

3D DOCUMENTATION FOR ARCHAEOLOGY DURING FINNISH JABAL HAROUN PROJECT

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ABSTRACT

The Finnish Jabal Haroun Project (FJHP) is an archaeological project focused on Jabal Haroun (Mt. Aaron) in Petra, Jordan. The Institute of Photogrammetry and Remote Sensing is creating and further developing 3-D model and database, which will be fully implemented once the project's fieldwork is completed. At the same time, various especially photogrammetric documentation methods are developed for the archaeological purposes of the project. Examples from the documentation of planar objects, creation of panoramic images and monoscopic approach to refine the existing DTM are presented here.

3-D database combines various data sources like 3-D tachymeter measurements, photogrammetry using digital camera and video imagery as well as sketches, drawings and notes done by archaeologists. Aerial photographs and GPS have been used to create the basic geographical reference for the project. In addition to the model itself, the available image data will be stored into the database, and the modelling can be later refined based on demand of various users or later needs.

Due to the usually non-repeatable nature of an archaeological excavation work reliable documentation methods are essential. Photogrammetry supported with other 3-D documentation methods enables 'the modelling on the demand' concept.

1 INTRODUCTION

1.1 The Finnish Jabal Haroun Project

The Finnish Jabal Haroun Project is an archaeological project focused on Jabal Haroun (Mt. Aaron) in Petra, Jordan. The FJHP is interested in the extensive ruins of an architectural complex (ca. 3,000 m²) located some 70 m below the top of Jabal Haroun on a wide plateau. The project is designed to uncover, preserve and publish archaeological remains located on the mountain. In addition, an intensive archaeological survey is conducted in the areas around the mountain. The project aims at a full understanding of the ruins of the monastic complex, the topography of the mountain, the history of human settlement on the mountain and in its immediate surroundings as well as the relations to the city of Petra. To support these goals, modern measuring and modelling methods as well as the creation of 3-D database have been part of the project from the very beginning of it.

FJHP is led by professor Jaakko Frösén from Helsinki University. He has collected a multidisciplinary project team. Project's chief archaeologist is Ph.D Zbigniew T. Fiema who has a long experience from archaeological work in Petra. Archaeological team consists mainly from graduate and post-graduate students of Helsinki University. Professor Henrik Haggrén's research group from Helsinki University of Technology (HUT) provides its technical knowledge to the project. In addition, to the project staff belongs architects, conservators and several visiting foreign specialists (for example, in ceramic and glass). During two-month excavation season the staff is approximately 30 people plus local workmen. The project started with archaeological reconnaissance in October 1997 and it is planned to be at least a five years project. The third excavation season is planned to take place in August-September 2000.



Figure 1. Mt. Aaron and part of the archaeological survey area in front of it (seen from SW)

1.2 The Role of Photogrammetry in the Project

Researchers from the Institute of Photogrammetry and Remote Sensing at HUT have been involved in the FJHP since its first season in 1997. The team has both an application and a research task during the project. The aim of the application task is to produce a 3-D model and a database from an archeological excavation site. The model will be focused during the time when excavations are done. The model is produced using various data sources like aerial photographs, video imagery, digital camera images, GPS and tachymeter measurements. The research task is to develop practical 3-D measuring and modeling methods for archeological documentation purposes based on video and digital imagery.

In the beginning of the project the lack of detailed maps and the known geo-reference system was one of the main problems. Aerial triangulation and creation of DTM from aerial photographs was done in co-operation with HUT, Espoo-Vantaa Institute of Technology (EviTech) and stereo-operator Juha Kanto from Finnish Consulting Engineers Ltd. EviTech was also taking part into creation of GPS-network for the project area during season 1998. (For details, see Koistinen et al, 1999).

Characteristic for the project is the cumulative data collection during the excavation season and during the years. Both the amount of data as well as the level of detail increases. Various data sources like aerial photographs, video imagery, digital camera images, GPS, and tachymeter measurements are to be combined to produce the 3-D model. The archaeological excavation work is non-repeatable and therefore it is essential to use reliable documentation techniques. Although tachymeter is used to provide basic 3-D-coordinates needed during excavation process, the very detailed model is more easily achieved using photogrammetry. One interesting subject during the project is to find the correct balance between the different documentation methods.

2 DEVELOPMENT OF DOCUMENTATION METHODS

During the FJHP various experimental photogrammetric studies has already been carried out. Especially the production and use of cocentric video and digital imagery for triangulation and mapping has been under development (Haggrén et al, 1999; Mononen et al, 1999; Pöntinen, 2000). Examples from the documentation of planar objects, creation and utilization of panoramic images as well as the monoscopic approach to digitize surface details are introduced in the earlier paper by the research team (Koistinen et al, 1999). The aim is to develop different documentation methods, for example, using single or several images or blocks, and recorded either with video or digital cameras. The main idea is to replace time-consuming tasks, which have to be done during the excavation season with effective and easy-to-use methods, which can partly or fully be done after the excavation season. The main ideas of the methods are summarized here as well as some examples are shown.

2.1 Documentation of Planar Objects

Documentation of planar objects is a practical tool, which can be utilized already during fieldwork. Traditional method for making accurate drawing of objects in scale can be rather time-consuming task. In case of planar objects, the documentation can be done using simple transformations when some reference points or even geometrical conditions (the simplest set is four points on the corners of a square) are known. By using these points and two-dimensional projective transformations, the images can be rectified "to the floor".

In figure 3 is an example of mosaic floor documented using this method. Image processing is done by Mr. Jyrki Mononen. The lens distortions were first removed. The digital images were combined using projective transformation based on the matching of the gray values of the images. The result is rectified into floor plane using known points. In this case, some details of the floor were measured using tachymeter. Alternative processing possibility would have been directly rectify the first image into floor plane using known points and then combine the other images using projective transformation. To emphasize the use of several images the shades between different images are not adjusted. The parts of the image that are not coplanar with the floor are distorted.

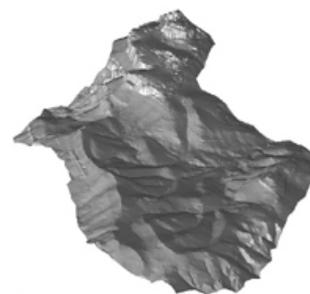


Figure 2. The DTM of Jabal Haroun and its environment seen from SW. After season 1999, it covers a total area of 3 km².



Figure 3. Image mosaic of the mosaic floor

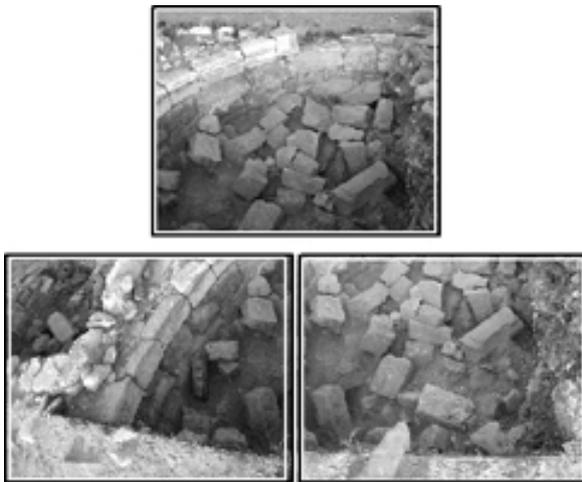


Figure 4. Unprocessed images taken from one of the excavation trenches.

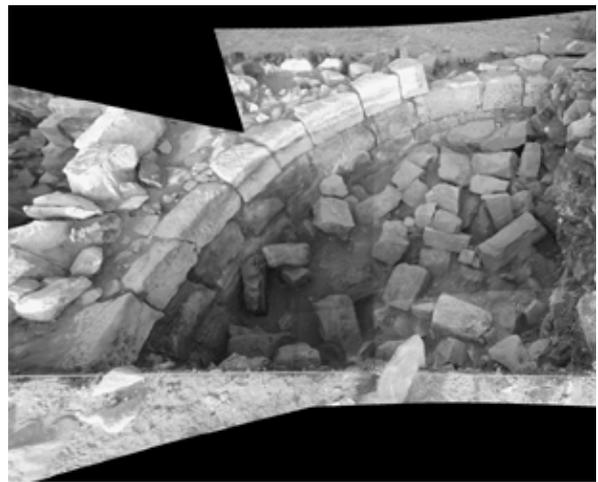


Figure 5. Part of the image mosaic created from three images (in figure 4) using projective rectification of cocentric images (see figure 6).

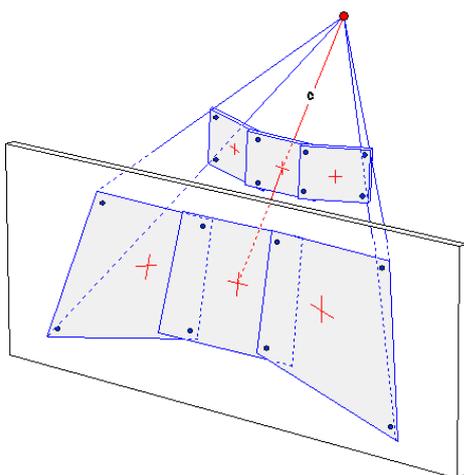


Figure 6. Projective rectification of cocentric images.

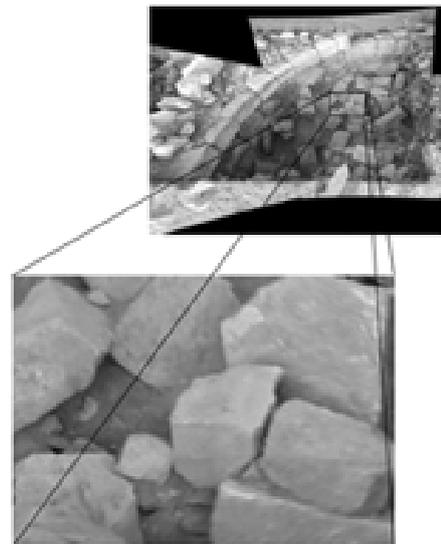


Figure 7. The resolution of mosaics created from cocentric images is high.

2.2 Utilization of Cocentric Images

Creation of panoramic images from cocentric image sequences has been a research topic already during several years in our Institute especially by Mr. Petteri Pöntinen. During FJHP's excavation seasons both video camera and digital camera has been utilized. Image sequences has been taken by rotating the camera on the tripod 360 degrees. If the projection center stays approximately in one place during the rotation, the frames (or images) can be considered to be cocentric central projections of the surrounding world. These frames can be projected onto the cylinder surface and adjacent frames can be combined to a one panoramic image by using the overlaps of the frames. More details from this method can be found in Pöntinen (2000), Haggrén et al (1999), and Mononen et al (1999).

During excavation season 1999 cocentric images were taken especially using digital camera mounted with special device on the tripod. An image mosaic created from such kind of images is shown in figure 5. In this case, images are rectified to the image plane of the rightmost image.

One of the advantages of image mosaics created from cocentric images is that the original resolution of every single image can be utilized. The need for control points is also reduced.

2.3 Refinement of Existing DTM using Monoscopic Photogrammetry

Currently, the tachymeter has been the only reasonable tool for detailed on-site mapping and collection of 3-D geometric data. However, the time that is necessary for performing the tachymeter recordings will nearly entirely reduce the time available for the excavations themselves. Therefore, it would be just beneficiary to find any image based recording solutions in order to reduce the total time of on-site recordings. One promising alternative seems to be the photogrammetric mapping approach based on monoscopic recordings (figure 8).

In case a DTM already exists, detailed mapping can be based on single images. The coordinates of any new point P' identified on image will be determined as the intersection P between the terrain surface and the collinear image ray. The use of collinear intersections presumes that the image should be first externally oriented. This will be done by resection using at least four surrounding points whose 3-D coordinates are already known.

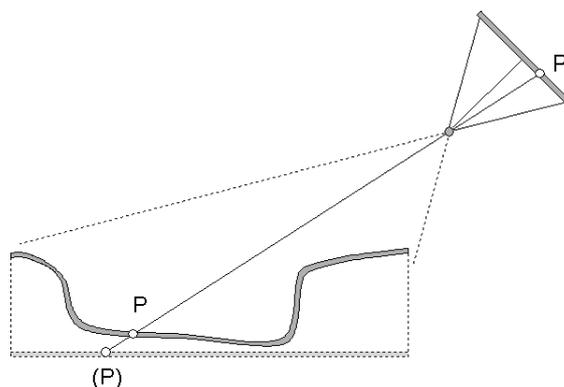


Figure 8. Collinear intersection of new object points on DTM using monoscopic image observations.

As both the DTM and the orientation of the image may be approximate, the 3-D coordinates of the new points will be approximate (P) as well. However, as long as the original image observations P' are also included and stored in the database, the correct location of P can be determined afterwards. This will be done by a bundle adjustment combining a wider block of images and their observations at this location. Similarly, the DTM and the orientation data become refined.

3 THREE-DIMENSIONAL DATABASE

One goal of the FJHP is to build three-dimensional model of the archaeological project, which will combine geometrical and descriptive data collected during the years. The imagery collected during the years should also be included into the database. In addition to the model itself, the available image data will be stored into the database. The suitable imagery can be searched from the database and it is possible to refine the modelling based on the demand of various users or later needs.

The information into the 3-D database comes from several sources and the origin of data should always be recorded. Data is produced using various measuring and modelling methods, which are currently developed and will be further improved for the archaeological purpose of the FJHP. These methods combine 3-D tachymeter measurements, photogrammetry using digital camera and video imagery as well as sketches, drawings and notes done by archaeologists. Aerial photographs and GPS have been used to create the basic geographical reference for the project.

The archaeological work during excavation and survey work produces descriptive and attribute data relating to the geometric model. Geometric data is stored into MicroStation SE files. The tachymeter data is imported to the model using Terrasolid Ltd's TerraSurvey and TerraModeler programs. All collected coordinate information is feature coded. The archaeological descriptive data is currently stored into Access-database created for the project. This data will be connected to the geometrical data. After this various kind of queries can be made based on various criteria.

To enable the effective use of available imagery, the geo-referencing of images should be included into database. The orientation information – even approximated one – is saved. Approximated orientation serves image management. Based on it various kinds of searches for the suitable imagery can be done. When image is selected for processing, for example, to be used for refinement of existing DTM or measuring of details, its orientation has to be considered again. If needed, the orientation is updated.

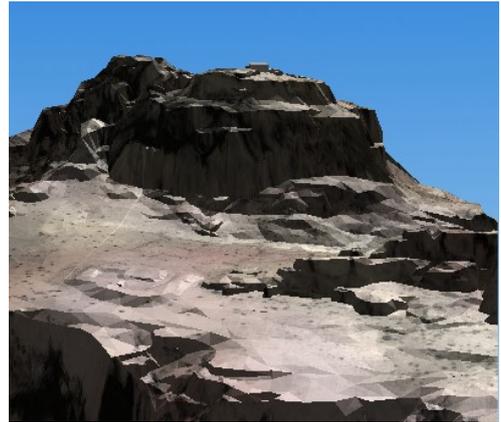
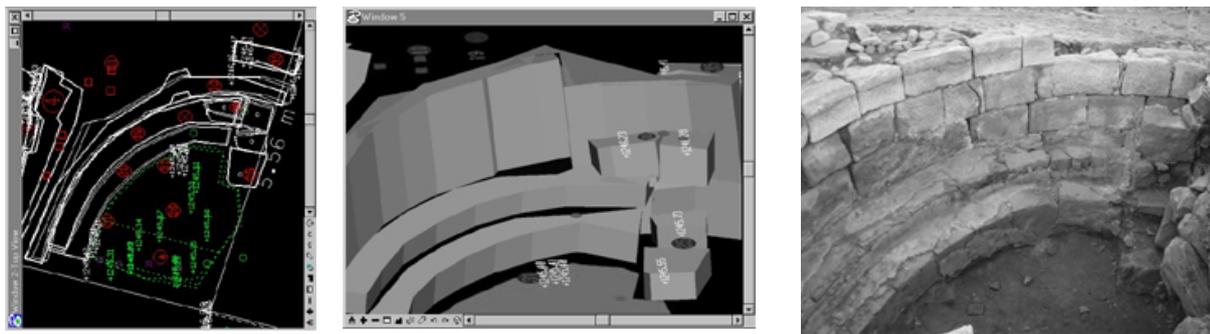


Figure 9. Visualization

Availability of an exact geometric 3-D-model establishes effective visualizations, reconstructions and analyzes of an archaeological site. The data can also be used for education. The visualizations like VRML-models, for example, can be used to get the archaeological site introduced to the publicity.



Figures 10-12. 3-D-data recorded with tachymeter; Rendered 3-D-model; Image to be utilized to add details to the 3-D-model

4 DURING EXCAVATION SEASON

The team has worked on-site already during two full-scale excavation seasons. These periods have provided a good understanding about the conditions on site as well as about the utilization of various methods developed so far. The conditions on-site are demanding both for the humans and the equipment. During the excavation season, the team lives in a Bedouin tent beside the excavation area. Sun, wind, and sand have to be taken into account when utilizing modern electronic equipment in the field conditions. The electricity is produced by the solar panels. The connections to the outside world are provided using GSM-phones and laptop computers. The functioning of modern technology is depending on small details. For example, dust-protection is provided using small plastic bags for the diskettes.

Beside the development of new photogrammetric methods to be used in archaeology, the HUT's team has taken care of the most measurement work on site. At the same time we are trying to find out the best combination of geodetic and photogrammetric methods. As already mentioned, the archaeological excavation work is usually unrepeatably. This sets special demands for the documentation and recording methods that have to be able to cover all the meaningful details at once. The recording methods have to be reliable and sometimes even redundant. Archaeology has strong traditions relating to the documentation methods and techniques during excavation work. In addition to the archaeological photographs taken according to the archaeological tradition, we are taking images (especially digital) to serve the geometrical modelling purposes. As soon as the new documentation methods show their robustness, it is possible to consider the rationalization of documentation processes.

Although the tachymeters are in daily use in both the survey and the excavation area, it has to be remembered that the amount of points measured during a day is limited. The tachymeter measurements are completed by photogrammetric methods. Digital images are taken using both convergent and stereo camera positions. The printed images can directly be used to make notes and interpretations during the fieldwork. The result can then be transformed into the model. The images of planar objects like walls and floors can be rectified, and image mosaics can be created to cover larger areas. The geometry of 3-D model can be complemented using available images, which can modify the existing geometry and enrich the details of the model.

The verification of tachymeter measurements is done daily. However, it can sometimes be difficult to verify what was the exact point measured. Much is relied on the experience of the prism-holder to select appropriate point. Experience is needed when the interpretation of the object and selection of the meaningful points for the 3-D modelling is done. During post-excavation work, even far away from the excavation site, it is possible to utilize collected imagery to verify model and add details not measured during excavation work.

5 CONCLUSIONS

The close co-operation of archaeologists and photogrammetrists has resulted in achieving an understanding of the needs of field archaeology and to visualize the possibilities of photogrammetry and 3-D CAD and GIS systems. Especially the fast feedback of the measuring and modelling work seems to be a very effective way. Undoubtedly, the result of this cooperation is the development of field methods, which can effectively assist archaeologists in their fieldwork and aid them in interpreting the past.

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