3D Data Utilization in Restoration Support for Fragmented Cultural Heritage Mural Painting

Case Study of the mural painting in the burial chamber of Mastaba Idout, Saqqara

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Introduction

The burial chamber of the Mastaba of Idout, located at the Saqqara site in Egypt, has been undergoing preservation and restoration of its wall paintings by a research team from Kansai University (Fig.1) (Suita, 2023). Numerous wall painting fragments, which had deteriorated and flaked off, were collected. However, the number of days available for work on-site was limited. After returning to Japan, work restored the original positions and images of the fragments by printing life-sized photographs of the wall and fragments. However, some uncertainties remained without the physical fragments, and inconsistencies arose when returning to the site.

This study proposes a DX (Digital Transformation) approach to support the restoration work in a virtual space based on 3D measurements of the burial chamber and wall painting fragments. By virtually reproducing the physical behaviours of artifacts and the site environment, it enables restoration work considering the three-dimensional shapes of the fragments and examines their effectiveness.

Fig.1. 3D Model of the Measured Mastaba Tomb of Idout

Previous Research

In 2022, an internal survey was conducted at the Mastaba of Idout in Egypt, obtaining 3D data of the remaining wall paintings and numerous wall painting fragments (Sumida, 2023). The 3D measurements were performed using an Apple iPhone 14 Pro incorporated with a LiDAR (Light Detection And Ranging) sensor. The fragments numbered in the thousands, including very fine pieces. Priority was given to fragments with distinctive surface coloration and those large enough to consider shape combinations. They were digitized jointly with a background featuring image characteristics, and individual pieces were manually extracted using the open-source software MeshLab. Comparisons of ten wall painting fragment samples with actual measurements revealed that the image data was accurate within a 1mm error. Although virtual restoration work using this 3D data was attempted instead of the fragments, the operation of individual fragment data with a mouse was highly complex and posed a significant challenge.

Methodology

This study imported 3D shape data of wall surfaces and wall painting fragments, similar to previous research, into the game engine Unreal Engine 5 (UE). We use UE's physics simulation feature to represent the contact and interference between fragments and wall surfaces. Additionally, we propose a system where the trial placement of printed mural painting fragments on a tabletop is input via a camera, allowing real-time reproduction of the positions and orientations of each fragment in UE. Such a system enables easier manipulation of more fragments than mouse operations, with immediate reflection of movements and rotations. The mural fragments, printed in actual size on paper, are created from orthoimages in Photoshop, with 2D markers on the reverse side to correspond with the 3D data of the mural fragments. The use of real-scale printed paper, which has been employed in conventional mural iconography restoration work, allows for good consistency with fragment positioning work and simultaneous confirmation of the contact between the fragment and the wall bedrock on the execution screen. This method makes it intuitive even for users unfamiliar with 3D data and software. The system performs the processing shown in Fig.2. The real-scale printed mural fragments are created from orthoimages using Photoshop, with 2D markers on the back for correspondence with the 3D

data of the fragments. Users perform restoration trials by solving the puzzle of printed fragments on a transparent tabletop. The position and orientation information of the markers on the back, read by a pre-calibrated webcam, is sent to UE in real-time. When contact occurs between the fragments, physical interferences as solid objects are generated, allowing parallel checking of the tabletop placement work and the three-dimensional shape in UE.

Fig.2. The proposed system's process chain

Results

In this paper, plaster replicas of some of the remaining murals in the mastaba of Idout were made and fragmented, and the proposed method was applied. Furthermore, the proposed method was evaluated through a trial restoration work using the system by a member who participated in the mastaba mural restoration project (Fig.3). The trial was conducted on more than a dozen pieces of crushed wall painting replicas with a size of 25cm x 40cm, some of which remained on the base. Compared to the use of existing 3D modeling software, in which each 3D model of a fragment is selected by clicking on it with the mouse and then dragged, moved, and rotated to manipulate it, the ability to fine-tune while simultaneously manipulating multiple fragments' data by physically arranging the pieces of paper the worker's own hands was unprecedented operability. In some cases, even fragments with little information on the iconographic surface due to wear could be confirmed to be adjacent fragments by checking the cross-sectional 3D shape. As a result, it was possible to identify and reproduce the positional relationship of 12 pieces of mural paintings with a size of 1.0cm x 1.0cm or larger in about 6 to 7 minutes, demonstrating a method of utilizing 3D data obtained from actual measurement of artifacts as a material for directly assemble and attempt restoration. The game engine uses 3D coordinate transformations to perform the movement of the mural fragments, and the ability to record the operation of arranging all of the mural fragments makes it possible to replay the process and compare different trials from the middle, suggesting a new way of documentation of the restoration process.

Fig.3. Working with the proposed system to manipulate 3D data of mural fragments

Conclusion

This study proposed combining restoration work using captured images with restoration work in a 3D virtual space using a game engine, enabling intuitive operation with printed sheets and restoration work considering the three-dimensional shapes of fragments. Since all work is data-logged in JSON format, it is possible to record, reproduce, and compare multiple trial plans, offering the advantages of DX. Our future work includes improving system accuracy and considering applications for larger-scale restoration targets.

References

Suita, H. et al. (2023),'Kansai University's Cultural Heritage Preservation and Restoration Project at the Saqqara Site in Egypt', Abstracts of the Annual Meeting of the Japan Society for the Conservation and Restoration of Cultural Property, vol. 45, pp. 242-243, in Japanese.

Sumida, N. and Muraoka, T. et al. (2023),'Support for Mural Restoration Using a Game Engine: A Case Study in the Underground Burial Chamber of the Mastaba of Idout at the Saqqara Site in Egypt', Abstracts of the Annual Meeting of the Japan Society for the Conservation and Restoration of Cultural Property, vol. 45, pp. 244-245, in Japanese.