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Case study

Preliminary digital health record of limestone walls in Al-Ziggurat, Al-Nimrud city, Iraq

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ABSTRACT

This study deals with the preliminary establishment of the so-called digital health record of an ancient monument: the Al-Ziggurat in Al-Namrud city, Iraq. This documentation tool is designed to store, organize and analyze heterogeneous data about the states of a monument around a 3D model. To promote and spread the use of this new digital technique, a low-cost and highly portable application is proposed here. The present study compares the mapping of degradation, and the mapping of the previous state of burial, stored and displayed on the 3D photomodel of Al-Ziggurat walls, in order to provide a preliminary analysis and diagnosis of the origin of stone degradations. Photogrammetric techniques appear suitable to create a primitive-based 3D model with textured surfaces for the drawing and the representation of mappings. It is concluded that gypsum pollution from the soil may trigger or enhance new degradations on the recently excavated walls through direct contact with stone or transport of dust by the wind.

1. Introduction

The health record of a historic monument considers different approaches in order to centralize and store all the heterogeneous data related to the monument for its analysis, representation, maintenance and long-term management and monitoring [1–3]. It is a complex process that typically involves the organization and visualization of data sets, such as archive documents, survey data, *in situ* stone alteration recording and sampling, sets of data from laboratory tests, 3D modeling, restoration reports, meteorological and geological data, etc.

The essential characteristic of a digital health record is its capacity to store and spatially organize meaningful information in a 3D restitution of the monument. The work in this paper aims to present a preliminary study based on the digital health record of Al-Ziggurat monument in Al-Nimrud city. The study involves building the 3D model of the monument, and conducting a preliminary analysis of the origin of degradations by comparing different mappings. Particular attention has been paid to using low-cost and highly portable techniques to spread and promote the use of the digital health record technique.

Al-Nimrud is an ancient Assyrian city located in the northern part of Iraq, about 30 km southeast of Mosul. The city was built during the Middle Assyrian Empire by the Assyrian King Shalmaneser I (1280–1260 BCE). Al-Ziggurat is the most prominent monument of Al-Nimrud city. Today, it appears as a conical structure of completely eroded mud-brick, with a square base 50 m per side and a height of 17 m.

2. 3D modeling

3D modeling is now intensively used to study archaeological monuments for the purposes of their management, monitoring, preservation and restoration [2–6]. Many techniques have been developed to build a 3D model [7], especially laser scanning and photogrammetry. In some archaeological sites and monuments, the use of heavy, large and expensive devices is impossible. Thus, a middle-end digital camera, which is extremely portable and not costly, was here preferred. In this paper, the photogrammetric methodology proposed by [1–3] was applied to create the 3D model of Al-Ziggurat walls. This methodology produces a primitive-based 3D model with textured surfaces to represent the essential shapes and visual aspect of the surveyed parts of the monument. The resulting surfaces are then used to draw and represent the required mappings.

Twenty-one photographs were taken *in situ* in 2013 with a 16 Mpix compact digital camera. The image processing was done

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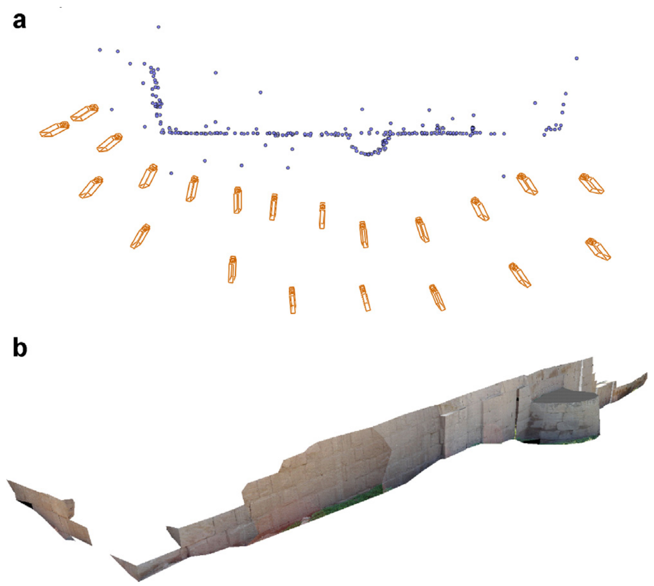

Fig. 1. a: orientation of camera, position of calibration points at the end of the calibration stage (top view); b: general view of the 3D construction of Al-Ziggurat walls.

with ImageModeler "image-based modeling and photogrammetry software" and is based on several steps. The first one, camera calibration, consists of manually locating control points on the photographs. These control points, also called "calibration points" at this stage, were chosen so as to cover the whole spatial area of the surveyed scene. Moreover, each point was simultaneously located on as many pictures as possible to make it possible to compute the camera position and orientation added to the focal length and distortion. Then, by inverse calculation, the positions of the calibration points were computed. Calibration points and camera orientations are presented in Fig. 1a. To give an idea of the scale of this 3D representation, the main face of the surveyed walls is 50 m in length. This figure shows that two different ranges between camera position and the surveyed walls were used: a long range was preferred for global registration of the 3D scene, and a shorter range to identify more precisely the shapes of the walls. Two distances were measured *in situ*. The first distance (77 cm) was used to set the scale of the model. The other one (117 cm) was used to assess the uncertainty by comparing the value of the model's distance to the real one, here about 1.5% (1.8 cm of error). Only one distance for validation is not assumed to be an optimized process for uncertainty assessment. However, the constrains of the local authorities to access and survey the site only made it possible to provide the presented set of data.

The second stage, 3D restitution, starts by the addition of control points required to define the essential shapes of the monument. The surfaces of the walls are defined by creating faces between control points, or by adjusting primitive shapes. These surfaces are chosen to represent the essential shapes of the walls, keeping in mind that the resulting model must be simple enough to be handled easily for the representation of mappings. For the latter objective, surfaces must be perfectly joined, so that there are no overlaps or gaps.

In the last step, texture extraction, each modeled surface is associated to a planar UV projection. Based on this UV projection, selected photographs are projected onto the surface of the model to create the surfaces' textures. At the end of this stage, the general appearance of the real structure can be obtained, see Fig. 1b.

3. Successive states of burial

Before the excavation campaigns accomplished in 1849 by Layard under the supervision of the British School of Archaeology in Iraq [8], in 1949–1958 by Max Mallowan [9], and in 1960–1963 by David Oates [10], the walls of Al-Ziggurat were totally buried.

Fig. 2. Photos showing the state of burial of Al-Ziggurat walls at two different periods: 27 June 2011 (left), and 23 March 2013 (right).

Fig. 3. Mapping of the state of burial in 2011 projected onto the model of 2013.