Spatiotemporal reconstruction of pot burial excavations

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Introduction

Archaeology has a long tradition of employing visual representations to document the archaeological process. Advances in three-dimensional documentation techniques have motivated the archaeological community to embrace 3D solutions, marking a significant paradigm shift (Roosevelt et al. 2015). In-field 3D recordings have enhanced the excavation practice, by offering diverse and informative perspectives (De Reu et al. 2014), yet the transition to accessible interactive multimedia applications for the inspection of documented material and processes remains limited.

This study focuses on the small-scale excavation case of pot-burials, a process which given the dimensions and the fragility of ceramic vessels and its contents, makes thorough documentation essential for post-excavation analysis and interpretation. The main goal was to establish a reliable complementary approach to typical documentation and recording of a pot-burial excavation, by integrating the temporal as well as the fully spatial dimensions of the excavated object.

Key objectives included the development of an interactive time-lapse of the excavation utilizing Structure-from-Motion (SfM) photogrammetry and an established interactive 3D visualization solution, while assessing the methodology's practicality for documentation, labor investment, and educational potential. The findings could significantly benefit both archaeological research and public engagement.

Materials and Methodology

The unexcavated pot-burial comes from the excavation of the Phaleron Delta Cemetery in Attica, Greece, which yielded a total of 2115 burials, dating from the 8th to the 4th century BCE. During the excavation campaigns (2012-2020), several pot-burials were block-lifted and preserved at the laboratory for future excavation.

The suitable methodology for the task was dictated by the pot's preservation state and shape. Due to the initially limited access to the pot's interior, SfM photogrammetry was selected as the reconstruction method of choice, since it could more easily handle occlusions, compared to structured light active scanning. Furthermore, it constituted a more convenient technique to employ on the field and the confined space of the laboratory, alike. Due to the shape of the object, no more than 50 photographs per object were required as the input for the geometry reconstruction of each excavation stage, making visual documentation an easy and fast process.

The reconstructed 3D geometry of each excavation phase was brought up to scale, using a scale reference and co-registered to establish a properly aligned set of textured models, using Meshlab software (Ranzuglia et al., 2013), with an average error bound of 1mm. The initial meshes were then simplified, to match the requirements of the final interactive application (mid-range or mobile graphics capabilities). The fact that a

large part of the pot and the surrounding material remained unchanged during the process, supplied the necessary landmarks for the alignment of all individual pot versions, as the gradually removed parts of the successive strata could not be used for registration. The foam bedding of the pot-burial was retained in the final 3D models for a more realistic reconstruction and aesthetic blending with the virtual laboratory environment specifically modelled for the application.

The interactive time lapse excavation inspection application was developed in the Unity game engine, due to its versatility and output to many different, commonly used platforms. A proper development life-cycle was established, starting from a requirement analysis for the interaction and functionality via interviews. A constrained orbit camera and a very intuitive slider to control the temporal axis were the primary controls of the application, controlling the viewpoint and the stage of the excavation, simultaneously, if required. Interactive arrow markers were used for 3D annotations on the various instances of the 4D model of the excavation, supplying the user with notes and metadata, provided by the expert(s).

Evaluation

The laboratory excavation was done into nine levels and did not yield preserved skeletal human remains but grain-sized skeletal fragments and two miniature ceramic vessels - grave offerings. Ten 3D models were reconstructed with SfM photogrammetry, one for each level.

The digitization process was found suitable for laboratory in-field excavation documentation in terms of accuracy, evaluating the results against measurements from the actual object and time requirement, since each photographic session was 5-7 minutes and did not interrupt the excavation's timeline. During post-excavation, a total of 17-25 minutes was required for the complete process of each reconstructed model.

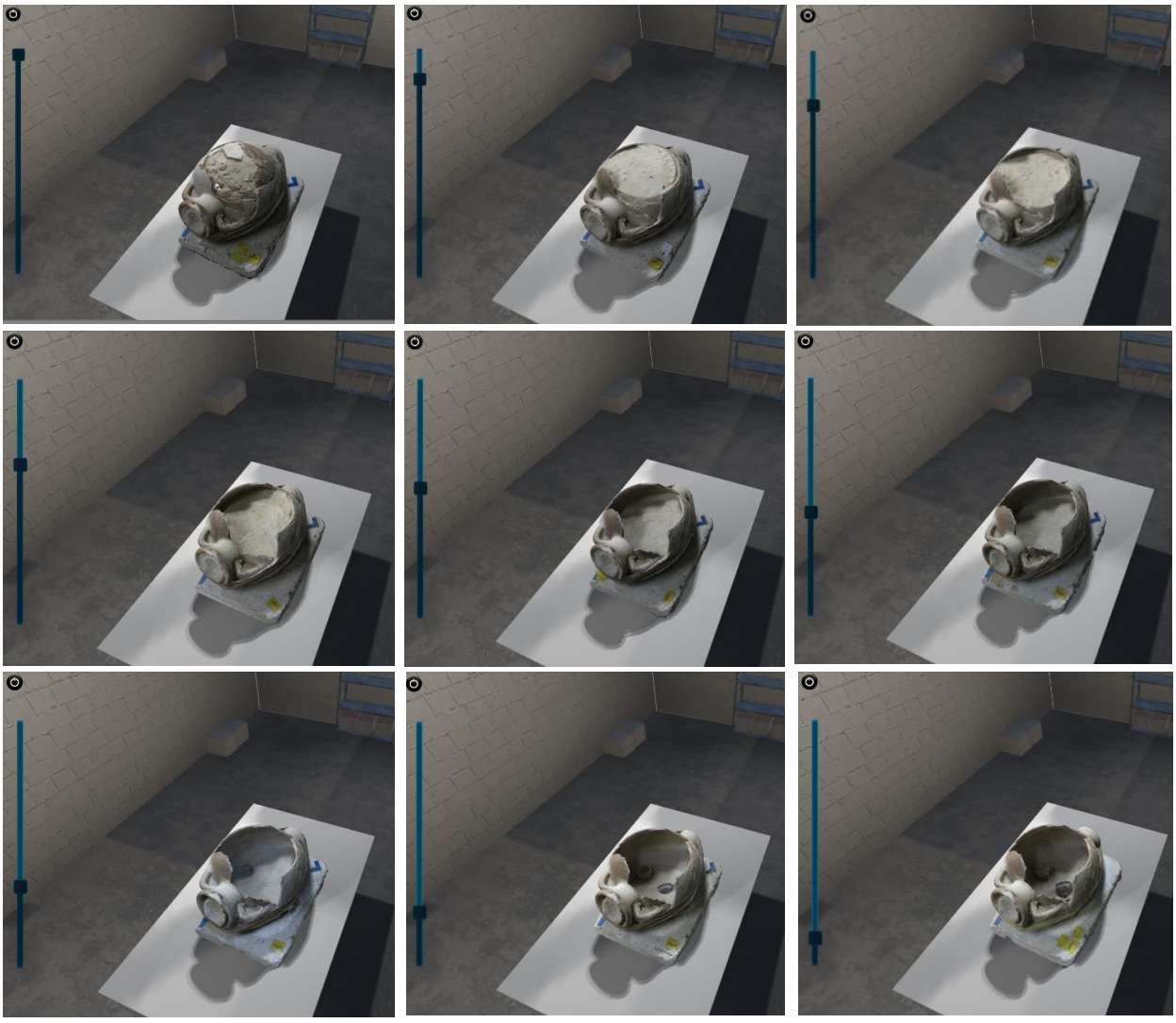
The end-user evaluation included tasks and questionnaires for a small group of participants, focusing on application effectiveness, efficiency, and engagement. Feedback was largely positive, with participants finding the application user-friendly, intuitive to use and engaging.

Discussion

This work shows the possibility of creating a virtual application of a small-scale excavation focused on recreating the temporal aspect of it. Although the interactive application was developed around a particular use case, the (laboratory) setting and all scripting functionalities can be used to accommodate different specimens, thus compensating for the length of the development process. Moreover, the set principles for the reconstruction and the application design and implementation could be also adopted to a larger scale excavation site for the fieldwork progression.

The findings indicate that the application not only provides an engaging representation of the archaeological methodology but also fosters active user participation. By allowing users to explore excavation stages and the pot's contents in a 3D environment, it transforms them from passive spectators into active participants. Cultural heritage and learning institutions could use such methods to present the intangible concept of an excavation and promote experiential learning that improves one's ability to retain new information.

Virtually experiencing the site and acquiring the spatial context of each remain could aid the archaeological “slow” approach to thinking and interpretation, allowing the archaeologists to virtually re-experience the unrepeatable process. Additionally, digital documentation can reduce the subjective nature of the archaeologists' reports and accelerate data sharing with the scientific community.



Screenshots from the various stages of the excavation.

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