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Virtually There:

Offsite georectified photogrammetric processing as onsite strategic excavation resource

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Abstract: With photogrammetric software becoming increasingly available and applicable to the archaeological research community, the three-dimensional output produced by these programs has the potential to extend beyond a merely documentary role to serve as a fundamental and on-going aspect of excavation methodology. As a technique limited by computing power, photogrammetric processing of photographs is most often an aspect of post-excavation data management. As such, photogrammetry is seldom exploited as an integral component of excavation strategy. This paper describes a collaborative experiment where we combined daily onsite photography and geospatial mapping of fragile cremation urns and inhumations at a Middle Bronze Age cemetery in eastern Hungary with offsite photogrammetric processing and georectification. The method and workflow presented in this paper demonstrates the potential of photogrammetry to serve as a powerful resource during the process of excavation of archaeological contexts. Advances in cloud computing and automatic processing will no doubt make this method of near to real-time photogrammetric documentation an independent process reliant on mobile devices in the near future, and in this paper we report on the successes and challenges that came about during our collaborative experiment.

Keywords: Photogrammetry, mortuary archaeology, international collaboration, offsite cloud computing

The photogrammetric frontier in archaeology

The universal adoption of digital photography in archaeological research over the past two decades represents a turning point, resulting in a drastic increase in both the quality and quantity of data collected by researchers in the field. Just as archaeologists largely abandon traditional photographic techniques, there are many indications that multi-image photogrammetric recording of research contexts is quickly becoming standard excavation methodology, and stands to revolutionize the field (DE REU *et al* 2013, 2014). Early archaeological applications of stereo-pair photogrammetric techniques required extensive manual editing and point referencing of photographs, and researchers did not use them to generate models with fine surface details (JEFFREY 2003). By exploiting the exponential increase in computational processing power over the past decade, numerous photogrammetric software suites are now available and capable of processing large batches of photographs with little user interaction (MCCARTHY 2014). These programs automatically detect and adjust for camera calibration, and automatically match visible features in order to recreate complex three-dimensional models. The speed at which these models can be generated is limited by the processing capacity of the computer, and considering that field computers are generally low-spec portable laptops, the creation of photogrammetric models is usually relegated to the post-excavation data processing stage. Although there is software like Autodesk's "123D Catch" that uses remote computers to process images, thereby bypassing the need for a local high-speed computer, the scale-free and ungeoreferenced output it generates cannot be easily integrated into an on-going ArcGIS session. The present paper outlines an experimental process in which—over six weeks and on a daily basis—excavation photographs of fragile Middle Bronze Age urn burials in eastern Hungary were uploaded to a powerful offsite computer in Toronto, Canada for photogrammetric processing.

Case study: The Bronze Age Körös Off-Tell Archaeology (BAKOTA) Project, Körös Basin, Eastern Hungary

The focus of the BAKOTA project is to understand how travel and trade networks affected sociocultural change, funerary customs, and the emergence of social inequality in later European prehistory. Since 2011, our research has centered on the cremation urn cemetery at Békés-Jégvermi-kert (ca. 2100-1500 B.C.). Describing burial patterns in prehistory requires detailed recording of object arrangements, but thousands of years of land use make the contents of human burials extremely fragile. Georectified photogrammetry models provide an important and additional means of capturing the spatial relationships, details, and orientations of burial contents before they are mapped, dismantled, and removed.

Methods

Discovery and excavation of a burial

Once we discovered a burial urn, we removed the pit fill and exposed the main vessel and surrounding grave goods (fig. 1). The condition of the burial goods varied, but most suffered postdepositional disturbance. Modern ploughing partly destroyed some vessels and bioturbation affected others, while almost all burial urns suffered cracks from land compaction. Vessels would crack and fall apart when removed from their pedestals, and sometimes even during initial exposure.

Preparing the context for photography and drawing

Following the exposure of a burial, the excavator carefully cleared the context of extraneous material as normally required for formal photographic documentation. Exposed burials waited to be drawn for several days when inclement weather prevented the team from working at the site.

Fig. 1 – Initial excavation (Copyright: Paul R. Duffy).

Fig. 2 – Placing the numbered nails into the excavation context. The spatial location of 16 points was recorded with a Total Station, information used to eventually georeference photos and the resulting photogrammetric model (Copyright: Paul R. Duffy).

Block photos

As soon as a burial was cleaned and ready for photo, a trench supervisor or assistant photographed the context with a photo board, north arrow, and scale.

Taking photographs for photogrammetric modelling

One of the authors (LT) took photographs of all burials for model creation. First, 16 coloured and numbered nails were laid in and around the feature (fig. 2). Second, the photographer took two or three concentric sequences of photographs in the same session and when possible, under identical and flat lighting conditions. Strong shadows under strong sunlight tended to create a high contrast that resulted in less nuanced models. Overcast conditions and artificially shaded contexts created the best results. Photographs had at least 80% overlap between images with a central point within the subject serving as a focus.

Total station points and drawing

In our experiment, LT also acted as the total station operator. She shot in the numbered nails in sequence using a stadia rod. The resident artist then drew the grave in plan and profile. Due to the fragile nature of the vessels, a pedestal of sediment matrix remained in place to support the burial. For proper definition of the vessels, some additional excavation took place at this time. Occasionally, the artist exposed new vessels, requiring an additional round of photography. This did not require any additional georeferenced points.

Transfer the field data offsite

LT scanned the artist's map and downloaded the total station points into a spreadsheet. She downloaded the photos, deleted fuzzy pictures and duplicates, and then uploaded the photos, total station points and maps to a Dropbox folder. For approximately 50 photos, this took a couple of hours on a wireless router signal, so we began the process before the field crew went to bed each night.

Align photographs

The offsite operator (GSM) opened all downloaded photos in Agisoft Photoscan and tested the alignment in a low level accuracy session to ensure sufficient overlap between images. Once the model attained a sufficient overlap between images, a high accuracy modeling session followed.

Build geometry

This was another fully automated stage in the production of the model, and by far the most time intensive. Once the offsite operator chose a target resolution, the model took 1-3 hours to process. This timeline proved sufficient for our purposes, but could be considerably longer if extremely high-resolution models were required.

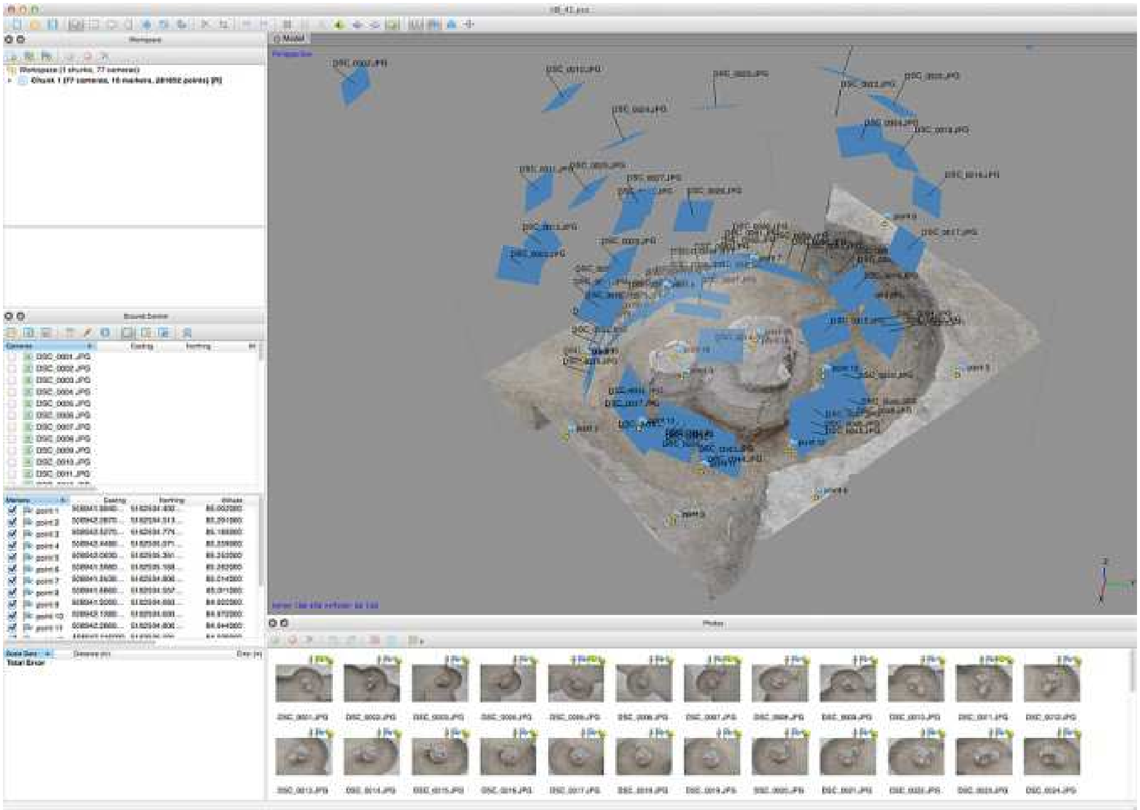

Fig. 3 – Agisoft Photoscan interface showing both the uploaded photographs (below) and their relative position (blue rectangles), in relation to the final georeferenced three-dimensional model of an urn burial (Copyright: Giles Spence Morrow).

Build texture

After choosing a target resolution for the final product, this stage of the process took between 5 and 10 minutes, again depending on the nature of the context and the level of resolution. At this stage, the model is scale free and without any geographic reference, but can be exported in a number of standard three-dimensional modelling formats such as VRML, OBJ, PDF or 3Ds (fig. 3).

Georeference model

By highlighting and entering easting, northing, and elevation coordinates for each of the ground control points recorded with the total station and visible in the photographs, the offsite operator established the absolute position of each nail in the model (fig. 3).

Export model

The resulting georeferenced model can be exported in a number of useful formats. For our purposes, in addition to generating a PDF (fig. 4), the offsite operator created an orthophoto, digital elevation model (DEM) and OBJ file, and uploaded them to the Dropbox account for use in ArcGIS or other modelling software such as Meshlab (figs. 5, 6).

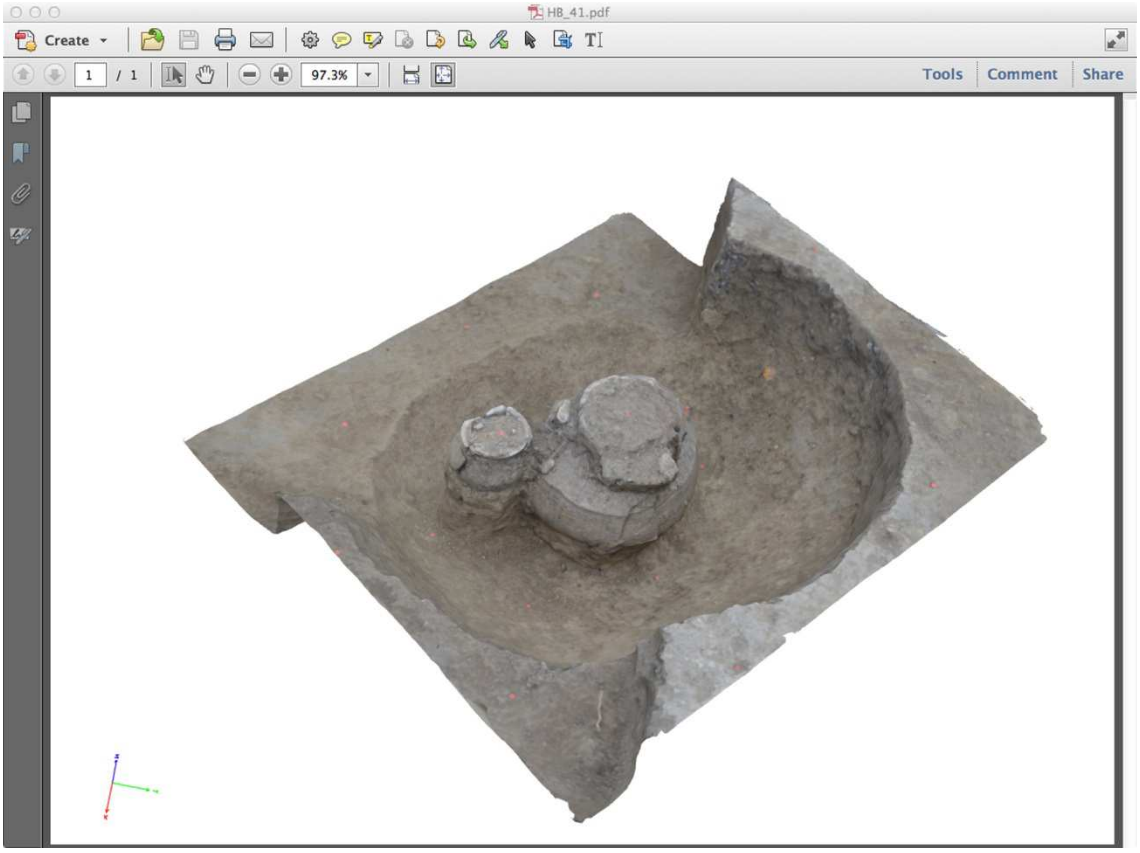

Fig. 4 – Screen capture of a three-dimensional PDF generated in Agisoft Photoscan (Copyright: Giles Spence Morrow).

Receiving the 3D models back at the lab

The trench supervisors received the 3D model as a PDF and could use it in writing up the description of the grave. As the graves grew in number, supervisors increasingly used the PDFs instead of photos and maps to remember different ceramic forms and the arrangements of funerary goods.

Overlay in the GIS

For each burial, the project director (PRD) received two raster files, a geotiff DEM and a colour orthophoto draping and dropped them into an ongoing session of ESRI's Arc Scene (fig. 6). The orthophoto file took the values of the DEM as base heights. This allowed a running reconstruction of the exposed cemetery, and offered an opportunity to view differences in depths and navigate the excavated features in relationship to one another. In fig. 6, the burial cuts and the edges of the excavation blocks are digitized and overlaid with the grave models.

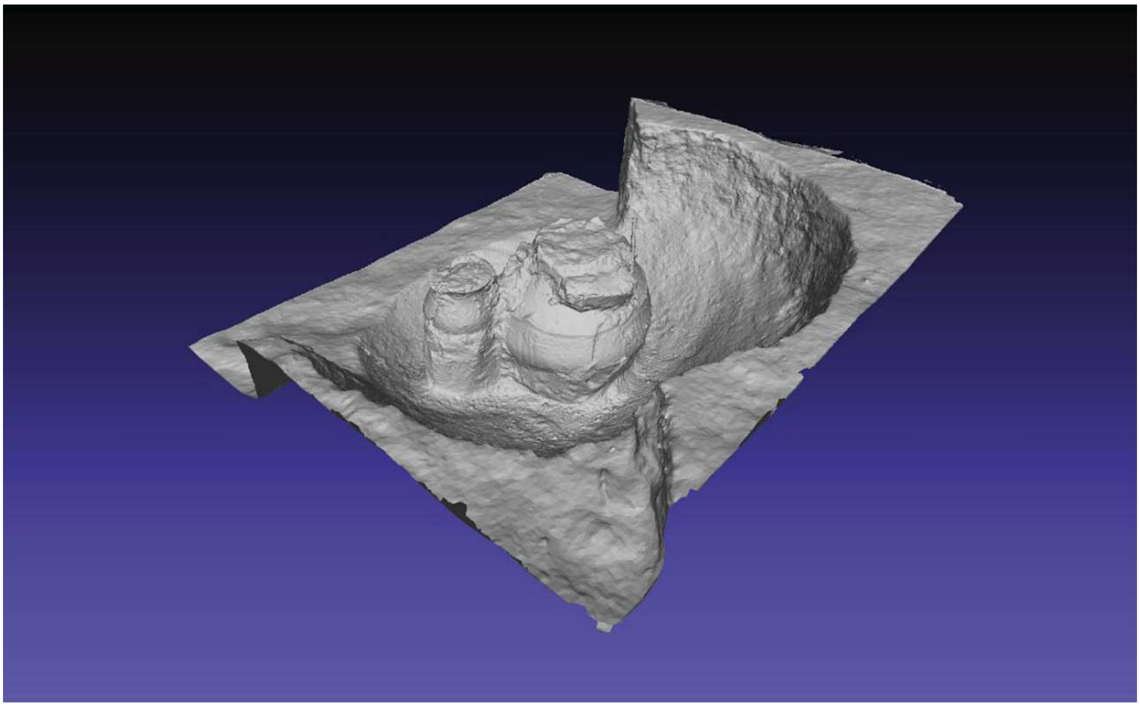

Fig. 5 – Screen capture of a surface-only OBJ version of the final three-dimensional model as viewed using Meshlab (Copyright: Giles Spence Morrow).

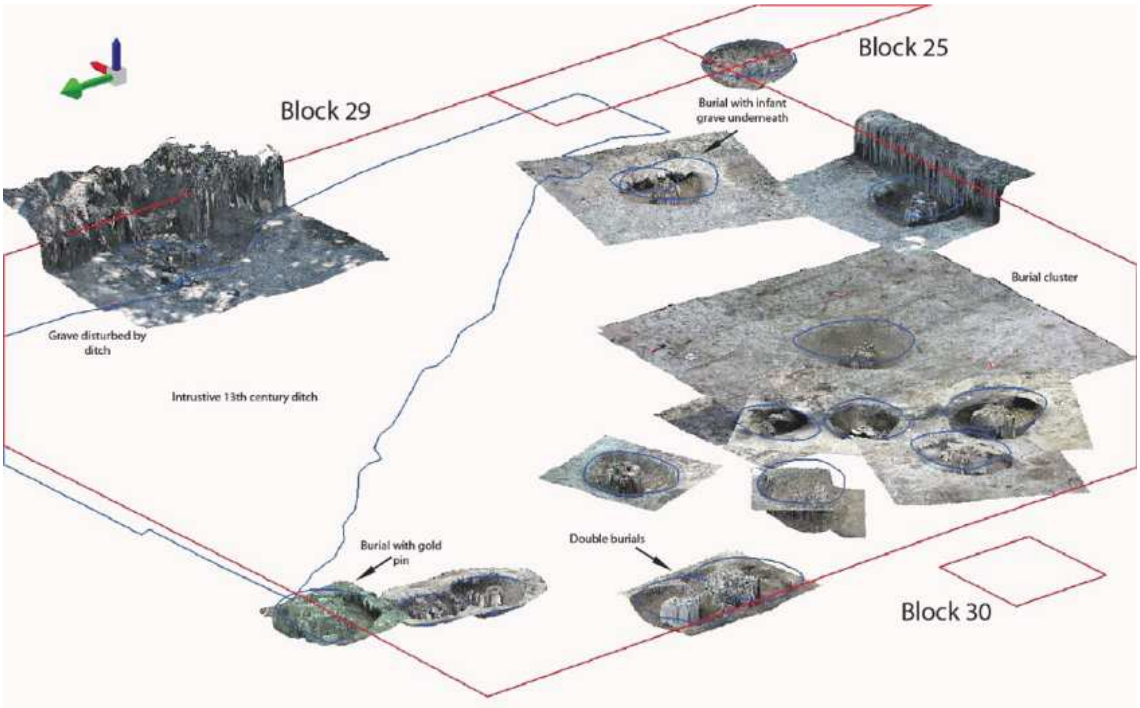

Fig. 6 – Screen shot of fully textured three-dimensional models displayed in relation to each other as viewed in ArcScene (Copyright: Paul R. Duffy).

Outreach to colleagues and the public

The capacity of Agisoft Photoscan to produce low file-size three-dimensional PDFs is enormously useful considering that this particular file format is highly accessible. Immediately after the excavation, we disseminated PDFs of burials to colleagues and locals interested in the research. The PDF format allows collaborators and members of the public to easily examine excavation contexts once project members uploaded PDFs to the project website (fig. 7). The PDFs allow vessel forms and funerary arrangements to be illustrated in a single manipulable file, without access to specialized photogrammetric or 3D modelling software.

Fig. 7 – Screen shot of the BAKOTA web site portal which will allow project collaborators to access, download and investigate photogrammetric models of specific burials (Copyright: Paul R Duffy).

Challenges and Successes

Our experiment to generate georeferenced models of human burials offsite for use by researchers on an active field project proved relatively simple and useful for decision-making by project staff. Producing models also simplified the sharing of excavation results. Considering the intensity of work involved in excavation and processing daily finds, it was beneficial to have an offsite colleague dedicated to developing models on a powerful desktop computer. The main challenge to the modeling process emerged during the first two weeks as the field crew became accustomed to the work sequence and streamlined the procedure. The learning curve for the software operator was in identifying the modeling resolutions and field conditions needed for superior models. Uploading photographs to Dropbox was also time consuming, and may be prohibitively slow when sharing over a weak internet signal or uploading hundreds of photos for very large models. Finally, models did not replace field maps but were very good stand-ins where an exposed feature could not be mapped immediately because of inclement weather. Georeferenced models therefore served as backups for worst-case scenarios where a context was damaged before it could be drawn.

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