Assisting Pottery Restoration Procedures with Digital Technologies

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ABSTRACT

The fragmentary nature of pottery is considered a common place. Conservators are requested to apply a proper restoration solution by taking under consideration a wide range of morphological features and physicochemical properties that derive from the artefact itself. In this work, the authors discuss on a low-cost pottery-oriented restoration pipeline that is based on the exploitation of technologies such as 3D digitisation, data analysis, processing and printing. The pipeline uses low-cost commercial and open source software tools and on the authors' previously published 3D pose normalisation algorithm that was initially designed for 3D vessel shape matching. The authors objectively evaluate the pipeline by applying it on two ancient Greek vessels of the Hellenistic period. The authors describe in detail the involved procedures such as the photogrammetric 3D digitisation, the 3D data analysis and processing, the 3D printing procedures and the synthetic shreds post processing. They quantify the pipeline's applicability and efficiency in terms of cost, knowledge overhead and other aspects related to restoration tasks.

KEYWORDS

3D Digitization, 3D Printing, Archaeology, Artefacts, Completion, Finds, Fragmentary, Open Source, Pipeline, Restoration

INTRODUCTION

Restoration science relies on a wide range of methods and principles to provide mechanisms that retain artefacts as close as possible to its original condition. The provided mechanisms are governed by ethical guidelines related to minimal interventions, use of appropriate materials and complete documentation of the followed procedures. According to Petzet (2004), conservators are challenged to provide an equilibrium between valid restoration solutions and their apparent traces on an artefact. The completion of fragmentary artefacts by closing gaps, that in most cases are of abstract and complex shape, is considered a restoration challenge. Nowadays, digital technologies such as 3D digitisation, 3D shape data analysis and 3D printing attempt to differentiate the ways conservators work by introducing novel tools for measuring, analysing and restoring fragmentary artefacts using both virtual and tangible approaches. Although they are still evolving technologies, they are capable to deliver the required, by many restoration projects, precision. For example, 3D digitisation results in accurate digital replicas of fragmentary artefacts that carry morphological information that is vital for their restoration. Through 3D shape analysis of such a 3D digital replica one can 1) create the digital representations of the missing shreds that can be 3D printed to fill the gaps of the fragmentary artefact, 2) produce missing shreds casts to be used with other compatible materials and 3) extract

knowledge related to the study of possible static strains and stress applied on critical points on the gaps or on the synthetic shreds (Balletti, Ballarin, & Guerra, 2017).

In this work, we present a low-cost restoration pipeline for assisting fragmentary vessels main body completion. The pipeline is based on the exploitation of photogrammetric 3D digitisation Structure from Motion / Multiview Dense Stereovision (SFM/MVS), 3D data processing and 3D printing. We focus on the restoration of fragmentary pottery that are considered the most common excavation findings and they play an essential role in providing information for various aspects of life (e.g. private, public, religion, death, economy, society, trade, etc.) (Tsiafaki, Koutsoudis, Arnaoutoglou, & Michailidou, 2016). We have selected two fragmented ancient Greek vessels of the Hellenistic period found in Athens' metro excavation that is performed along the construction works of extending the third line of Piraeus, Greece.

The rest of the paper is organised as follows. In Section 2, we reference related works that present case studies of applying 3D digitisation and printing technologies for various applications derived from the cultural heritage domain. In Section 3, we present the proposed pipeline by providing implementation details related to our case study vessels. We discuss and evaluate the application of the pipeline in relation to aspects and challenges derived from a conservator's point of view. We conclude in Section 4 by outlining the important findings of the application of the proposed pipeline while discussing on its impact on pottery restoration.

RELATED WORK

Recent advances in image-based 3D digitisation in combination with modern low-cost 3D printing technologies such as Fused Deposition Modelling (FDM) compose a powerful set of digital technologies that may address specific needs of cultural heritage practitioners including conservators. The combination of these two technologies (3D digitisation and 3D printing) can be considered as a medium to transfer parts from an analog to a digital world and vice versa. Several published research works that describe the use these technological combinations to complete various conservation tasks, are listed below.

Turunen (2016) discussed on the idea of exploiting 3D printing in producing low-cost replacements for obtaining an impression of the originally destroyed historical decoration parts (cherubs) found in Castello di San Martino dall'Argine (Mantova, Italy). Meijers et al. (2015) presented the restoration of an antique Roman mask based on structured-light 3D digitisation and a high-cost powder-bed based 3D printer by exploiting mirroring depiction properties of a mask. In order for the conservator to fit the printed part in the mask's gap, he manually removed parts of the 3D printed missing part. Greene and Aja reassembled a fragmentary ceramic lion by initially forming a semi-complete 3D model based on digital replicas of its fragments (https://news.harvard.edu/gazette/story/2012/12/an-ancient-statue-re-created/). Then by carving foam using a CNC they produced approximations of the missing pieces. Iaccarino et al. (2017) reassembled elements of limestone funerary busts by mirroring 3D digitised parts of the artefacts that were later 3D printed and attached to the originals using magnets. Idelson et al. (2017) exploited 3D milling technologies to produce exhibition stands for fragmented artefacts. Arbace et al. (2012) presented the use of 3D printing technology for creating support structures that hold the various parts (head and bust) of a fragmented terracota statue (Pietranico Madonna). Barreau et al. (2014) used 3D printing to create an exhibition stand that was used to hold the scattered fragments of vessels. Bigliardi et al. (n.d.) exploited 3D digitisation and printing technologies to perform restoration works in a room of the Plazzo Ducale of Mantua which was decorated with heavily fragmented crown moulding. Furthermore, Cimino et al. (n.d.) evaluated a wide range of 3D printer filament types to be employed for conservation treatments. Ballarin et al. (n.d.), evaluated the metric characteristics of 3D printed models in relation to the original data to quantify the process that leads to physical representations.

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