Quantitative Visualization of Secular Changes based on 3D Viewpoint Estimation for archaeological heritage maintenance

A Case Study at Barber Temple Ruins in Bahrain

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Introduction

In recent years, by applying the concept of Building Information Modelling (BIM), which is widespread in the fields of engineering in architecture and construction, research on Heritage-BIM (H-BIM) for managing the life cycle of archaeological heritage is being promoted (Murphy et al., 2009, pp.311-327). However, H-BIM is mostly intended for modern buildings suitable for the conventional BIM model, and it is still challenging to apply it to archaeological cultural heritage that is entirely different from modern architecture. Even for such cultural properties, it is necessary to integrate the results obtained in the previous surveys and studies and build an information modelling system to manage the life cycle of maintenance management, starting from the current situation. In this study, we aim to develop an information modelling system for Barbar temple in Bahrain, which dates back in 2200 BC and to support the sustainable maintenance and management of the site. This system links 3D models of the entire temple with academic research and management information and allows browsing on a web browser.

The Barbar Temple has many changes due to the placement of the stone, the loss of the stone, the backfilling, and repair since the Danish Corps excavated it in 1953 through now. As a method for accurately grasping these changes, 4D modelling that adds a time axis to 3D models and compares temporal changes is attracting attention. Rodriguez et al. restored a 3D model of old age, using the past set of aerial photographs and Structure from Motion (SfM) for the Great Wall of Hadrian in England (Rodriguez et al., 2018, pp119-140). The authors also tried to create a 3D model with the past photographs taken at the time of excavation by the Danish team in the Barbar Temple. However, SfM did not work because many of the photographs were close shots with slight overlaps each other. Therefore, the secular change of each

Fig. 1. BIM for the Barbar Temple under development

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Fig. 2. Process chain of the system

recorded picture the proposed method observed from the same point of view by using the camera's 3D viewpoint estimation from the correspondence between the past photographs and the current 3D coordinates (Mori et.al., 2018, pp.3-14). Our system allows the aggregation of the results obtained in each part and sharing among project members (Fig. 1). By placing a photo icon at the camera position and direction estimated for each old photo, clicking it enables displaying the superimposing result of that photo to the current situation. By measuring the displacement between the past and the present at any part observed by the superimposed display and accumulating it in the information model, we can use it as a precise index which will become the reference at the time of future maintenance and restoration. This paper introduces this displacement measurement function into the information modelling system and verifies the effect quantitatively.

Method

Figure 2 shows the process flow of this method. In order to quantitatively measure the differences visualized by overlaying current 3D data with past photographs, it is necessary to handle the contours of past photographs and the shape of current 3D data in the identical 3D space. Therefore, a 3D grid plane is virtually arranged so as to include a specific point on the image coordinates of the recorded photograph and the corresponding point of the current 3D data. It is possible to obtain coordinates in 3D space by mouse-picking on the arranged virtual plane. For this purpose, this paper has implemented a new function to estimate the plane of the point to be measured in 3D space and calculate the normal of the plane. Plane estimation was performed using RANSAC (Random Sample Consensus) to exclude outliers, and the normal was calculated robustly.

For verifying the accuracy of the proposed method, we placed a brick in the target space of the experiment, and moved it as secular change, and also recorded the displacement as the grand truth. A picture was taken as a past record before moving the bricks. After moving the bricks, we obtained 3D point cloud with a laser scanner and SfM with a digital camera and applied this method. We used Focus3D (FARO Inc.) for the acquisition of 3D point cloud and COOLPIX L820 (Nikon Inc.) for photography. In this experiment, the corresponding points were not selected from the peripheral part of the image, and only the adjustment of the angle of view was performed to match the viewpoints, assuming that the influence of camera distortion was small. In order to initialize the internal parameters, it is necessary to prepare the pixel width and height of the photographed image and the size of the image sensor of the camera. These refer to the basic specifications of COOLPIX L820. The outline image of the scene and the recording photograph which observed the present condition from the photography position presumed from these elements were rendered.
Thus, the secular change was measured within the error range about 2 mm. As a result, in the case of photographic quality that lens distortion can be neglected, it has been confirmed that it is quantitatively reliable in cm unit by assuming the image sensor size or the film size of the camera.

**Case study**

The proposed method was applied to the offering table located in the central part of the Barbar Temple. Figure 3 (I) is a photograph of the offering table taken in 1959. Figure 3 (II) is rendered CG of the current 3D model from the estimated camera viewpoint at the time. Comparing Fig. 3 (I) and Fig. 3 (II), the stone used as the base of the left side of the offering stand is widely deviated compared with the recorded photograph. We matched feature points based on the right part of the table and applied the proposed method. Fig. 3 (III) shows the result of overlaying the outline of the past photograph (Fig. 3 (I)).

In the right part of Fig. 3 (III), the past photographs and the present conditions overlap with each other. However, it is clear that the stone at the right end is currently lost. The normal to the top surface of the stone was calculated, and a three-dimensional grid plane was virtually placed along this surface. The grid plane was set so that the height matches the stone outline of the past photograph, and two points on the outline were selected with the mouse, and the distance between the two points was measured. Fig. 3 (IV) shows this situation, and the pink line shows the measurement point. As a result, it was confirmed that the width of the lost stone was 28.92 cm. The ongoing future work includes investigating temporal changes at each place in the site by using this method and accumulating the results in the BIM system for making them available for reference at any time.

![Fig. 3. Applied result of the method to Offering table at Barbar Temple](image)

**References**

