PHOTOGRAMMETRY

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COSCH Case Studies that have employed this technology: Kantharos, Roman coins (fig. 19.1), Bremen Cog (fig. 19.2), Germolles (fig. 19.3), White Bastion, Romanian cultural heritage

Definition

Photogrammetry is a metric imaging method that enables digital reconstruction of the form and geometry of a real object in three dimensions. This reconstruction is based on a set of photographic images covering all areas of the surface with enough overlap to enable identification of common details on each photo. Photogrammetry was originally developed around 1860, and can be regarded as the first non-contact measurement method.

Description

Through photogrammetry, a realistic 3D model based on simple photos including detailed and accurate colour recording of the object's surface can be achieved. It is a very good tool for recording cultural heritage objects, of any size and any type. With commercially available cameras, together with recent software developments, photogrammetry has opened up to many end-users.

The data sets are useful at different levels: on-the-ground and on-site recording (e.g., during an archaeological excavation), technical analysis (surfaces and volumetric measurement after post-processing), and public dissemination through dynamic and easy-to-manipulate 3D models.

Digital close-range photogrammetry is a robust and established, non-contact method for the documentation of museum artefacts. The equipment, typically consisting of a digital SLR camera and lighting equipment, scale bars, and a colour target, is easily transportable to museums or other sites. It is capable of recording the current condition and damages on the surface of an artefact offering visualization of details of the order of 50 microns.

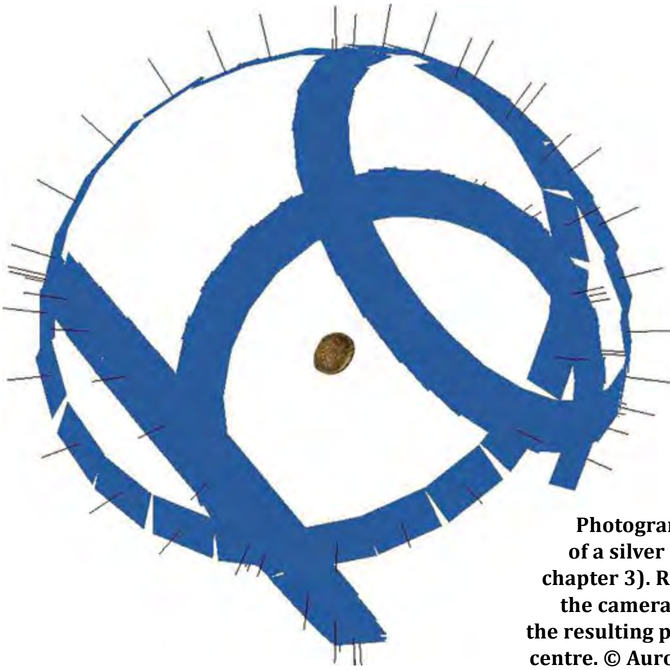
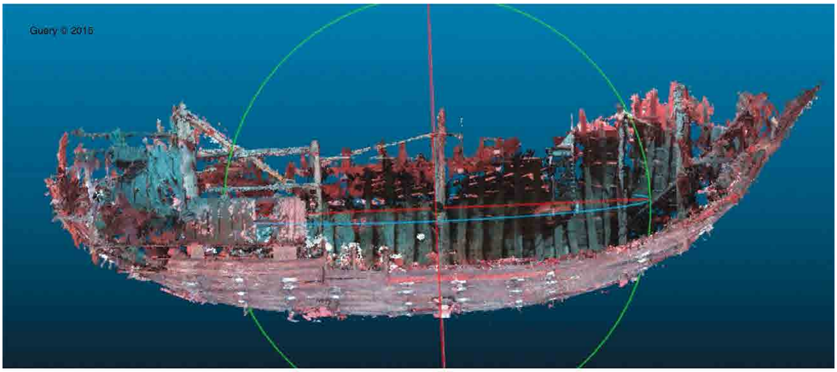


Figure 19.1. Photogrammetric capture of a silver Roman coin (see chapter 3). Representation of the cameras' positions with the resulting point cloud in the centre. © Aurore Mathys 2016.

Two or more overlapping images are taken from different locations. Measurements of a distribution of common imaged features, usually discrete points, are recorded from which both the image and surface geometry can be solved. If many overlapping images, often termed an "image network," are taken, it is possible to estimate both the pose and interior optical parameters of the camera and to produce accurate 3D surface measurements with consumer-grade digital cameras. This procedure, termed "self-calibrating bundle adjustment," is fundamental to many automated 3D image reconstruction procedures when it is combined with automated image feature and area matching processes. Given that colour images are taken, it is a relatively straightforward process to map the colour in the images onto the 3D surface. However, one key point concerning the use of photogrammetry is that the scale of the developed model is unclear unless a scale bar or a known separation between a camera pair is included (MacDonald et al. 2012). The final 3D model can be output as point cloud or TIN (triangulated irregular network) in various formats.

The restitution of the surface relief through photogrammetry is based on the principles of stereoscopy (like human vision), where each pair of photos represents the same details from a different viewpoint (Kraus and Waldhäusl, 1998). Algorithmic analyses of these photo pairs makes it possible to identify each detail



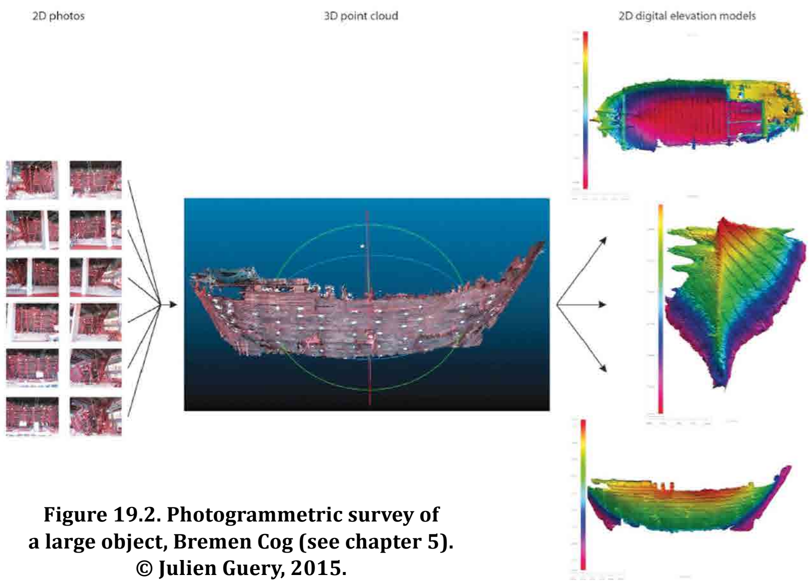


Figure 19.2. Photogrammetric survey of a large object, Bremen Cog (see chapter 5). © Julien Guery, 2015.

as common points, which are then used to determine the relative position of each photo in relation to the others (this operation is called aerotriangulation; Pierrot-Desseiligny and Clery 2011). It is then possible to triangulate the position of specific points recognizable on at least three photos, according to the principles of epipolar geometry (this is referred to as dense epipolar correlation; Zeroual et al. 2011). The procedure can be repeated until several million points have been generated, forming a point cloud comparable to that obtained by a laser scanner, with the difference that each point generated by photogrammetry, besides XYZ information, has colorimetric information derived from the corresponding pixels in the images (Hullo 2010).

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Significant Applications

Example 1: Rescue Photogrammetry: Reconstruction of the Great Buddha Statue in Bamiyan

The two statues of the Great Buddha in the Bamiyan Valley, Afghanistan, which were created in the fourth and fifth centuries, were destroyed in March 2001 by the Taliban. A virtual reconstruction in 3D of the larger 53 m high figure, using photogrammetry was carried out by a team from ETH Zurich. Researchers used amateur photographs taken from the Internet and scanned photographic prints from the 1970s. This was a significant application because it enabled reconstruction of lost heritage, using pictures that were not made for scientific purposes. Since then many similar photogrammetric reconstructions were undertaken using the same principles, in particular for the sites destroyed in Syria during the Civil War since 2011.

Figure 19.3. Photogrammetric survey of architecture, the Château de Germolles (see chapter 4). © Julien Guery, 2015.

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Example 2: Underwater Photogrammetry: The Phanagorian Shipwreck

In 2012, a wooden ship was discovered on the Taman Peninsula at the ancient Greek settlement Phanagoria (Zhukovsky 2013). Photogrammetry was used *in situ* to acquire the 3D model. Underwater photogrammetry works in a similar way to terrestrial photogrammetry, but presents a few extra challenges such as the refraction of water, the presence of the camera housing, low visibility, and turbulence of the water. Underwater photogrammetry can be done by a diver or by using an underwater remotely operated vehicle (ROV).

Extracting wood remains from water is an extremely delicate process since the wood has a tendency to disintegrate once in contact with air. Storms can affect or destroy at any time the unearthed artefacts. Hence the excavation and field documentation recording need to be conducted in a very limited time span. In this case photogrammetry proved to be an efficient recording technique. Furthermore underwater sites can rarely be experienced first hand by archaeologists and the general public. It is therefore crucial to generate a faithful 3D reconstruction of the site, which can provide virtual access to all archaeological data (Drap 2012).

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Example 3: Dimensional Monitoring for Conservation of Artefacts by Photogrammetry

Digital documentation supporting the conservation intervention of museum objects can be enabled by photogrammetry. An example is the detailed documentation of the medieval Westminster Retable made for Westminster Abbey, London, a fine example of late thirteenth-century panel painting. A multi-image photogrammetric system was used to carry out periodic, non-contact, detailed motion analysis of mechanical deformations (dimensional monitoring) in response to environmental changes. The image record and associated spatial data were then used as a visual database used to manage the conservation process and automatically generate a 3D surface model which allowed the art conservator to make measurements and comparisons between different parts of the structure (Robson et al. 2004). This methodology can also be applied to dimensional monitoring of other contexts in cultural heritage, such as building façades and rock faces with rock art, provided that stable surface features are present and/or an independent system of reference points is installed.

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