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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

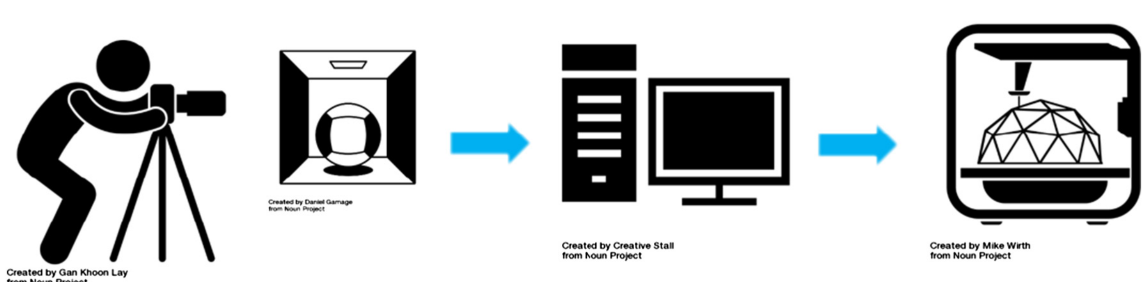

Fig. 1. Photography & Image Management, Mesh Construction, and Texturing & Printing (Images by Gan Khoon Lay, Creative Stall, and Mike Wirth from *Noun Project*).

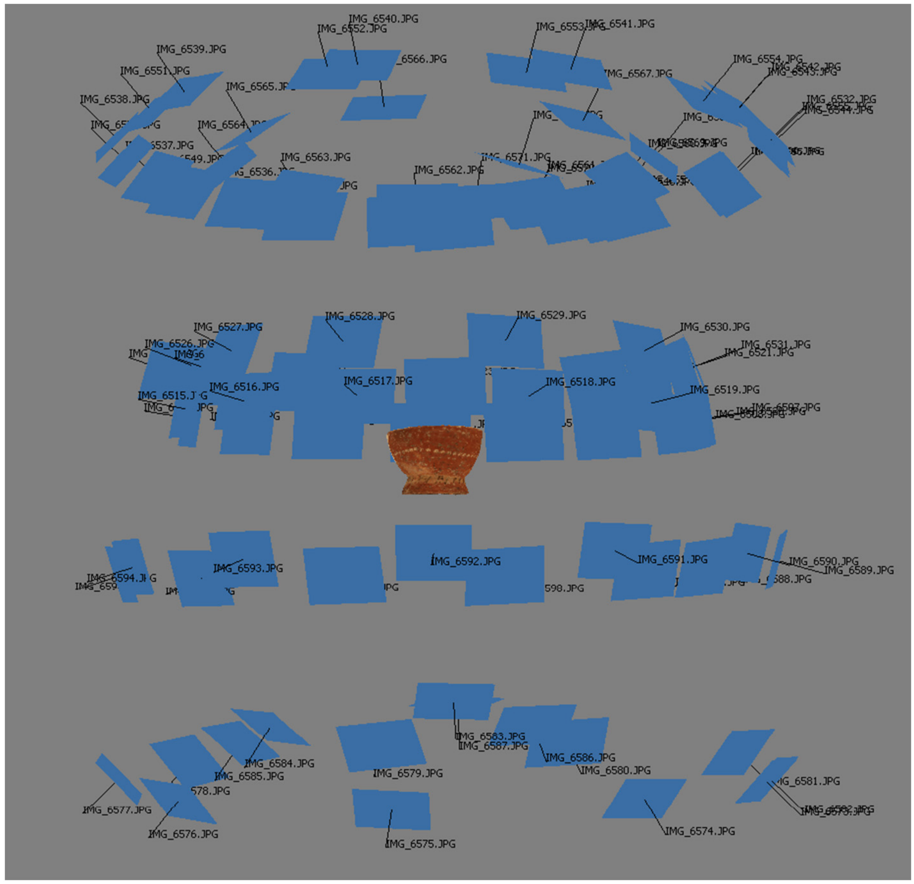

Fig. 2. Screenshot of late Shangshan bowl. Modeled using Agisoft Photoscan by Daniel H. Kwan.

still a hotly discussed topic. In the public realm, this new found agency in re-creation and re-mixing becomes challenging when viewed from the lens of cultural misappropriation. However, in the context of museums, this access has the potential to widen the process of exhibition design and the organizational systems to a more diverse set of stakeholders, as museums can at times be outdated due to disparities in funding. This new digital accessibility builds the foundations for greater participation, empowerment, and ownership in the preservation of cultural history.

Furthermore, due to the obvious spatial constraints presented by museums, less than 10% of collections are often displayed in physical galleries (Bradley, 2015). This technique in digitization has the potential to not only create interactive digital media that enriches physical exhibits, but also create the opportunity for both scholars and industry professionals to collaborate more directly in building exhibit narratives through both digital and physical media. This can effectively utilize a smaller subset of an archaeological assemblage or a single artifact to open up a discussion about an entire museum collection. For example, 3D printing digitized archaeological materials, such as particularly friable artifacts such as Shangshan ceramics, could be an effective way to connect delicate physical artifacts with digital objects and durable printed proxies to create more inclusive, accessible, and engaging exhibitions that encourage multisensory learning.

4. Conclusion

While the use of photogrammetry is certainly new in China, the technique has been utilized by a number of archaeological projects around the world. From the work of the Louisiana State University Digital Imaging and Visualization in Archaeology (DIVA) lab on the Underwater Maya Project in Belize to the Ikaahuk Archaeology Project in the Canadian Arctic, a growing number of archaeological projects around the globe have been using 3D imaging and printing to varying degrees (McKillop, 2013; Haukaas and Hodgetts, 2016). This report

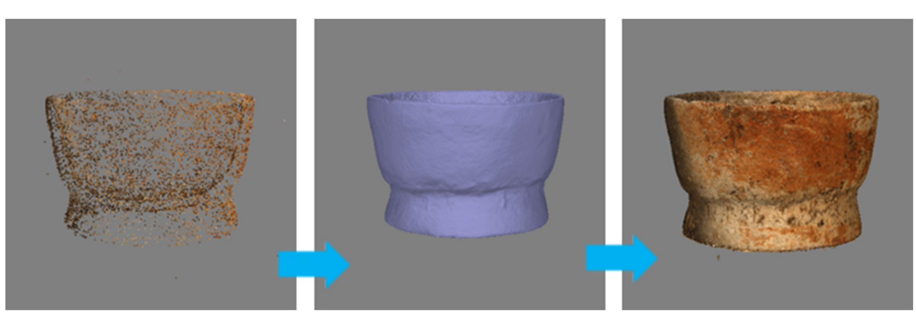

Fig. 3. Models by Daniel H. Kwan.

demonstrates that the practice of documenting cultural heritage in China, which has become increasingly threatened by the accelerated growth of cities and the urbanization of rural landscapes, would also benefit from the integration of macro-photogrammetry as a means to disseminate archaeological evidence between scholars and share knowledge with archaeological interest group communities and the broader public. Furthermore, due to the vast geographic expanse of China, the documentation of sites, particularly those threatened by development, cannot be efficiently completed exclusively through the efforts of archaeological and cultural heritage professionals. Due to the low-cost nature of this particular methodology, aspects of future Shangshan archaeological project efforts can be conducted by local non-archaeologists as a form of community-led documentation of archaeological sites throughout the study region of Zhejiang Province, China. The use of digital technologies to disseminate information still remains in its infancy in China. One of the future challenges of digital archaeological efforts is sharing generated 3D models with communities within and outside of China. Unlike community-led documentation projects like the Ikaahuk Archaeology Project (Haukaas and Hodgetts, 2016), which use highly popular internet channels like Facebook and YouTube to disseminate 3D data from remote Canadian Arctic locations, such platforms remain unavailable in China. As such, appropriate online platforms for sharing digital archaeological data must be further explored.

In the case of the Shangshan Archaeological Project, photogrammetry has been used to pre-emptively create greater access to delicate and uncommon archaeological materials, not only collecting data on relevant features of the artifact (shape, relief, texture, and damage), but intellectually conserving Shangshan objects in their assumed-whole states to empower other types of communities/stakeholders in both local scholarly research in China and in the sharing of cultural knowledge at both local and global scales once the proper communication and sharing protocols have been established (Gajski et al., 2016: 263; Haukaas and Hodgetts, 2016; Nicolae et al., 2014: 451; Yilmaz et al., 2008: 490). Constructing a rudimentary digital archive of faithfully textured and structured three-dimensional models using a low-cost technique such as photogrammetry clearly demonstrates the utility of digital technologies as a means of mitigating the destructive nature of archaeometric analyses, supplement physical data collection, and provide an engaging means of disseminating archaeological evidence to professionals and non-archaeologists alike. Access to heritage objects in contexts that would have otherwise been impossible due to the international nature of scholarly collaboration or the fragile nature of the materials themselves. While photogrammetry may have not yet “defeated” 3D scanning methodologies, and itself may not be the best practice method of digitizing cultural heritage, this study has certainly demonstrated that it is the most financially accessible and easily integrated into routine archaeological practice.

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