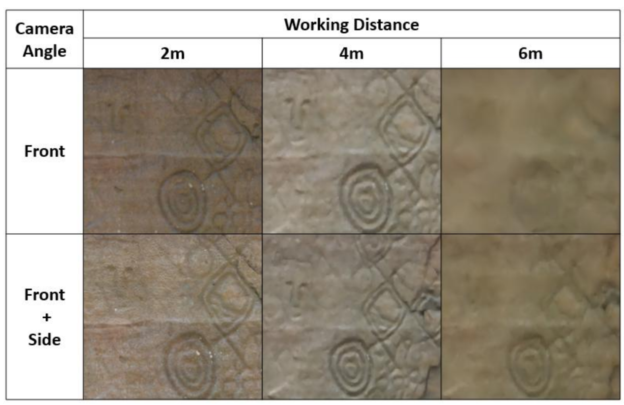

Figure 9. Results of realism comparison by shooting parameters.

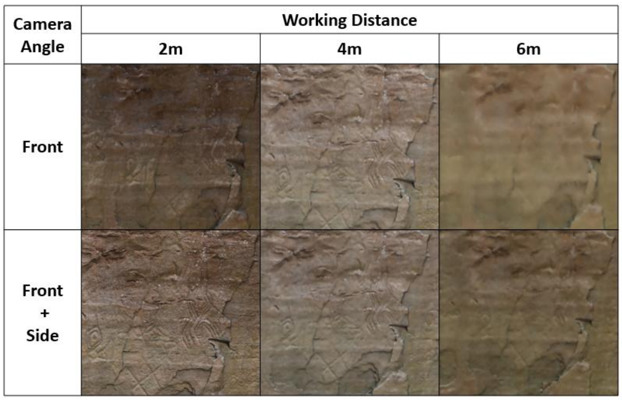

Figure 10. Results of realism comparison by shooting parameters (2).

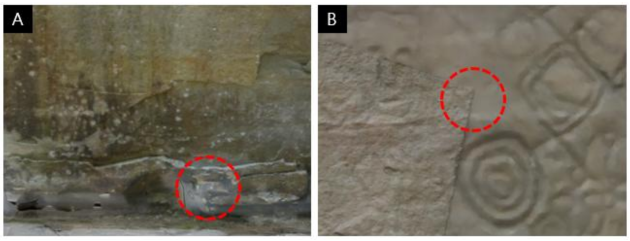

Figure 11. Model errors A: texture error in 6m working distance model, B: Surface difference in distance mixed model.

As the results of the accuracy evaluation based on different image acquisition parameters, 3D models incorporating side-angle photographs exhibited lower standard deviations compared to those constructed with frontal images only (Table 4).

This suggests a higher degree of consistency and alignment between model pairs when multi-angle data are utilized. In contrast, models generated by combining images captured at different distances exhibited the highest mean distances and standard deviations among all conditions tested, indicating significant reductions in geometric accuracy and surface realism. Therefore, the use of mixed-distance image sets is considered unsuitable for applications requiring precise and consistent data accumulation over time.

Notably, the lowest standard deviation was recorded in the model generated at a 4-meter distance using both frontal and side-angle images. This acquisition method demonstrated the highest level of reliability and geometric stability, making it the most appropriate configuration for future monitoring of the site. These findings support the conclusion that acquiring images from a relatively close distance improves resolution, and that incorporating multi-angle photographs enhances both the realism and accuracy of the resulting 3D models.

A protective fence surrounds the Cheonjeon-ri Petroglyphs, installed approximately 3 m from the rock surface. Within the fenced area, uneven ground conditions due to the presence of rocks and gravel hinder the establishment of a stable photographic setup at close range. Considering these site-specific constraints, a 4-meter shooting distance represents a practical compromise between accessibility and data quality. Furthermore, incorporating multi-angle photography at this distance enables comprehensive surface capture while minimizing alignment errors and distortion. Based on these considerations, this study recommends multi-angle image acquisition at a distance of 4 meters as the most effective and stable approach for future photogrammetric monitoring of the Cheonjeon-ri Petroglyphs.

Working Distance	Camera Angle	Mean Distance	Standard Deviation
2m	Front	-0.1515	1.6153
	Front + Side	0.2104	0.7942
4m	Front	0.0504	0.8196
	Front + Side	-0.0434	0.6604

Table 4. Accuracy Evaluation Results by shooting parameters.

3.3. Results of the evaluation of change detection

To evaluate the capability of photogrammetry in detecting physical changes, photographs were taken of a test surface with artificially simulated damage, and corresponding 3D models were constructed. The results confirmed that the geometry of the damaged areas was successfully reproduced in the photogrammetric models. Surface deformations caused by the simulated damage were clearly reflected in the 3D reconstructions, making the affected areas visually distinguishable from the undamaged reference models. These findings demonstrate the potential of photogrammetry as a practical tool for change detection and damage monitoring in cultural heritage applications

Cloud-to-Mesh (C2M) distance analysis was performed to identify the location and extent of the simulated damage, and the results were visualized using a color scale that clearly differentiated the damaged zones from the surrounding surface.

In this experiment, two damage depths—5 cm and 2.5 cm—were tested. While the 5 cm damage exhibited distinct color contrast and clear separation from the background in the C2M analysis, the 2.5 cm damage resulted in less distinct color segmentation. This suggests the existence of a sensitivity threshold in damage detectability when employing photogrammetry and Cloud-to-Mesh analysis. Further quantitative research is needed to determine the minimum detectable damage depth and to evaluate the accuracy of photogrammetric detection under various conditions.

In summary, the results highlight both the applicability and limitations of photogrammetry-based change detection, particularly regarding its effectiveness for visualizing and quantifying surface alterations.

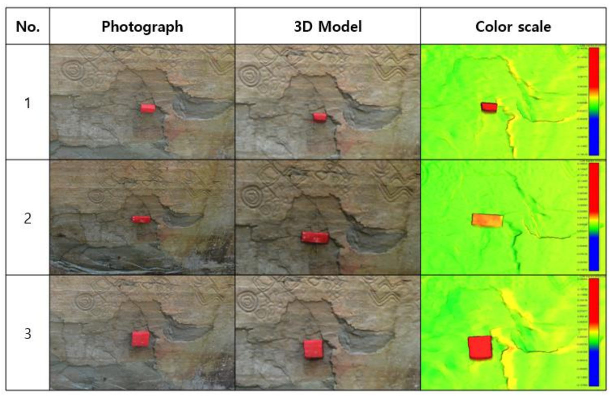

Figure 12. Verification of Damage Representation and Detectability in the Model.

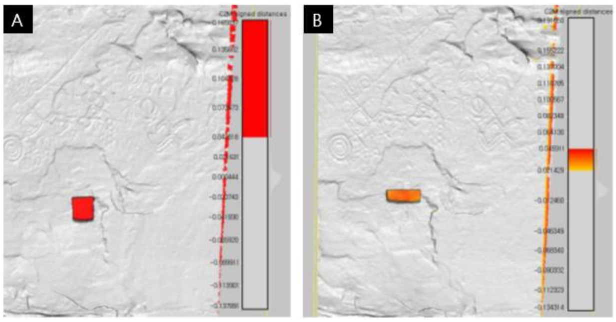

Figure 13. Comparison of Color Differentiation for Damaged Areas.

4. Conclusion

This study applied photogrammetry as a practical method for the preservation and monitoring of the Petroglyphs of Cheonjeon-ri, which are highly vulnerable to damage due to their exposure to outdoor environments. To propose suitable image acquisition parameters, 3D models were produced using varying shooting distances and angles and subsequently analyzed for realism and accuracy. The results demonstrated that models incorporating images captured from multiple angles exhibited significantly improved representation of carved features and enhanced three-dimensional depth. Furthermore, under identical distance conditions, the inclusion of side-angle images contributed to a reduction in standard deviation, confirming that multi-angle acquisition enhances the precision of photogrammetric models.

Considering accessibility, safety, and the ability to acquire high-quality data, these results suggest that multi-angle image acquisition at a 4 m distance is the optimal configuration for documenting the Petroglyphs of Cheonjeon-ri. Additionally, simulated damage models were generated to visualize surface deformation through color-coded analysis, demonstrating that photogrammetry-based 3D modeling can effectively support change detection and damage monitoring of cultural heritage sites.

Photogrammetry offers high accessibility and cost-efficiency, relying on standard imaging equipment and straightforward workflows to produce reliable 3D models. Its visual outputs allow non-specialists to identify and document surface damage, expanding participation in routine monitoring. As a complement to high-precision methods, photogrammetry enables more frequent inspections and delivers early visual cues of potential deterioration, effectively bridging gaps between formal monitoring intervals. Outdoor heritage sites face unpredictable environmental threats—such as heavy rainfall, flooding, and biological colonization—that can cause rapid, varied damage. Consequently, flexible and repeatable monitoring protocols are essential rather than one-time precision surveys. Photogrammetry meets these needs by supporting both short-term change detection and the accumulation of long-term 3D records through repeated image acquisition and processing.

Accordingly, the photogrammetry-based monitoring system proposed in this study offers a practical and sustainable response strategy for the preservation of outdoor cultural heritage. This study is significant in that it experimentally evaluated the applicability of photogrammetry and clarified the impact of acquisition parameters. Additionally, this study provides foundational insights toward optimized acquisition strategies for 3D documentation. Given these points, the findings are expected to serve as a foundational reference for developing optimized image acquisition guidelines tailored to various types of cultural heritage and for expanding practical applications in the field of heritage conservation.

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References

An, J., Kim, C., 2016. Digital heritage: 3D documentation and application of cultural heritage. Sigmapress, Seoul, ISBN 978-89-686-6673-5.

Choi, S., Lee, S., Choi, D., Kim, G., 2023. Establishment and evaluation of image matting-based turntable system for creating 3D models of small artifacts. Journal of the Korean Society of Surveying, Geodesy, Photogrammetry, and Cartography, 41(1), pp.39–49. http://doi.org/10.7848/ksgpc.2023.41.1.39.

Choi, I., Yang, H., Lee, C., 2021. A study on digital documentation of precise monitoring for microscale displacements within the Tomb of King Muryeong and the Royal Tombs in Gongju, Korea. Journal of Conservation Science, 37(6), pp.626–637. https://doi.org/10.12654/JCS.2021.37.6.02.

Choi, J., Yu, M., Yoon, Y., 2020. Visualization of the tilt amount for cultural property monitoring system., Journal of National Heritage, 5(2), pp.143–149. ISSN 2508-2825.

Cultural Heritage Administration, 2019. Guidelines for Precision Safety Diagnosis of Architectural Heritage. (in Korean). ISBN 978-89-299-1564-3.

Cultural Heritage Administration, 2018. Guidelines for Constructing 3D Scan Data for Cultural Heritage. (in Korean). https://www.khs.go.kr/synap/skin/doc.html?fn=BBS_20190326 0117261430&rs=/convertResult/commonBoard/ (last visit: 25/04/2025).

Cultural Heritage Administration, 2014. Guidelines for Precise Survey of Architectural Cultural Heritage. (in Korean). ISBN 978-89-299-0614-6.

Davis, A., Belton, D., Helmholz, P., Bourke, P., McDonald, J., 2017, Pilbara rock art: Laser scanning, photogrammetry and 3D photographic reconstruction as heritage management tools, Heritage Science, 5(25), DOI 10.1186/s40494-017-0140-7

Juan, M., Polo, M.E., Felicísimo, Á .M., Daire M.Y., Güimil-Fariña A., Mañana-Borrazás, P., Vilaseco Vázquez X.I., López-Romero, E., 2024, Comprehensive workflow for erosion monitoring of coastal archaeological sites by means of digital photogrammetry: An Iberian case study, Digital Applications in Archaeology and Cultural Heritage, 35, https://doi.org/10.1016/j.daach.2024.e00373

Jeon, H., 2019. A comparative study on the photogrammetry scanning quality by illumination conditions. PhD Dissertation, Kwangwoon University, Seoul.

Jang, K., 2011. 3D modelling of surface cultural assets by digital photogrammetry. MSc Thesis, Kyungpook National University, Daegu.

Kim, J., Lee, S., Kwang, Y., Han, M., 2021. Measurement of Bangudae rock joint using non-adhesive, non-contact inclinometer slope laser measuring system. Journal of Conservation Science, 37(6), pp.617–625. https://doi.org/10.12654/jcs.2021.37.6.01.

Koo, J., 2015. The study on recording method for buried cultural property using photo scanning technique. Journal of Digital Contents Society, 16(5), pp.835–847. https://doi.org/10.9728/dcs.2015.16.5.835.

Kong, D., Lim, J., Kim, J., Kim, K., 2013. Application of digital photogrammetry to dinosaur tracks from the Namhae Gain-ri tracksite. Journal of the Korean Earth Science Society, 31(2), pp.129–138. https://doi.org/10.5467/JKESS.2010.31.2.129.

Koutsoudis, A., Vidmar, B., Ioannakis, G., 2013. Performance evaluation of a multi-image 3D reconstruction software on a low-feature artefact. Journal of Archaeological Science, 40(12), pp.4450–4456. https://doi.org/10.1016/j.jas.2013.07.007.

López-Armenta M.F., Nespeca, R., 2024, 3D change detection for cultural heritage monitoring: Two case studies of underground sculptural reliefs, Digital Applications in Archaeology and Cultural Heritage, 33, https://doi.org/10.1016/j.daach.2024.e00328

Lim, J., Lee, S., So, Y., 2023. Comparative study of 3D model reconstruction quality according to filming angle: Focusing on photogrammetry. Journal of Digital Contents Society, 24(1), pp.69–78. https://doi.org/10.9728/dcs.2023.24.1.69.

National Research Institute of Cultural Heritage (NRICH), 2023. Monitoring and Evaluation Report of Priority Cultural Heritage Sites. (in Korean). ISSN 3022-0513.

National Research Institute of Cultural Heritage (NRICH), 2022. Guidelines for Safety Management of Architectural Cultural Heritage. ISBN 978-89-299-2615-1.

Oh, J., Kim, C., 2017. Study on the usefulness of photogrammetry through 3D recording of the Rock-carved Standing Buddha in Singyeong-ri, Hongseong. Korean Journal of Heritage: History & Science, 50(3), pp.30–43. https://doi.org/10.22755/kjchs.2017.50.3.30.

Remondino, F., Campana, S., 2014. 3D Recording and Modelling in Archaeology and Cultural Heritage: Theory and Best Practices. Archaeopress, UK. https://doi.org/10.30861/9781407312309.

Supaporn, M., Tripathi, N.K., Arunplod, S., 2019, Three-Dimensional (3D) Modeling of Cultural Heritage Site Using UAV Imagery: A Case Study of the Pagodas in Wat Maha That, Thailand, Applied Science, 9(18), https://doi.org/10.3390/app9183640

Shin, D., Kim, J., 2011. Analysis and modelling of surface cultural heritage by digital photogrammetry. Journal of the Korean Society of Cadastre, 27(2), pp.115–124. https://doi.org/10.22988/ksc.2011.27.2.008.

Yoon, S., 2023. Economical cultural property archiving using photogrammetry and 3D modeling. Journal of Korea Multimedia Society, 26(9), pp.1197–1203. https://doi.org/10.9717/kmms.2023.26.9.1197.

Yu, M., Song, H., 2021. Basic research for improvement of real-time monitoring slope amount warning method for architectural cultural properties. Journal of National Heritage, 6(3), pp.219–224. http://dx.doi.org/10.69756/jnh.2021.6.3.219.

Y. H. Jo and J.Y. Kim, 2017, Three-Dimensional digital documentation of heritage sites using terrestrial laser scanning and unmanned aerial vehicle photogrammetry, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2-W5, 395-398, https://doi.org/10.5194/isprs-archives-XLII-2-W5-395-2017, 2017.