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3D survey and virtual reconstruction of archeological sites

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ABSTRACT

As demonstrated in several case studies 3D digital acquisition techniques may greatly help in documenting an archeological site and the related findings. Despite such information supports for the traditional analytical approach for hypothesizing the most probable interpretation of an archeological ruin, mainly focused on excavations and stratigraphic examination; an accurate reality-based representation may be also used as the starting point for creating a scientifically sound virtual reconstruction of the site, embedding historical information of different provenances.

The aim of this paper is to describe this whole process step by step, focusing on the iterative feedback that can allow us to reach the best virtual reconstruction solutions, helping the archeologists to better focus their reasoning through a detailed visual representation, and the technological experts to avoid misleading details in the final virtual reconstruction. The methodology has been experimented on a group of Cham temples located at MySon, an UNESCO archeological area in central Vietnam.

1. Introduction

In the last decade the use of 3D acquisition techniques in the archeological field has allowed to widen the scope of the geometric survey process, providing high resolution *reality-based digital models* capable to be linked with different historical documentations, greatly improving the conventional bi-dimensional hand-made survey with a consequent gain of knowledge for the archeologists.

Another possible output, supported both by reality-based models and historical data, can lead to the generation of suggestive *3D digital reconstructions* of architectures not anymore existing, made lively through Computer Graphics. These can be useful for a careful interpretation of the existing ruins but sometimes they might also be capable to suggest new archeological discoveries.

A weak part of the latter process is represented by the possible lack of scientific reliability on the reconstructed model, due to the actual disjunction between the modelers producing the final computer graphics output, and the archeologist owning the knowledge for creating the appropriate reconstructive hypotheses. The methodology here proposed is based on a first extensive 3D documentation of the site in its current state, followed by an iterative interaction between archeologists and digital modelers, leading to a progressive refinement of the reconstructive hypotheses. The starting point of the method is the reality based model, that, together with ancient drawings and documents, is used for generating the first reconstructive step.

Such rough approximation of a possible architectural structure can be annotated through archeological considerations that have to be confronted with geometrical constraints, producing a reduction of the reconstructive hypotheses to a limited set, each one to be archeologically evaluated. This refinement loop on the reconstructive choices is iterated until the result becomes convincing by both points of view, integrating all the available starting data in the best way.

The aforementioned approach to the digital reconstruction problem has been verified on the ruins of five temples in the Mỹ Sơn site, a wide archeological area located in central Vietnam. Created by the ancient Cham civilization active in Vietnam from 7th to 18th century, it has been listed as UNESCO World Heritage in 1999. Mỹ Sơn area contains a reasonably well preserved system of 78 Cham Temples, some of them destroyed by the nature in the last centuries (Ky Phuong et al., 1990). The integration of 3D surveyed data and historical documentation has allowed supporting a digital reconstruction of not existing architectures, developing their three-dimensional digital models step by step, from rough shapes to highly sophisticated virtual prototypes. The 3D acquisition and modeling of a specific set of five temples, indicated by the archeologists as "G group", is presented here and methodologically discussed.

2. Methodology

Although the process supporting the transformation from a set of 3D point clouds to a polygonal model is well known since more

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Table 1
3D laser scanner configurations.

Scan scale	Operating distance (m)	Resolution	
		Qualitative	Quantitative (mm)
Framework	8–16	Coarse	7–60
Architecture	4–8	Medium	4–15
Details	1	High	2

Table 2
Number of point clouds acquired at different resolution levels (first three columns), and total number of 3D points acquired (last column).

	Resolution			Size (points × 10^6)
	Coarse	Medium	High	
G1 (Kalan)	7	43	22	126
G2 (portal)	/	9	/	21
G3 (assembly hall)	/	8	/	15
G4 (south building)	/	13	/	31
G5 (pavilion for the foundation stone)	/	6	4	4
DTM	49	/	/	27
21 Finds	/	/	60	2
Total	**56**	**79**	**86**	**226**

than a decade (Levoy et al., 2000; Bernardini and Rushmeier, 2002; Beraldin et al., 2002), it has been progressively improving to better suit the Cultural Heritage field (Guidi et al., 2010). For this reason many advances have been suggested in the last years in order to optimize this process for the archaeological field (El-Hakim et al., 2008; Guidi et al., 2009; Remondino, 2011).

The reality-based digital model, generated through laser scanning of the ruins, had a double purpose in this project. On the one hand it allowed an accurate documentation of the current site status, a valuable source of information for interpreting Cham architectural structures and the possibility to analyze it with a great level of detail on a PC, possibly far from the site or in a different time. On the other hand it was a starting point for a digital reconstruction of the group G structure as it was at its foundation, that can be a useful support for explaining the roles of each temple in the G group not only to specialized scholars, but possibly also to non-expert people like students or common visitors.

Differently from the reality-based models, the archetypal reconstructive digital models present very different purposes (Frischer et al., 2002; Beyond Illustration, 2008; Rua and Alvito, 2011). Thanks to the virtual representations of the current and reconstructed temples, an effective diachronic analysis becomes possible, stacking on the possibility to “see” what in the last few years was possible to be figured out only through written descriptions or rough drawings (El-Hakim et al., 2008).

The path from reality-based to interpretative models is not so widely developed as the conventional modeling from real data (Russo and Guidi, 2011). In this case, besides the particular attention given to the integration between 3D surveyed data and historical sources, a precise iterative feedback strategy was defined in order to check each important interpretative step during the virtual reconstruction. This procedure was based on a sequence of archeologist's controls on the modeling evolution, starting from a volumetric simplified version to the best detailed one. The application of this approach should allow to reach a better shared solution between 3D starting data, historical sources and archeological knowledge, exploiting a strong interaction between historical and technological experts.

For the whole process different software were used (Cyclone, Geomagic, Polyworks, Rapidform, Modo) in order to get the best functionalities from each of the mentioned systems.

3. Survey

3.1. Planning

As known several factors may affect the quality of 3D data acquired by a range device (Fig. 1). Equipment choices, logistics and environmental conditions have to be considered in a survey planning, especially when operating in the middle of a forest, like

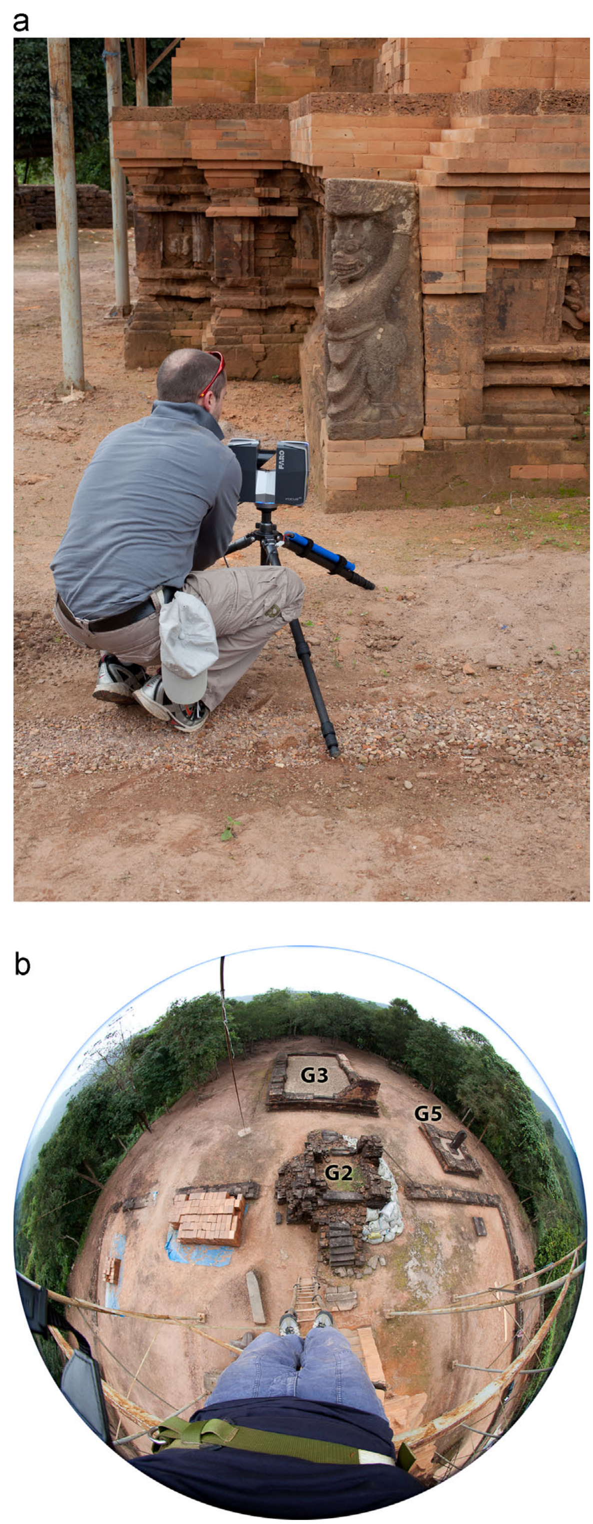

Fig. 1. Different 2D and 3D image acquisition steps: (a) 3D survey acquisition of the decorated basement; (b) fisheye image of G2, G3 and G5, taken from the structure covering the main temple (Kalan).