# STRUCTURE FROM MOTION

*see also* PHOTOGRAMMETRY

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*COSCH Case Studies that have employed this technology: Roman coins, Germolles, Kantharos, Bremen Cog*

## Definition

Structure from Motion (SfM) uses the principle that movement through a scene allows an understanding of the shape of objects within the scene in three dimensions, in the same way as walking through a room allows one to visualize the space and objects within it. In SfM the movement is represented by a series of systematic viewpoints; overlapping photographs taken from different locations around the object. This can be achieved from the ground in the field, in a photo studio, or from the air with a drone or other unmanned aerial vehicle (UAV).

## Description

SfM is a method of photogrammetric recording. It is used for area-based recording and for object recording. A series of single images are photographed and the reconstruction of the 3D model uses similar steps to a photogrammetric workflow with orientation through image point comparison and bundle adjustment, measurement and analysis based on internal and external geometry, possibly using image masking, and output of a coloured point cloud or polygon mesh. Workflows include the combination of free software for photogrammetry, or licensed but affordable software, increasingly tailored for easy use. Whereas photogrammetry was previously used to measure a set of discrete points, typically using markers placed on objects within the scene, SfM extends the method (without the need for markers) by automatically finding feature correspondences and using dense matching techniques to reconstruct complete surfaces. The drawback is that where photographic coverage is poor the point clouds generated by SfM may be quite noisy and have "holes" in the surfaces represented by the point clouds, requiring subsequent smoothing and filling operations.

**Figure 21.1. Edinshall kite aerial photography. Photo: Susie Green, 2011.**

SfM can be used for the archaeological investigation of landscapes and built structures. The use of a kite or UAV can enable coverage of a large area in high resolution, allowing earthworks to be traced across the landscape. When used in conjunction with an archaeological excavation, its simplicity, low cost, high coverage and speed of recording, allows individual aspects of the 3D data to be analysed in ways that are simply not possible with 2D records. The amount of detail that can be captured makes this an ideal means of recording features that could be damaged or destroyed, such as fragile wooden objects, landscapes that are to be developed, or stratigraphic layers that must be removed. Similarly, the speed at which data can be gathered makes this a potentially important tool for the recording of underwater archaeology.

The recording of surface colour, as well as form, by SfM enables the creation of photorealistic 3D models at high spatial resolution. Such models are popular and powerful tools for disseminating archaeological ideas to the public.

For finds and smaller objects, examples of morphometric analysis and comparative taxonomy by SfM models contribute to scientific research projects (Bevan et al. 2014). Whilst SfM works well on its own, often a combination with other recording techniques yields better results (MacDonald et al. 2014). SfM can be used to record high-resolution 3D digital surface models of museum objects of all scales and materials, in the round, to scale and with the option to include calibrated colour mapping. The technique can be used with little training, and free software tools allow the reconstruction of the 3D surfaces, online or on a local desktop computer or laptop. One software package that has become popular in recent years is


**Figure 21.2. Edinshall georeferenced colour map derived from point cloud. Photo: Susie Green, 2011.**


**Figure 21.3. Edinshall georeferenced elevation map derived from point cloud. Photo: Susie Green, 2011.**

Agisoft PhotoScan. Such digital 3D models can be used for online dissemination, teaching in the classroom and for creating physical reproductions by 3D printing.

## Sources

Bevan, A., Li, X., Martinón-Torres, M., Green, S., Xia, Y., Zhao, K., Zhao, Z., Ma, S., Cao, W., Rehren, T. 2014. "Computer Vision, Archaeological Classification and China's Terracotta Warriors." *Journal of Archaeological Science* 49: 249–54. doi:10.1016/j.jas.2014.05.014.

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## Example of Application

### SfM with UAV for Archaeological Research

Edinshall in Berwickshire, Scotland, consists of a double rampart iron age hillfort, within which there is a broch (also known as an Atlantic roundhouse) and evidence of a settlement, dating from the second half of the first millennium BC through to the period of Roman occupation. The hillfort is approximately 140 m by 100 m. Edinshall was photographed using a remote-controlled camera rig attached to a kite in June 2011, following an unusually dry spring, which enabled the earthworks to be seen as crop marks where the grass was dry.

Using SfM a 3D point cloud of the hillfort ground surface was created from the photographs and georeferenced using Ordnance Survey maps. The points were then loaded into ArcGIS and used to create a digital elevation map using the Z coordinate of the points to represent height, and a colour map taking the colours from the points. These maps have a resolution of 5 cm, which is sufficient to pick out individual stones and the paths left by animals. The height map and elevation map are derived from the same data so the elevation details can be directly compared with the crop marks. The time taken to create these maps, the cost of equipment and results achieved compare very favourably with the traditional method of topographic survey.

## Reference

Green, S., Bevan, A., Shapland, M. 2014. "A Comparative Assessment of Structure from Motion Methods for Archaeological Research." *Journal of Archaeological Science* 46 (June): 173–81. doi:10.1016/j.jas.2014.02.030.