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Empowering cultural preservation in China through participatory digitization

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ABSTRACT

This paper reports on the use of photogrammetrically triangulated two-dimensional close-range photographs to create three dimensional models of artifacts stored in the Shangshan museum in Pujiang County, China. A case study for archaeologists working in China, this report demonstrates an efficient and cost-effective digital documentation methodology will not only augment the preservation of cultural historical data, but also empower new forms of engagement with cultural knowledge at both local and global scales.

1. Introduction

There is marked interplay between nationalism, ideology, and archaeology in China – a relationship mediated by opportunism, pragmatism, and nationalistic sensibilities. The protection of cultural heritage has, therefore, emerged as a key issue in the maintenance and accessibility of the archaeological record on the one hand and Chinese national and regional identities on the other. Since the birth of modern Chinese archaeological practice in the early twentieth century, attributes of pottery have been diligently recorded from potsherds and complete vessels as a means of culture historical classification and typological differentiation (Glover, 2006; von Falkenhausen, 1995). A broad range of additional evidence is obtainable through archaeometric means. Unfortunately, the systematic destruction of ceramics is often necessary to attain such information. That said, with the increasing volume of scholarly collaboration inside and outside of China, limits placed on internet use in China have had a profound impact on how cultural heritage can be made globally accessible to the public and scholars alike.

This report documents a photogrammetric study of Shangshan earthenware housed in the Shangshan Museum in Pujiang County, Zhejiang Province, China. Ceramic vessels dated to the Shangshan phase (11,400 to 8400 cal. BP) are the earliest known organic tempered pottery in Asia. Shangshan cultural materials have presented themselves in two forms: as one of the most important sources of information regarding the development of early ceramic technologies; and that of human diet as it relates to the initial domestication of rice. Pottery of the earliest phase represents the first known vessels to be tempered with organic materials such as rice. In fact, in contrast to contemporary pottery-producing Holocene cultures in China, settlements belonging to the Shangshan culture are the earliest known examples in which possible burials, dwellings, permanent storage facilities, ground stone tools, and the consumption of significant quantities of plant foodstuffs occurred simultaneously alongside the development of a highly advanced ceramic technological tradition (Liu and Chen, 2012). It is hypothesized by members of the Shangshan Archaeological Project – a collaborative endeavor between the University of Toronto Mississauga, Stanford University, Fudan University, and the Zhejiang Provincial Institute of Relics and Archaeology - that Shangshan peoples engaged in low-level production of rice and began the process of bringing this important cereal towards domestication (Jiang and Liu, 2006; Zheng and Jiang, 2007; Pan, 2011; Yunfei et al., 2016). However, archaeobotanical evidence of early rice exploitation has not proven to be particularly abundant; apart from those readily observed in the carbonized rice by-products used to fabricate Shangshan pottery. That said, the direct association between early domesticated rice and ceramics has made studies of Shangshan ceramics particularly valuable in developing an understanding of early rice domestication. However, the relative age of some of the earliest Shangshan ceramics, combined with their highly friable nature, makes them highly delicate archaeological materials to transport and document. As such, studies of Shangshan ceramics remain in their infancy – with vessels being photographed and drawn; with the resulting documentation generally inaccessible to wider academic and public audiences.

2. Photogrammetry & cultural heritage

From the documentation of artifacts to excavation mapping, archaeology as a discipline has become increasingly reliant on photogrammetry. One of the most reliable, entry-level digitization programs available is *Agisoft Photoscan* - a stand-alone photogrammetric software product that is capable of performing the automatic processing of two-

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dimensional digital images into dense point clouds, georeferenced orthomosaics, 3D spatial data, and textured polygonal models for use in cultural heritage documentation, visual effects production, and GIS research. Although active triangulation sensors that utilize structured light or lasers are the most reliable and user-friendly solutions to digitize archaeological materials at almost every scale, the requisite equipment is expensive, not portable, and unusable in harsh environments. The use of close-range digital 2D photography alongside *Photoscan* presents itself as a highly attractive and cost-effective alternative due to the portable and inexpensive nature of the prerequisite equipment. Data collection can be conducted in any environment in which a digital camera can function, making photogrammetry a highly versatile technique. But perhaps the greatest advantage of using proprietary software like *Photoscan* is that it remains functional despite China's heavy internet censorship laws. Unlike other photogrammetry products or services such as *Autodesk ReMake*, which outsource the heavy computation of photo conversion and mesh construction to cloud-based processing, *Photoscan* is capable of processing the entire reconstruction of an artifact without an internet connection – the online limitation being the hardware of the user's computer. This offline performance is also bolstered by the cross-platform compatibility of the software; which can run on Windows, macOS, and Linux operating systems.

In general, the goal of photograph processing with photogrammetric software is to build textured 3D models. For this study, the procedure of building a complete model was comprised of three broad phases – photography and image management, mesh construction, and texturing and printing (Fig. 1). Photographs were taken using a *Canon EOS 7D* digital SRL camera fitted with an *EF-S 15–85 mm IS USM Lens Kit*. This particular lens offered the analyst excellent performance in capturing photographs from wide-angle to telephoto. Providing a narrower field of view with magnification, a telephoto option proved to be particularly useful in capturing variation in surface treatment on the subject ceramics. This being said, a lens capable of wide-angle through to telephoto shots is not only a versatile tool in its ability to capture a variety of archaeological materials (from artifacts to features and sites), but is also cost-effective single purchasing unit. Depending on the nature of the vessel, 50 to 120 photos were taken from three different angles corresponding to approximately 0°, 30°, and 60°. This was done in order to ensure that *Photoscan* would find common points on photographs and be able to accurately model the surface textures and complex geometries of each vessel. Care was taken to ensure that there was at least 15 to 20% overlap between photos (Fig. 2).

Using Photoscan, common points on photographs were matched and positioned in three dimensional space to form a sparse point cloud, and ultimately a 3D mesh (Fig. 3). A dense point cloud is built by the software based on estimated camera positions. Once complete, the dense point cloud can be edited prior to 3D mesh (model) generation. A 3D polygonal mesh representing the surface of the object is then reconstructed using the completed dense point cloud. *Photoscan* provides two algorithmic methods for mesh generation – "Height Field" and "Arbitrary". The "Height Field" algorithm is commonly used for planar surfaces, whereas the "Arbitrary" algorithm is used for any other kind of object; like those subjected to this study (Agisoft LCC, 2013). After the mesh is constructed, it can be textured for presentation based on references taken from the aligned photographs. After this, completed models can be exported in a variety of file types depending on intended use (Wavefront OBJ, STL, VRML, 3DS, COLLADA, Autodesk DXF, Stanford PLY, U3D, and PDF). In total, 32 vessels belonging to the early and late phases of the Shangshan Period were documented; with 3400 photographs intended for use with *Photoscan* taken alongside 350 scaled reference photos.

3. Discussion

Photogrammetry itself is not without flaws. In a number of cases, particularly when documenting Shangshan vessels with intricate bases or flaring forms, the total number of photographs may be too large to process and generate a 3D model in a single workflow. Caused not only by the amount of photographs, but also the limited processing power (8 GB of RAM) of the author's field laptop, some objects were very difficult to reconstruct. To overcome this, sets of photos – usually divided between exterior form and base – were split into separate "chunks" within a single project. Therefore, photo alignment and dense point cloud construction were conducted separately before being merged together into the resulting 3D mesh. Objects best suited to photogrammetry are those with structured surfaces, edges, amorphous geometries, and heterogeneous colouring. Conversely, it is widely noted that image-based reconstruction methodologies produce limited results when applied to monochrome, unstructured, reflective, translucent, or self-resembling object surfaces. Due to their unglazed surfaces that are often painted with matte slip, one of the primary limitations of any image-based 3D digitization technique - reflective surfaces - does not present itself. However, the friable nature of early Shangshan ceramics has resulted in a lot of plaster reconstruction attempts to produced complete vessels for display in the Shangshan Museum in Pujiang, China. Despite careful and rigorous documentation, the most problematic aspect of digitizing Shangshan cultural heritage are the unstructured, monochrome, and self-resembling plaster surfaces that often comprise most reconstructed vessels. These reconstructed components are rather difficult to model, as they present little textual and visual differentiation for photogrammetric software to detect – resulting in amorphous textures.

However, the benefits of this technique far outweigh these limitations. Relative to illustration, digital works are durable and present scholars with more accurate, precise, and economical documentation that is subject to far more analytical measurement. Rather than documenting an idealized symmetrical form as generated by traditional hand-drawing techniques, the actual existing form of the artifact can be documented using digital means. As mentioned in the beginning of this report, Chinese internet censorship has a profound effect on the general public and the mediums through which information can be accessed. Beyond adding analytical value to the artifact documentation process, 3D models created through digitization efforts can be used by scholars and the public to remotely access museum collections for study and education. This is not without discussion however, as the ethics of creating access to 3D models to the public, scholars, and industry professionals is

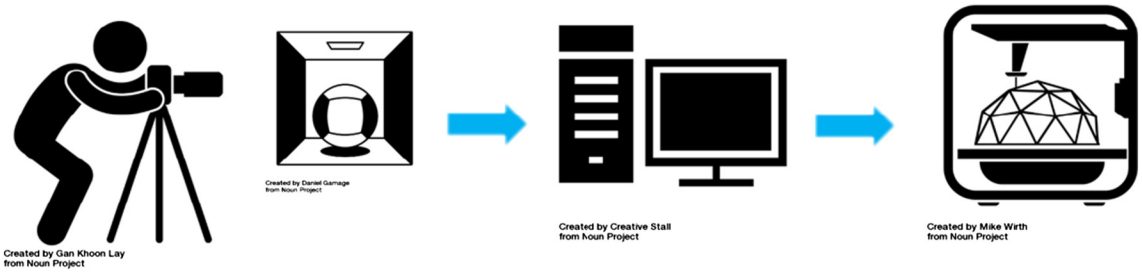

Fig. 1. Photography & Image Management, Mesh Construction, and Texturing & Printing (Images by Gan Khoon Lay, Creative Stall, and Mike Wirth from *Noun Project*).