# Structure from Motion for Systematic Single Surface Documentation of Archaeological Excavations

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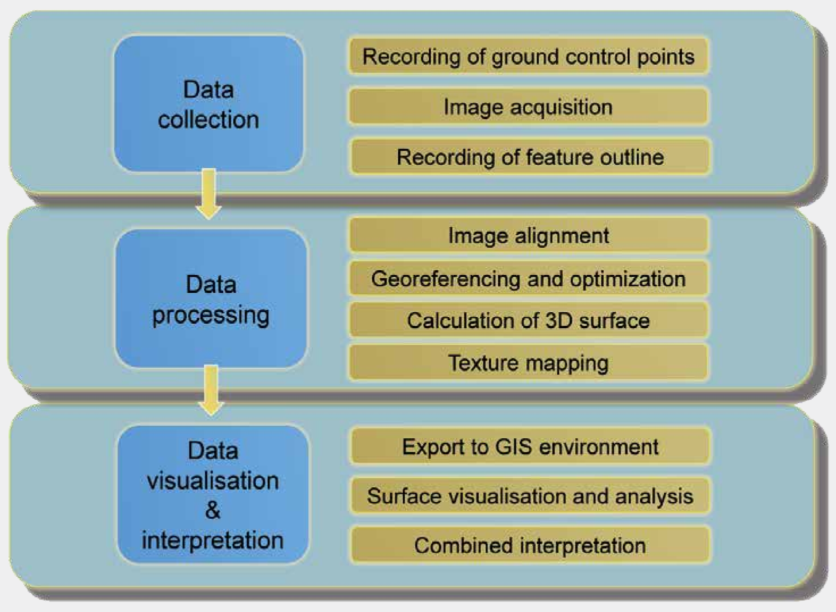
## Introduction

Single Surface Documentation is a stratigraphic excavation and documentation method allowing the virtual reconstruction of the volume of excavated deposits. To achieve this, a three-dimensional record is needed for both the top surface and the bottom surface of every deposit.[1]

The past few years have seen a rapid development of computer vision techniques using overlapping photographs to generate 3D models. The aim of this study is to show how image based modelling can be used within the workflow of documentation and interpretation of an archaeological excavation.

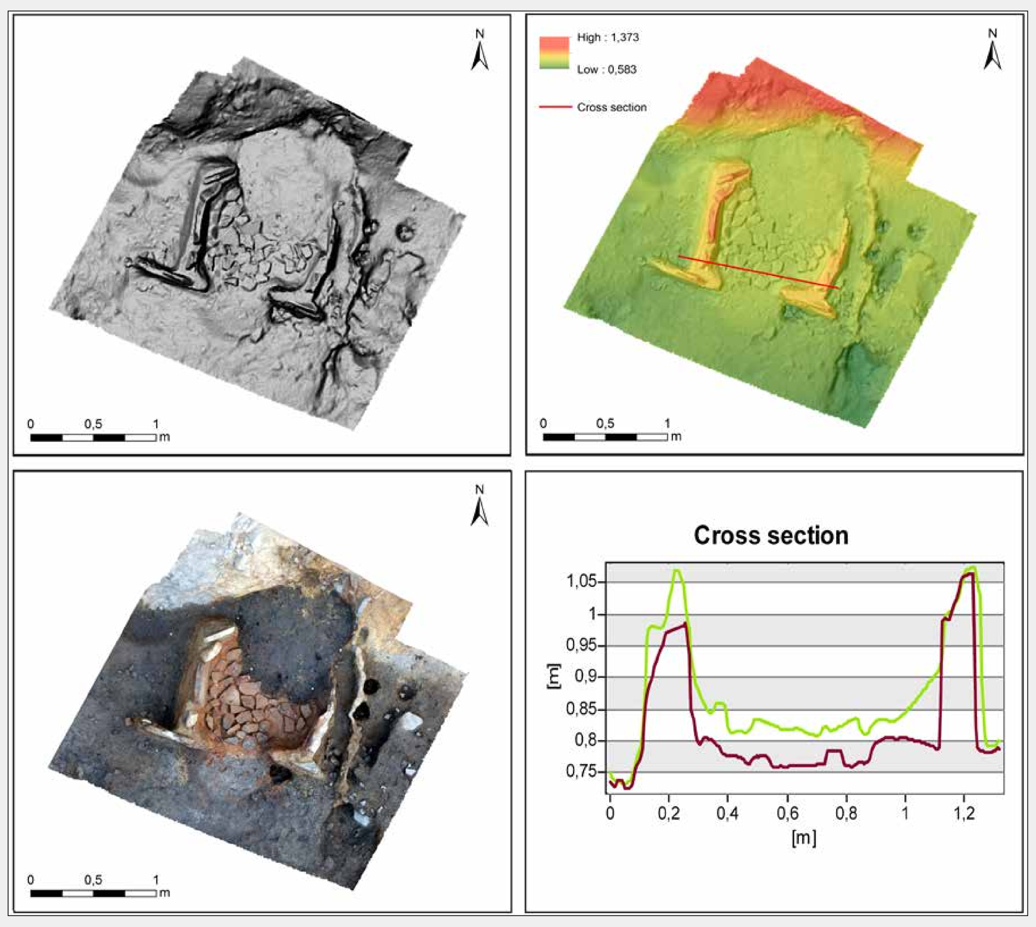



## Workflow

Conventionally digital documentation of stratigraphic excavations is done by taking measurements of the features outlines and topographies (i.e. height points), sometimes complemented with the generation of rectified and georeferenced photographs. As – in terms of quality and confirmability – this approach was not deemed sufficient for the study site of Kleiner Anzingerberg, another straightforward workflow was developed for the application of image based modelling, resulting in a more accurate, but still relatively cost efficient 3D documentation.

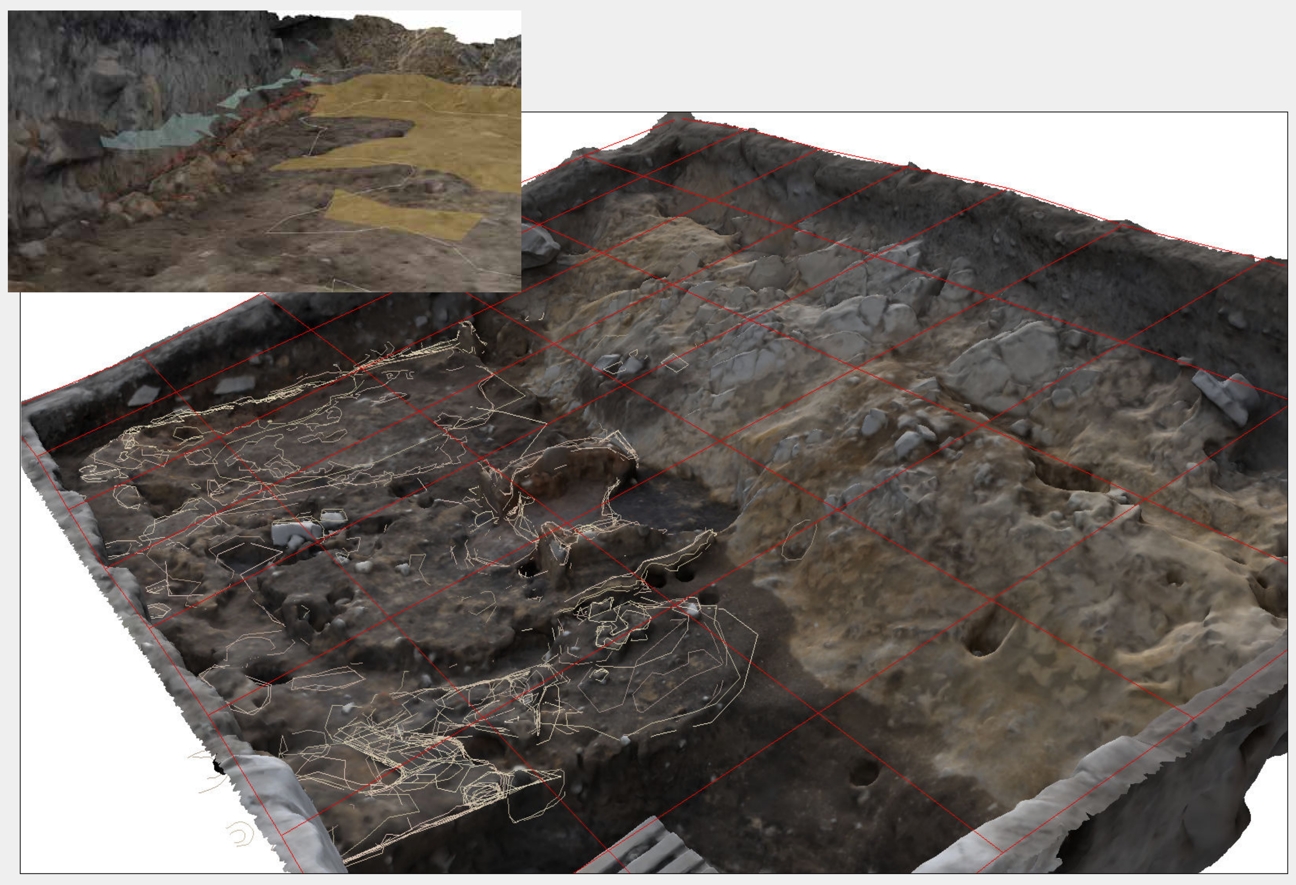
## 2D Data Visualisation

Once imported in a GIS environment, the digital terrain models can be displayed 2-dimensionally; e.g. as (shaded) relief models, as colour coded elevation models or as true orthophotos. Cross sections can be created as well. The stratigraphic documentation method allows to compute virtual profile graphs for every part of the excavation trench, displaying the whole stratigraphic sequence.




## 3D Data Visualisation

3D data should probably best be analysed in 3D. Therefore the different spatial data streams collected during the excavation (outlines, artefacts, samples) are displayed together with the 3D models. Additionally, within a GIS, this data can be augmented with non-spatial information like descriptions or interpretations. This is a rather forceful tool for a combined interpretation, based on "objective" data like 3D models as well as on "subjective" observations.



## 4D Data Visualisation

The 3D models can be animated in time. By moving through the realistically texturized 3D models, sorted according to their stratigraphic position, a 4 dimensional virtual reality can be constructed. With this technique, a digital copy of the recorded features, arranged in time and space, is still accessible after the destruction of the examined deposits and enables a virtual desktop based re-excavation of the site.

Future developments may even lead to (semi-)automatically created matrices based on topological relations of the models.

## Reliability and Accuracy

So far all 118 surfaces recorded in two field campaigns at the study-site could be properly modelled. The average number of photographs used per model is 70. None of the models had an absolute error exceeding 1 cm or 1 pix RMSE measured against the ground control points.

## Costs

As only archaeological standard equipment (measurement unit and camera) is needed for the data-recording, no additional hardware costs are incurred in the field. However, image acquisition needs time and experience. The better the lighting conditions and the choice of camera locations the faster the post-processing, which might require additional hard- and software (although freeware exists as well). The post-processing is quite time-consuming, but it has to be stated that (in particular concerning rescue excavations) there is often no need to compute the models prior to the definition of research questions. But taking suitable images and recording ground control points gives you the chance to calculate and georeference the models at some point in the future.

## Summary

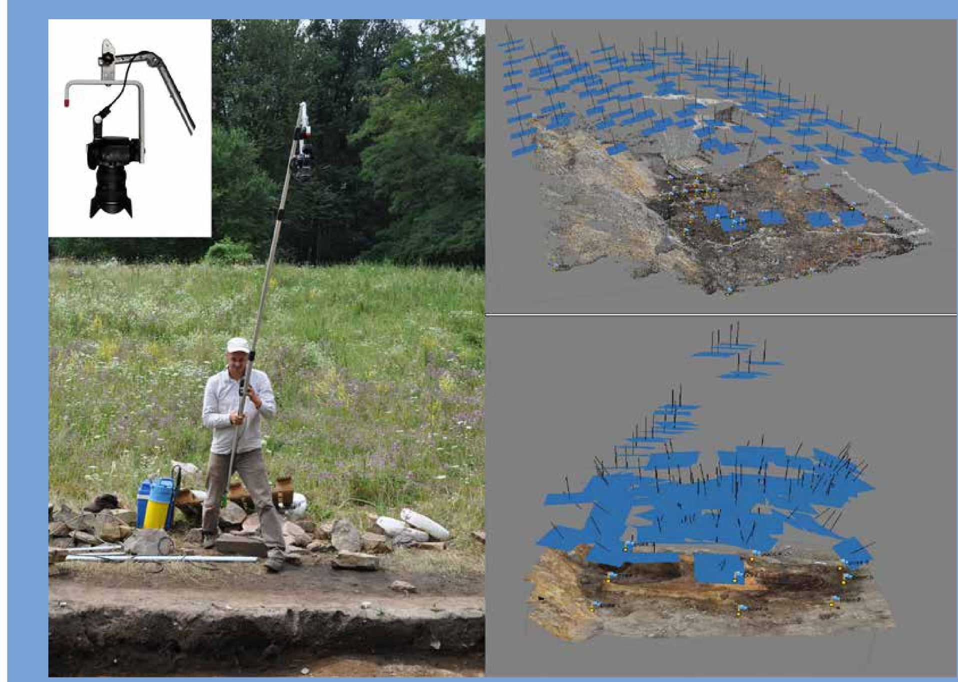
Structure from Motion offers an affordable, easy-to-use and accurate documentation method for stratigraphic excavations. The photo-realistic three-dimensional models can be viewed as virtual replicas of stratification units and thereby allow a verifiable documentation of archaeological remains, which makes the models an excellent basis for interpretation purposes. The main drawback is the lack of immediate control whether the photographs are sufficient to build a model.

## Case Study: Kleiner Anzingerberg

The site of Kleiner Anzingerberg/Meidling im Thale, located in Lower Austria, is an exceptionally well preserved Copper Age settlement (around 3000 cal BC) with a complex sequence of extraordinarily fine layers, indicating numerous different activities.[2]

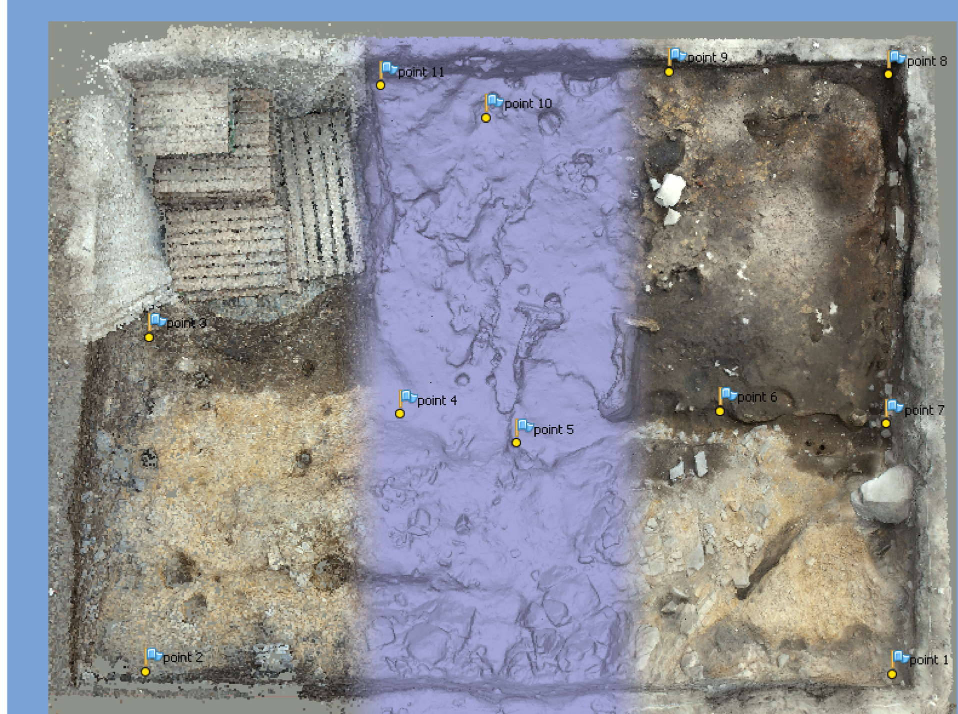

## Pole Aerial Photography & Structure from Motion

To receive accurate and reliable results with Structure from Motion, special attention has to be paid to the process of data acquisition: high image quality and good light conditions are as obligatory as a high stereo coverage of the images. For this purpose, ground based aerial photography was used at the study site. Both a telescopic pole and a photo crane served as camera platforms for the recording of serial vertical and overview shots.[3] Images taken that way can improve the accuracy and point density as well as reduce the computing time required to build the models.



## Data Processing

Computer vision can be used to create 3D models from overlapping images using Structure from Motion (SfM) and Multi-View Stereo (MVS) algorithms.[4] The commercial software Agisoft Photoscan was used in the current case.



| Photo alignment: Sparse point cloud of recognised features (SfM) | Geometry building: Meshed dense point cloud (MVS) | Texture building: Texture projection on the mesh |
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**References**

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**[4]** De Reu J., Plets G., Verhoeven G., De Smedt P., Bats M., Cherretté B., De Maeyer W., Deconynck J., Herremans D., Laloo P., Van Meirvenne M., De Clercq W. 2013, Towards a three-dimensional cost-effective registration of the archaeological heritage. Journal of Archaeological Science 40 (2), 1108–1121.