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3D Technology for Archaeological Documentation

Abstract

Much effort has been expended in order to completely and comprehensively document the excavation progress and archaeological finds. With the latest advances in digital technologies, a new method of creating 3D representations of finds and complete sites has been developed. In this paper we will present our methods and workflow for creating digital 3D representations of archaeological finds and their integration into the documentation process of the excavation. The methods range from recording 3D data in the field and lab to creating a virtual museum. We discuss our techniques and compare them with other 3D-capture methods. Moreover, we will demonstrate our methods as part of the documentation workflow. In particular, Structure from Motion (SfM) will be discussed as a scalable, reliable, easy to use, robust, non-invasive, easy to import and export, and cost-effective method. We suggest that SfM is the best method for 3D-scanning at all scales, as it only requires photographic images for input data. Finally, we will present different examples of our documentation, where 3D data has improved the work.

Introduction

3D technology has advanced in recent years and is a fast-growing field in archaeological research, influencing ways of finding archaeological material in the field and automating and enhancing the documentation process. In this paper, we demonstrate how these two processes are performed at the Biblical Archaeological Institute at Wuppertal and how they are integrated into the work.

3D Technology and Archaeology

3D technologies can be integrated into archaeological workflows in many different ways (Bitelli 2007). They can be used to identify possible excavation sites, *e.g.* by finding leveled areas.

They can also be used to record the boundaries of squares and the exact location of finds using a differential GPS.

Within the archaeological documentation process, drawings are usually done by hand, digitized and then integrated into the database. A major disadvantage of drawing by hand is that it inevitably incorporates a certain artistic licence. If one illustrator redraws a find that has already been drawn, the new drawing will almost certainly be different to the original. This can be a problem when a new drawing is added to a pre-existing one. For stone-by-stone drawings, this subjectivity gets even worse as connections between walls that were not taken into consideration by the illustrator may subsequently have disappeared. Some projects use an earth-bound laser scanner for the task of in-field 3D-scanning. These systems are expensive and can only be used by engineers and trained staff. If they are damaged it can take a long time to obtain a replacement. In sum, it can be said that at present no standardised, robust method of data creation and information retrieval is at hand.

For lab-based 3D-scanning of finds, 3D scanners based on laser and structured light technology are now available. Both systems can be tricky to use and are far from automated. They typically use inbuilt cameras to generate texture, but these tend not to deliver acceptable image quality. Another issue is that certain categories of find cannot (or only with difficulty) be exported, so 3D-scanning in the field becomes a necessity. Once again, the scanners are specialised items of hardware that frequently cannot be imported and exported without problems; if they break the documentation process cannot proceed.

A good candidate for a standardised method will be introduced in this paper. It is robust, fairly easy to use, can be done using simple and cheap hardware, and does not need any special training.

Applied 3D-Scanning Methods

3D-scanning can be understood as the process of digitising real-world objects. The basic principle is to generate a virtual point cloud consisting of a finite number of spatial vectors. There are many ways of performing the physical measurement of a probe. One basic starting point is a contact scanner that touches the surface and creates a point cloud of every single contact. Depending on the quality of the device, the data can be very exact (μm-error). For archaeological work this method is not suitable as some finds are fragile and cannot be touched. This kind of scanning can be found in the GPS-aided positioning of finds and the corners of squares. The most comprehensive means of 3D-scanning is an optical scanner that uses light. As the size and type of objects vary, we do not rely on one single method but use three different types of optical scanner for flexibility. The 3D models are not only used to create drawings, but can also be used to generate photorealistic rendering (see FIGS. 6 and 8).

Laser-Scanning

NextEngine's Desktop 3D-scanner and ScanStudio software have been used on the project since 2012. The advantages of this technology are high levels of automation and good surface detail reconstruction. It has been used for pottery sherds and mid-sized objects on which high surface detail is required (FIGS. 1 and 2).

The scanning process is done in multiple steps (Bernardini 2002). The object is placed on a small turntable and can either be clamped (for sherds) or freestanding. For one sherd, it gathers about 200,000 vertices which takes about 45 minutes.

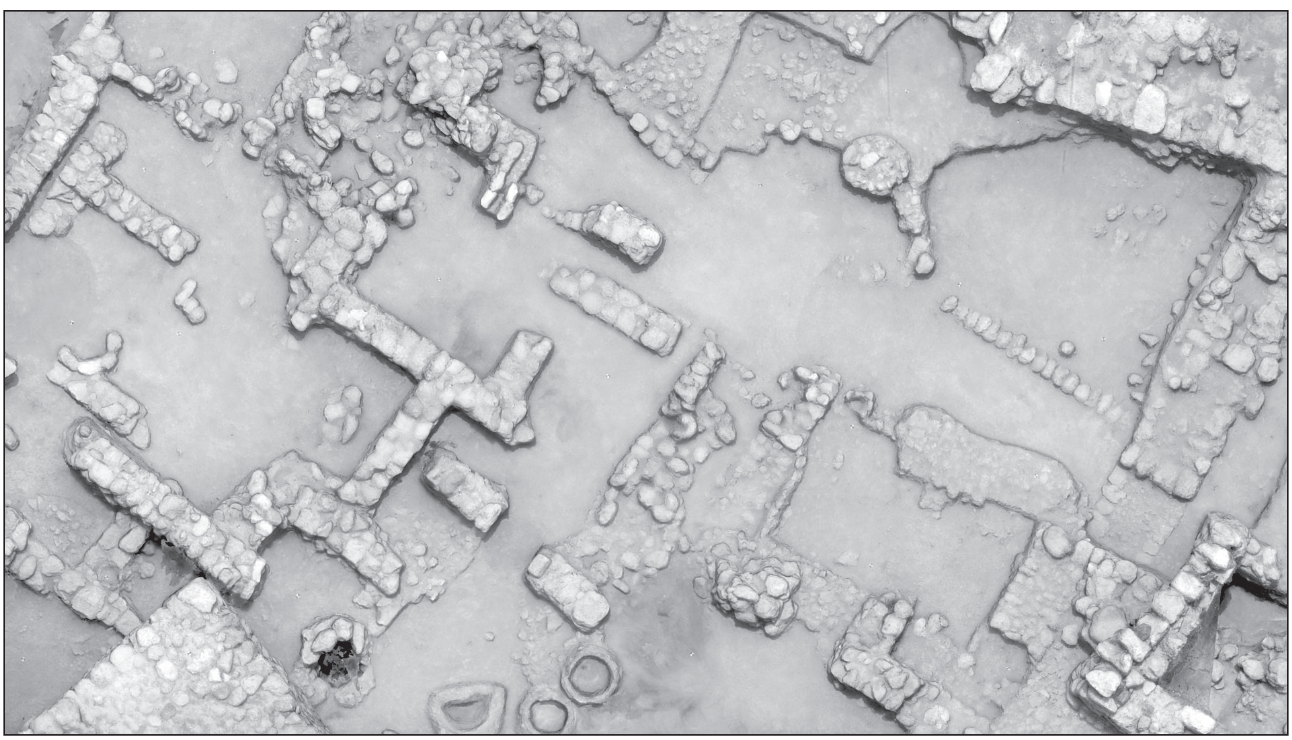
Laser-scanning is often used to scan areas of an excavation site. This method requires special equipment and trained staff. Also, laser-scanning is not hazard-free as IR lasers are not visible to the human eye but can do serious damage.

Structured Light-Scanning

Our structured light scanner is a custom-built device consisting of three different parts:

1) A Canon DSLR connected to a workstation.
2) A Pico Beamer connected to the same workstation.
3) A turntable for automated object rotation

1. View taken with a 35 mm lens.



2. Orthophoto from the same point as FIG. 1.

that is controlled by a microcontroller communicating with the workstation by a means of a serial connection.

Structured light-scanning cannot be used for large outdoor areas but only for the 3D-scanning of finds (Tao Peng 2005) (see FIG. 7).

Structure from Motion

Structure from Motion (SfM) is the most flexible of all scanning methods. The input data consists only of photographic images (Dellaert 2000) (FIG. 3).

For this object, a turntable rotating in 15°

3. Structure from Motion (SfM) as used by *Agisoft Photoscan* photogrammetry software.

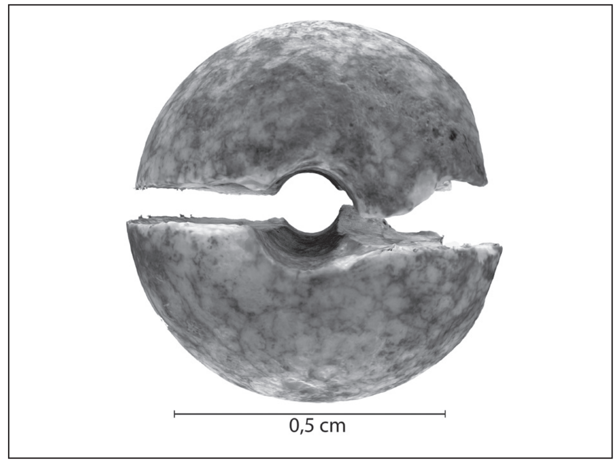
increments, controlled by a microcontroller attached to a Canon EOS 5D mark III with a EF 100 Macro lens, took 24 images from three different pitch-angles. The capture process lasts about 10 minutes. The images are white-balanced and downscaled to 2048 × 1365 px. To separate the object from the background, image masks need to be created. This step takes another 10 minutes (see FIG. 10).

Scanning marks have been positioned on the rear of the object to allow for digital scaling (FIG. 4).

For the reconstruction process, *Agisoft Photoscan* has been used successfully. It generates a triangulated and textured 3D model consisting of 520,000 vertices. The automation is so high that it does not need any further user interaction, with a manual user time of 20 minutes. For a simple sherd just 7 - 10 minutes are required.

This workflow works equally well for excavation areas and whole sites. These 3D models can be used to create orthophotos. Images for an area of this size need to be taken from an aerial camera platform, such as a balloon or other UAV. Direct comparison of the orthophoto with an image taken with a 35mm lens shows that no high-altitude photography is required. For a small area, such as 20 × 20 m, the requisite images can even be taken from a pole. These can then be used to generate plans of walls (see FIG. 9).

4. Markers below the object.



5. Digitally reconstructed glass bead.

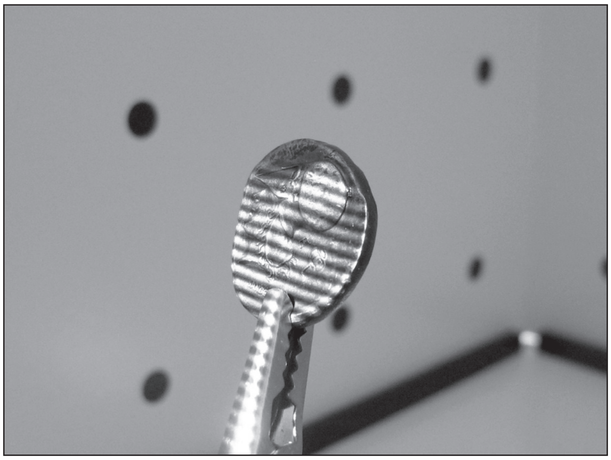
6. Photorealistic rendering from different 3D-reconstructed vessels.

At the other end of the scale, very small objects such as glass beads can also be scanned and reconstructed. This reconstruction consists of two parts, each taking 20 minutes to create. The virtual reconstruction of bead parts and rendering is done in an open source programme, *Blender* (FIG. 5).

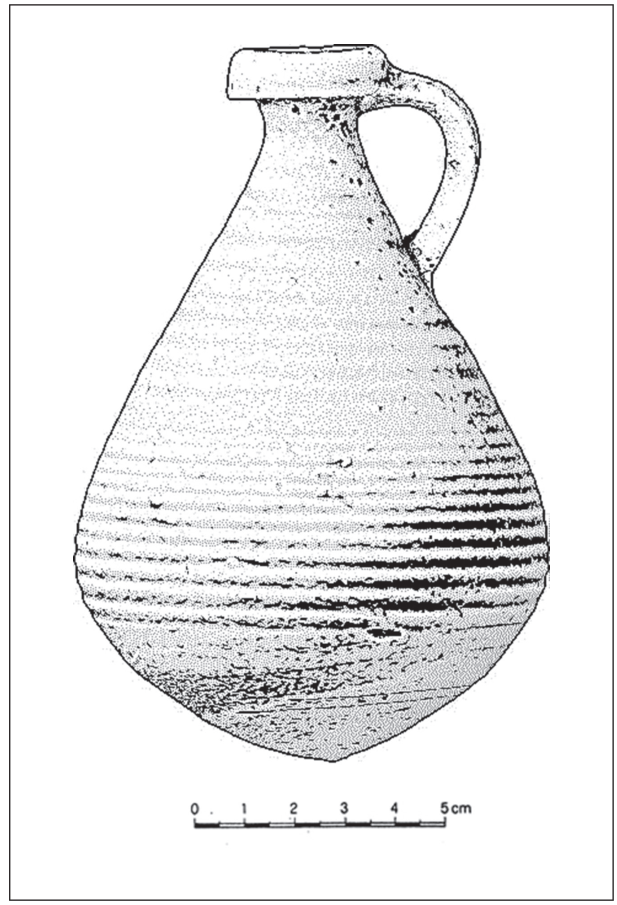
In comparison with laser- and SL-scanning, SfM is very robust and easy to use as it does not need any special hardware except a workstation and an off-the-shelf DSLR camera. It works in sunlight and can be done by non-professionals. The quality is reasonable and, owing to its flexibility, SfM can be easily integrated into any existing documentation workflow.

Future Work

New developments aim to create an even more robust workflow that works under all circumstances. Many 3D-scanning methods can only be carried out by specially trained staff. In the field of archaeology, 3D-scanning needs to be a task



7. Structured light-scanning of a coin.

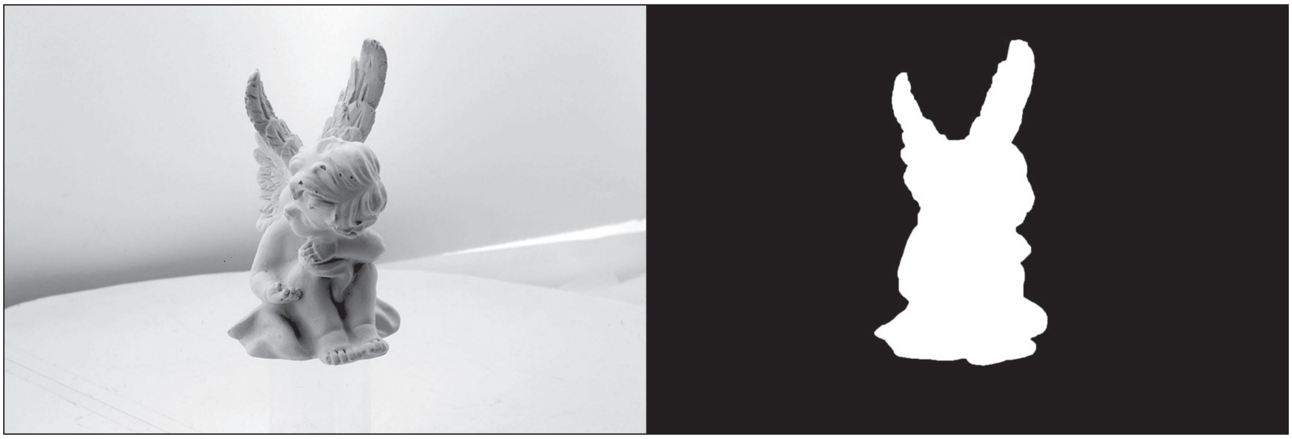


8. Drawing of a reconstructed vessel derived from a 3D scan.

that can be done by archaeologists themselves in a way that generates high-quality results. Therefore, the main task of engineers working with archaeologists is not to develop proof-of-concepts, but to build systems for practical use.

By using SfM to create orthophotos, high-altitude aerial images are no longer required. It is much simpler and cheaper to create a pole-and-camera-gimbal system to take the necessary photos from all directions. A system like this is independent of weather constraints.

9. Map of walls made from 3D-reconstruction of two squares.



10. Photograph and its mask for Structure from Motion.

A light-diffusing plane can be used to avoid shadows caused by direct sunlight. The daily progress of excavation can be documented and, with a motorised setup, excavation area- and find-images can be taken without difficulty.

For the 3D-scanning of pottery sherds, a new and more compact system will be developed that holds the sherd between two shafts in order to obtain 360° images in one rotation. This will reduce the manual scanning time to 1 - 2 minutes per sherd. The data can then be used to reconstruct the vessel virtually and to create drawings.

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