

## **THE CUMULATIVE 3D DATA COLLECTION AND MANAGEMENT DURING ARCHAEOLOGICAL PROJECT**

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### **ABSTRACT**

During an archaeological project various data sources and various levels of accuracy and geometric details will be needed in 3D modelling. The subject has been discussed based on the experiences gathered during the Finnish Jabal Haroun Project (FJHP) in Petra, Jordan. Especially the data collection processes - aerial photogrammetry, tachymeter measurements, and terrestrial photogrammetry - are considered. The data management of 3D data and image data are presented.

### **1 INTRODUCTION**

The Institute of Photogrammetry and Remote Sensing at Helsinki University of Technology (HUT) has been taking part into Finnish Jabal Haroun Project, in Petra, Jordan since its beginning in 1997. The project takes care of the archaeological excavations, conservation work and publication of the results at the Monastic complex of St. Aaron and its close environment. The essential part of the project is the archaeological survey conducted in the near environs of the mountain. The project is led by Professor Jaakko Frösén from Helsinki University.

The photogrammetric research team from HUT led by Professor Henrik Haggrén has two basic roles in the project. It takes care of all cartographic documentation work and 3D-modelling during the excavation seasons together with the project's archaeologists and architects. The documentation methods used during field seasons are mainly tachymeter measurements and collection of digital imagery. Beside this practical task the research team is intensively developing new 3-D documentation techniques for the archaeological purposes. The imagery gained during the excavation seasons has been utilised for this.

### **2 PHASES OF AN ARCHAEOLOGICAL PROJECT: VARIOUS SCALES - VARIOUS NEED FOR THREE-DIMENSIONALITY**

An archaeological project can consist of several phases starting from an archaeological reconnaissance or an archaeological survey utilising usually small-scale to middle-scale maps and models. Archaeological excavation work can be seen already as a large-scale project. When considering modelling of finds or artefacts, or documentation for the conservation work, we start to approach one-to-one models or even enlargements of the reality. The need for managing changing level of details sets special demands on the 3D data management of an archaeological project.

Beside the scale also the meaning and need of three-dimensionality varies depending on the scale and purpose of maps and models in archaeology. For small-scale index maps or similar even 2D might be enough. Height information can be very useful in archaeological survey, because the height level might be a significant factor for locating specific sites. The 3D surface fulfils this purpose. It can also be used to produce other presentations, like contour map etc, if needed.

Archaeological excavation work is definitely demanding for the 3D data management. Both 3D GIS as well as 3D CAD modelling features are needed when using stratigraphic excavation technique. The level of detail in 3D models is especially interesting question. It is different to make a 3D model of a modern straightedge houses than, for example, Byzantine partly ruined walls where straight walls are usually an exception. The management of different free-form stratigraphic layers is also one question to be answered.

3D can also be fully utilised when modelling artefacts. Again the level of detail should be selected accordingly to modelling purpose. However, the artefacts can often be modelled using all the possibilities of 3D CAD modelling. If needed, 2D projections can be created when needed.

Further question is to consider, if the maps and models are representing the archaeological data as it is found during the archaeological work, or if they are hypothetical reconstructions based on documented remains.

### **3 EXAMPLE OF DATA ACCUMULATION AND VARIOUS MEANS OF IT**

Archaeological projects last often several years and several excavation seasons. This sets special demands on the data management during such a project. The Finnish Jabal Haroun Project (FJHP) is an example of a long-term archaeological project.

During FJHP, the DTM created using aerial photographs provides the basic small-scale reference for the accumulating data. The tachymeter data collected during field seasons have to be related to this. The further refinement of the model will be done using terrestrial imagery (mostly taken using digital camera). The digital images can be utilised already during the field season to collect specific notes done by an expert on the subject (for example, archaeologist, conservator, or geologist). After georeferencing the

images (the orientation of the image is defined based on the common features on the image and the available 3D model), it is possible to transform the notes into the 3D model - as geometric features or as texture depending on the content.

The geometrical data of the project is currently saved in MicroStation and the collected archaeological attribute data is saved in Access database. The data sets can be linked to create project's GIS solution. This provides additional tools for data analysis after fieldwork seasons. The main methods to collect geometrical data during FJHP (aerial photogrammetry, tachymeter measurements, and terrestrial photogrammetry) are further presented.

### 3.1 DTM CREATED FROM AERIAL PHOTOGRAPHS

The FJHP started with a reconnaissance season in October 1997. Before it the only available means for geo-referencing were a topographic map on a scale 1:50 000 and a set of old aerial photographs. These were too small-scale to be used and a larger scale map was needed. This was achieved using the aerial photographs to measure a DTM (digital terrain model). The DTM covered the upper part of the Jabal Haroun Mountain and it was also used to create larger-scale maps (1:2 000 - 1: 5 000) to be used during the reconnaissance. The process has been described with more details in earlier papers (For example, Koistinen et al (1999); Frösén et al (1998)).

Archaeological excavation work has been conducted on the remains of the monastic complex on the upper plateau of Jabal Haroun since 1998. Beside this an archaeological survey has been conducted on the environs of the mountain in 1998-2000 and will be continued. For this purpose the DTM has been enlarged and it covers now the total area of 6 square kilometres. The enlargement of the DTM is shown in figures 1-4. The excavation site and the survey areas are shown in figure 5. The maps for the use of the archaeological survey have been derived from this DTM. The model can also be used for various analysis, visualisations etc.

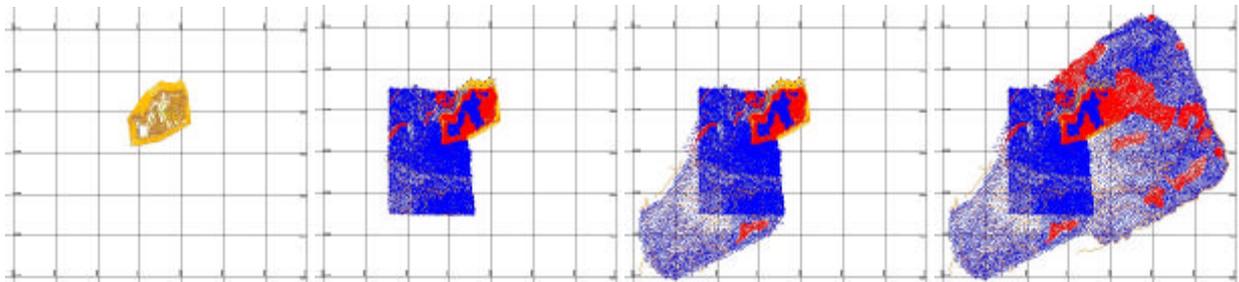


Figure 1-4: DTM was enlarged to cover the survey areas around the Jabal Haroun Mountain.

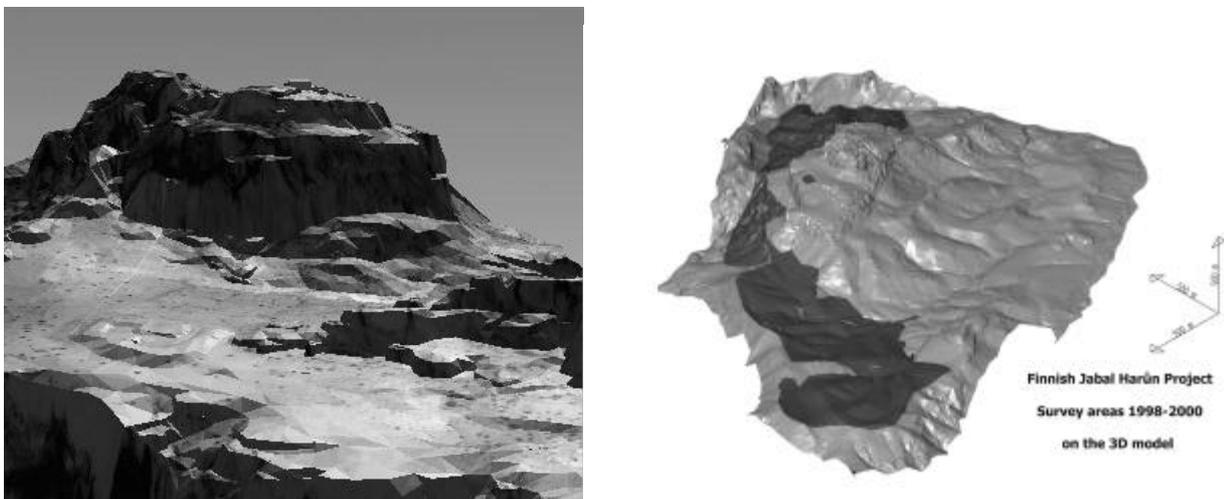


Figure 5-6: The DTM of the Jabal Haroun Mountain. The survey areas and the excavation site are shown on the right figure.

### 3.2. TACHYMETER MEASUREMENTS DURING EXCAVATION SEASONS

The DTM created using aerial photographs is useful during archaeological survey as well as for visualisation, analysis etc. However, the details of it have to be increased with other means. The FJHP has used tachymeters to collect 3D data from excavation site and from the survey areas around the mountain. In the beginning of the first excavation season in 1998 two tachymeter networks were measured. One tachymeter network was located around the excavation site and one in the survey area. The two tachymeter networks were connected using geodetic GPS-measurements.

Tachymeter is used both at the excavation site as well as in the survey area. In survey area tachymeter measurements are taken from various structures like barrages, dams, ruins etc. including, for example, agricultural and hydraulic structures. The archaeologists

walk through the survey areas systematically dividing the area into tracts. The corner points of these tracts are measured and they can be utilised when creating various thematic or statistical analyses with the survey data. The tachymeter data is combined with DTM created from the aerial photographs.

At the excavation site tachymeter is used to collect 3D data during the whole excavation work. The measurements are downloaded daily to the computer. The downloaded data is visualised by importing it into MicroStation program (from Bentley) using TerraSurvey program (from Terrasolid Ltd). Also TerraModeler program (from Terrasolid Ltd) is used especially in DTM creation. The tachymeter measurements are controlled daily to ensure their validity. It is possible to provide up-to-date plans for the use of excavators and to create 3D models and visualisations by using MicroStation. Besides the computer modelling the archaeologists can utilise the coordinate data in their traditional documentation.

It has to be remembered that the quality of tachymeter measurements depends a lot on the skills of the prism-holder to select the points to be measured. Tachymeter measurements should follow the same basic rules regardless of the data collector or the year. The data collection rules (for example, the interpretation of the irregular objects) have to be fixed as early as possible to ensure that the measured data is homogenous. A close co-operation of the archaeological and the data management staff is vital for a successful and usable database. Thus a daily check of the collected data by the both parties is recommended.

### **3.3. TERRESTRIAL PHOTOGRAMMETRY**

Tachymeter measurements can be very time-consuming method to record complicated structures. Therefore terrestrial photogrammetry is used to complete the data collection. During FJHP various strategies to collect image data have been utilised. During reconnaissance season 1997 the use of video camera was extensively tested (Frösén et al, 1998). Especially, the image data was collected by rotating a video camera on the tripod around its projection centre. This data has later been utilised, for example, to create panoramic images.

Since 1998 digital camera (Olympus C-1400L) has been used as the basic photogrammetric recording device. The digital images have many advantages compared to a traditional film camera. The imagery can be verified immediately on the site. The digital images can be used already during excavation season for various purposes. During FJHP both archaeological surveyors as well as conservators have been using the printed images for making notes. These notes can be later transformed into the 3D model because they are related to the image content. An example of notes done during the archaeological survey is shown in figure 7.

The digital imagery is collected systematically during the progress of the excavation work. The stereopairs are taken when there is need to get immediately a 3D image from specific structures. Cocentric image sequences are collected using tripod and specially made equipment which enables the rotation of the camera around its projection centre (Pöntinen, 2000a, 2000b). The imagery collected this way has been processed to create panoramic images. The panoramic images has been successfully utilised for measuring purposes (Haggrén et al, 2001). Images enable the continuation of 3D data collection and modelling after field season.

## **4 USE OF DIGITAL IMAGES**

The digital images can be utilised immediately during the archaeological field season or afterwards when the demand arises. By taking digital images regularly it is ensured that also the data, which doesn't seem to be important at the time, can later be measured from the georeferenced image and thus be documented. This possibility is especially important in the archaeological excavations, where the researcher more or less destroys the research subject. Also some unexpected events can reduce the amount of data collection possibilities. For example, excavated trench walls can collapse before the measurements. If it appears, that insufficient documentation was done while excavating, additional data can be added to the documentation using photogrammetric techniques. The georeferenced images are also a possible data source for the future archaeologists.

### **4.1 DIGITAL IMAGES AND NOTES**

The simplest way to use digital images is to use them already during field season to collect various kind of notes. During FJHP both archaeologists and conservators have conducted this. Of course, the target points for photogrammetric purposes can also be marked on the images. Due to working conditions in Jabal Haroun it has been easiest to print the images and make the notes using pen. The notes have later been digitised. An example of notes on the image done by an archaeologist is shown in figure 7. These kinds of notes are useful for later interpretation of an image. Also the conservators of the project are using digital images to record their notes. The conservators have marked on the images their conservation treatments done during the season as well as the treatment plan. All the notes can later be transferred to 3D model, if needed.

### **4.2 DOCUMENTATION OF PLANAR OBJECTS**

The digital imagery can be easily utilised in documentation of planar objects. This has been described in previous texts by authors (Pöntinen, 2000a; Pöntinen, 2000b; Koistinen, 2000; Koistinen, et al, 1999). The process begin by removing the lens distortions based on calibration data. Some reference data like points or distances should be known from the plane. Simplest set is four points on the corners of a square. The two-dimensional projective transformations are used to rectify the image(s) to the plane defined by the known reference points. The rectified images are combined based on matching of the grey values of the images. The parts, which are not coplanar with the plane, are heavily distorted and can be cut off. During FJHP this technique has been used to create photomaps (image mosaics) of the floors (Koistinen, 2000; Koistinen et al, 1999). An example of such map is shown in figure 8.



Figure 7. Digital images can be used to make notes on top of an image (image Henrik Jansson, FJHP).



Figure 8. Photomap of the mosaic floor. The radiometric differences between images have not been adjusted.  
(Image processing by Jyrki Mononen)

#### 4.3 PANORAMIC IMAGES

Although panoramic images as such are already very fascinating, they have also many advantages relating to their use for 3D documentation purposes. Pöntinen (1999, 2000a, 2000b) has developed algorithms to create panoramic images from cocentric image sequences collected by rotating camera around its projective centre. So far, the image sequences has been collected as video sequence which is framegrabbed or as single images taken by digital camera. A specific device has been developed to enable the rotating of camera around its projection centre. The panoramas can be full circle (360 degrees) or less. The full circle panoramas are projected to the cylinder. The smaller panoramas can be kept in selected image plane and utilised for measurement purposes like they were single images. The advantage of such images is, for example, that the need for control points is reduced. Example of panoramic image is shown in figure 9.



Figure 9: Panoramic image created from the apsis of the church (image processing by Jaakko Järvinen)

#### **4.4 DOCUMENTATION OF ANCIENT ROAD**

The documentation of an ancient road is an interesting example of archaeological documentation using terrestrial images. The digital images have been taken during FJHP field season 2000. The basic route of the ancient road found in the survey area SW from Jabal Haroun has been mainly recorded using tachymeter. To create a more detailed documentation terrestrial digital imagery has been collected. It consists of close-up stereo views along the road line sighting back and forth, and of panoramic images recorded aside the road. Both the tachymeter data and the DTM collected from aerial photographs (various features like wadi bottoms) have been used for image orientation. A separate paper on the subject is presented in CIPA Symposium 2001 by Haggrén et al (2001).

#### **5 DATA MANAGEMENT**

The data management plan of an archaeological project has to be well defined and tested. Data flow from the measurements until the end products (maps, plans, and visualisations) has to be considered in advance. During the fieldwork the data management personnel can then concentrate on the well-defined routines and they will not waste their energy in trying to control the increasing data amounts. Post-fieldwork research is also easier when data is well classified and archived. The data flow should also include necessary backup routines. Both the management of 3D data and image data during FJHP are shortly presented in following chapters.

##### **5.1 MANAGEMENT OF COLLECTED 3D DATA**

To ensure that all the data is compatible one coordinate system (UTM) is basically in use. However, due to the different accuracy levels of various data sources the original data is kept separately from each other and referenced when needed. The coordinate transformations between different data sets are defined, if needed. MicroStation's feature to use reference files is effectively utilised to manage different data sources and data types.

The collected data is hierarchically organised. Every point or element has its encoding relating to the entity it belongs to. For example, a measured coin gets a unique tachymeter-ID-number, code number telling it is a coin, and an entity number which tells in which trench and locus it has been found. This information is available when the data has been downloaded into DGN-file and can be utilised when linking attribute data from Access-file.

##### **5.2 MANAGEMENT OF COLLECTED IMAGE DATA**

One important question to be answered is the management of the collected image data. During past excavation seasons thousands of digital images has been taken. In addition to the original files we have to consider the management of processed images (distortion free images, panoramic images, rectified images etc.). One important aspect is the management of orientation data related to the images. In the beginning just a rough orientation information is available. During the processing more accurate orientation data will become available. The update procedure for image orientation data is therefore essential. Geo-referencing of images can be done using various techniques. Most simple way to do it is to define the camera place and the point at which the camera was aimed. From the georeferenced images it is possible to search the available images when image need arises. In archaeological application also the time stamp has to be considered. The efficient management of images enables that suitable imagery is easily available when measurement need arises. In this way it is possible to follow the 'modelling-on-the-demand' philosophy (Koistinen, 2000).

Image data management in FJHP is currently under development. So far all the images have their time stamp (date, time of the day), and at least a rough georeferencing. During field seasons image diaries are written using HTML-language. The HTML-files enable an easy visual evaluation of collected imagery. The describing comments written by photographer are useful when further processing images. For example, these comments might relate to imaging strategy ("panoramic taken with tripod and special device" or "stereopair") or specific conditions.

#### **6 CONCLUSIONS**

The combination of various data sources and methods (including photogrammetric, geodetic, GIS, CAD, and archaeological) enable the cumulative creation of the 3D database. The data management need to be considered during all the phases of project to enable sustainable system. Collection of image data enables the completion of documentation even after the field season. Furthermore, the collected data can be used as source data when deriving virtual models, functional models or, for example, maps showing areas of distribution. Various data sources and various scales set special demands on the data management.

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