

VISUALISATION OF A NECROPOLIS ON THE BASIS OF A PORTABLE AERIAL PHOTOGRAMMETRIC SYSTEM AND TERRESTRIAL LASER SCANNING

R. Brechtken^a, H.-J. Przybilla^a, D. Wahl^a

^a Bochum University of Applied Sciences, Department of Surveying and Geomatics -
rainer.brechtken@hs-bochum.de

Commission V, WG V/4

KEY WORDS : Application, Archaeology, Cultural heritage, Fusion, Photogrammetry, Terrestrial, Three-dimensional, TLS, Navigation

ABSTRACT:

This paper describes data collection for three dimensional visualisation based on measurements of terrestrial laser scanners in combination with digital aerial photogrammetric data. For these methods an archaeological excavation area in Egypt is chosen. The whole process, with special focus on the different measuring methods and the data fusion, will be described. 3D visualisations of various objects are demonstrated.

1. THE ARCHAEOLOGICAL EXCAVATION „ATHRIBIS“

The ancient city of Athribis is located 140 km northwest of Luxor and 400 km south of Cairo on the east side of the river Nile. One of the most significant historical buildings in this area is the temple of the lioness queen REPIT. This temple was build between 80 and 50 BC.

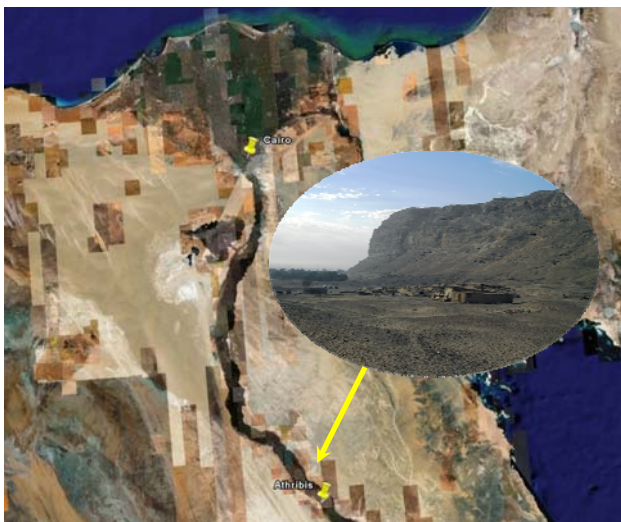


Figure 1. Athribis, Egypt. (© GoogleEarth Copyright 2007)

The archaeological excavation site of the Athribis temple is an example of a research project with international partners. Since 2003 the entire surveying work in Athribis is achieved by Bochum University of Applied Sciences, Dep. of Surveying and Geomatics. Besides classical geodetic surveys (for setting up the geodetic net) more and more 3-D technologies, like terrestrial laser scanning and digital photogrammetry, are used for the documentation process.

In addition to the temple complex a neighbouring mountain site (more then two kilometres long and about 200 m high (figure 18)) is part of the research project. It is the place of the necropolis and generates increasing interest. In the 2007 campaign a documentation concept was planned which consists of long range terrestrial laser scanning on the one hand and low altitude aerial photogrammetry on the other hand.

2. MEASUREMENT METHODS

2.1 Terrestrial Laser Scanning

During the last campaigns a complete survey of the area in the vicinity of the Repit temple was carried out by means of the medium range scanner Z+F Imager 5003 and 5006 (Obertreiber & Stein, 2005, figure 2). The typical data amount of such a campaign: 37 Scans / 1.8 Billion Points / 9.3 GByte.

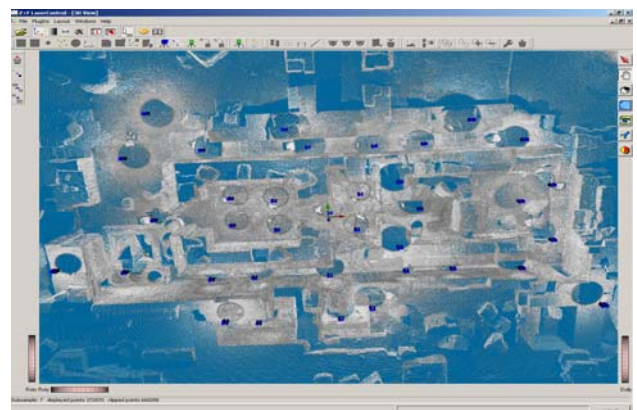


Figure 2. Athribis, Repit Temple pointcloud

After the completion of the geodetic survey in the vicinity of the temple, the archaeologists asked for a method to extend the survey to the surrounding terrain. Because of local restrictions

(military exclusion zone), no measurements outside the temple area could be arranged.

The first step was to use the Riegl LMS-Z420i (figure 3), a long range terrestrial laser scanner, with a maximum range of up to 800 meters. Because of the rough terrain and the military restrictions it was not possible to get a complete point cloud of the requested area. So the idea for a photogrammetric mission flight was born to fill the existing gaps of the point cloud and to extend the captured area (figure 4).



Figure 3. Riegl LMS-Z420i

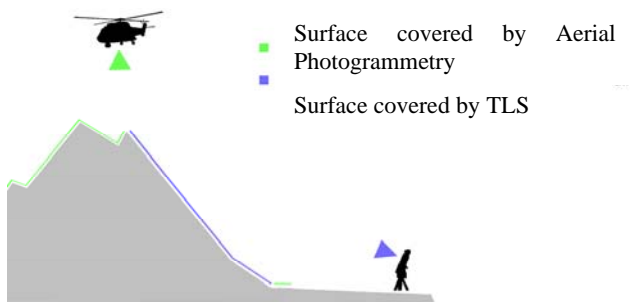


Figure 4. Surface Measurements TLS / Aerial Photogrammetry

2.2 Aerial Photogrammetry

Taking aerial images in Egypt, by a foreign university, is a more than complicated process and can only be successful with good connections and supporters. In cooperation with the Egyptian military a helicopter flight was realized. Because no photogrammetric equipment was available on the location, the complete camera-, navigation- and data processing hardware and software had been brought from Bochum. For the aerial images a Rollei AIC (Figure 5) with 39 MPix was used. Technical specifications are as follows (table 1):

Focal length:	51 mm
Shortest Exposure Time:	1/1000sec
Sensor format:	7228 pix by 5428 pix

Table 1. Sensor specifications



Figure 5. Rollei AIC



Figure 6. Nav-System EasyNav

The available flight crew did not have any experiences in flying for aerial survey, therefore the application of a GPS based navigation system was strongly recommended. For that, the EasyNav System was chosen, which is part of the LEO system, developed by Bochum University of Applied Sciences (Heimes & Brechtken, 1992, Baeumker et al., 1997, 1999). This system is especially designed for small and medium photogrammetric systems. The complete hardware is rugged assembled under military specifications. For the Athribis project only the navigation part of LEO was used, the complete hardware is shown in figure 6. This system can be operated without any use of mouse or keyboard during the flight. If required the navigation system can be extended by DGPS / INS and also with a stabilized mount. The mount for small and medium sensors is shown in figure 7.



Figure 7. Stabilisation Mount

The mission planning was also done with EasyNav. It had been planned to acquire the desired area with a ground resolution of 25 cm, and smaller areas with 10 cm and also with 2.5 cm. To avoid unsharpness, especially at GSD = 2.5cm, it is necessary to reduce the ground speed of the sensor platform. The maximum distance during exposure should not be larger than half a ground pixel. With a shutter speed of 1/1000 sec the maximum ground speed is:

$$0.5 \cdot 2,5\text{cm} \cdot 1000 = 12.5 \frac{\text{meter}}{\text{sec}} \approx 24\text{knots}$$

This maximum speed is too slow for using airplanes, but with a helicopter it can be realized. For data processing on the location a powerful notebook with a high resolution display was used. Based on information extracted from Google Earth (Figure 8), all mission planning were already completed in Germany.

The photogrammetric work was done with Socet Set 5.3 by BAE Systems (BAE Systems, 2008). The complete system, consisting of camera, navigation system and photogrammetric workstation, was carried in one suitcase as hand luggage to Egypt.

For the mission flight only 2.5 hours were arranged. The helicopter, a Russian MI-17 (Figure 9, maybe a little bit oversized for such a compact photogrammetric system), was located in Luxor. The ferry flight to Athribis and back to Luxor took 1.5 hours, so nearly 60 min were left for the real photogrammetric flight. There was no possibility for a test flight or to teach the pilots. Only during the ferry flight to Athribis some kind of training was done. These, of course, were no perfect conditions, but the pilot did a very good job. Because of the limited time schedule it was not possible to collect all images, but enough images could be taken in all three planned flight levels. To be on the safe side, the low level flight with a

2.5 cm ground resolution, was changed in such a way that a ground resolution of 4 cm was finally obtained; this decision was made during the flight. In addition to the Athribis excavation area also one high resolution line was flown above Achmim, an archaeological site 10 km north-east of Athribis. In total 36 images were taken, with 4 cm, 10 cm and 25cm above Athribis, and 4 images with 2.5 cm above Achmim (figures 10 - 13).



Figure 8. Google Earth Mission Planning (© GoogleEarth Copyright 2007)



Figure 9. Russian MI-17



Figure 10. Athribis 4 cm GSD



Figure 11. Athribis 10 cm GSD



Figure 12. Athribis 25 cm GSD



Figure 13. Achmim 25 cm GSD

3. DATA PROCESSING

3.1 Photogrammetric Data processing

The acquired aerial images were used to produce digital elevation models with a raster width of 10 m for production of orthophotos with a GSD of 4 cm, 10 cm and 25 cm (figure 14). TLS control points in the vicinity of the temple were used as control points for the aerial triangulation. Concerning the 25cm orthophoto it was necessary to use some points from the Riegler laser scanner point cloud as additional control points.



Figure 14. Athribis Orthophoto 10 cm GSD

In addition to these photogrammetric mapping results, also a digital elevation model with a raster width of 50 cm was calculated for the later fusion with the Riegler data (figure 15).

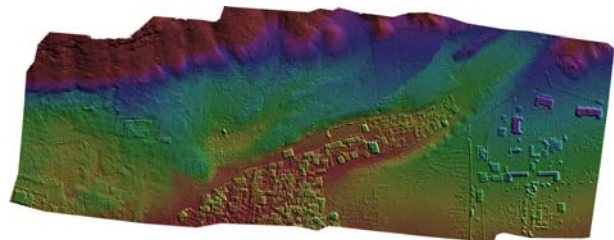


Figure 15. Athribis 50 cm grid DEM

3.2 Surface measurement with Riegl LMS-Z420i

To capture the surface of the necropolis as well as the surrounding area of the temple the Riegl laser scanner was chosen. In total 11 positions were used for these measurements (figure 16). The control points were determined by rapid static GPS. At least 5 control points were visible on every single position. Using the software package RiscanPro the single point clouds were transformed into the reference system, with an accuracy between 1.5 cm up to 4 cm for a single registration. As shown below the scanner point cloud is very detailed but there are some gaps as a result of the local topographic conditions.



Figure 16. Riegl scans (overview)

3.3 Data Fusion TLS - DEM / Photogrammetric – DEM

The DEM which was derived from the TLS was completed by the high resolution 50 cm photogrammetric DEM. So the area was extended and also the existing gaps were filled. Some accuracy investigations were done to compare the fitting between both data sets. Several subareas with complete coverage of TLS and photogrammetric elevation data were compared with the software Geomagic Qualify (Geomagic, 2008, figure 17). The accuracy of the photogrammetric height data (based on the 25 cm GSD DEM) was determined with ± 18 cm. Therefore the TLS data were taken as the reference DEM, because of its higher accuracy.

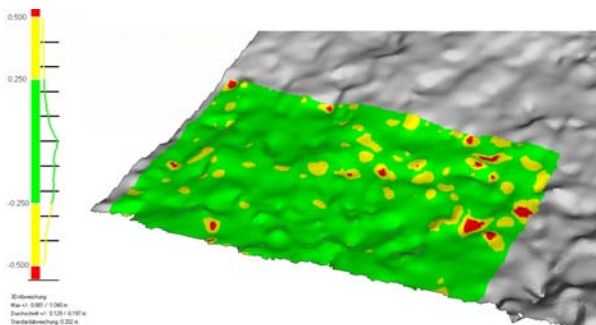


Figure 17. Comparison of overlapping TLS and photogrammetric DEM

4. VISUALIZATION

Based on different data resources, like aerial and terrestrial images, the unified DEM and several mid range scans by Z+F 5003 and Z+F 5006, the Repit temple area and also the Asklepios temple, located between the tomb caverns at the necropolis, were visualized (figure 18). For that several software packages and tools were used; the workflow is shown in figure 19 [Wahl, 2008].



Figure 18. Mountain site with necropolis and Asklepios temple

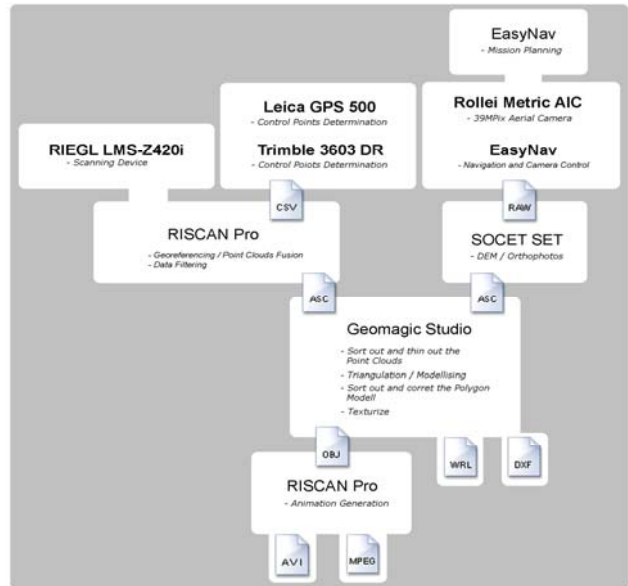


Figure 19. Visualization Workflow

The Asklepios temple had been cut into the rocks, which also contains the tombs. The interior of this temple was scanned by the Zoller + Froehlich Imager 5006. The georeferencing, the data manipulation and the 3D modelling was done also with RISCAN Pro and Geomagic Studio. As a result a very precise 3D model of the complete temple could be realised. Figure 20 shows the main portal of the Asklepios temple and also several subsurface chambers.



Figure 20. 3D-Model of the Asklepios Temple

In addition to these visualisations a number of cross sections (figure 21) through this subsurface building were generated. Especially these precise cross sections are of great value for the documentation of this excavation site. Further on some flights through and overflight animations were created.

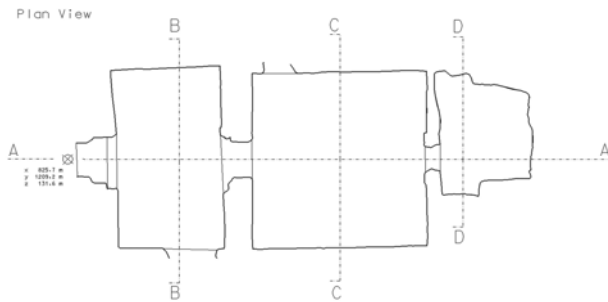


Figure 21. Asklepios Temple cross section (plan view)

5. CONCLUSIONS

As a result of the innovative developments in geodetic measurement technologies on the one hand and enormous improvements concerning GI-technologies on the other hand, a lot of new methods are available for archaeological documentation. The Athribis project is an example for this kind of processes. Using different ways of measurement techniques, with the intention of data fusion, leads to a complex 3D database of the archaeological site, as a basis for further investigations.

Goals of next campaigns will be the localization of all tomb caverns of the necropolis by means of GPS and their adoption into the archaeological GIS. Also the surrounding area of the Repit temple will exempt from the covering sand. So the complete excavation site will increase and the geodetic and photogrammetric data, in combination with the archaeological results, will complete the GIS.

The experiences at this excavation site during the last years demonstrated the great benefit of the wide range of geodetic and photogrammetric methods for the archaeologists. Besides the "classical" results, like cross settings or geodetic net measurements, the combined TLS and photogrammetric

methods in combination with the 3D visualization gave impressive results to the archaeologists.

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