PHOTOGRAMMETRY IN EPHESOS – RECORDING BASIC SPATIAL DATA

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The presented project is a co-operation of the Department of Photogrammetry (TU Istanbul), the Institute of Photogrammetry and Remote Sensing (TU Vienna) and the Austrian Archaeological Institute (Vienna).

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ABSTRACT:

Ephesos, on the west coast of Turkey, has been one of the most important cities of the Roman empire. Here, Austrian archaeologists carry out research and excavation for more than a hundred years. The first and the last comprehensive geodetic surveying of the whole area of Ephesos dates back to the very beginning of the Austrian activities. Aim of the current project is to obtain a valid mapping of the region of ancient Ephesos with the neighbouring sanctuary of Artemis. Seven infrared aerial photographs form the fundamentals of the photogrammetric process. Contoureline, inclination and shaded relief maps were derived from a terrain model and research work done into ancient water conduits. A Mosaic-Orthophoto was generated from the arial images with help of the terrain model. This map, together with the revised photogrammetric line analysis and the city plan, the latter generalised for a scale 1:5000, have been united in a GIS.

1. INTRODUCTION

Ephesos, on the west coast of Turkey, was one of the most important cities of the Roman Empire. Here, Austrian archaeologists have been carrying out research and excavation for more than a hundred years. The first and the last comprehensive geodetic survey of the whole area of Ephesos dates back to the very beginning of the Austrian activities (Schindler, 1906).

Aim of the current project is to obtain a valid mapping of the region of ancient Ephesos including the neighbouring sanctuary of Artemis. Drawing up a digital terrain model, an orthophoto as well as a cartographic map are the pursued goals. A digital plan of the ancient city, generated by means of digitised plans and new surveying, was already available at the start of the project.

In the following, the possibilities and applications offert by spatial data will be shown at the example of Ephesos.

2. ORIGINAL MATERIAL AND PRECONDITIONS

Seven infrared aerial photographs taken in 1997 form the basic material of the photogrammetric process. The arial photographs were taken by Turkish authorities on the occasion of an inspection flight regarding the amount of standing timber:

- aerial photograph format: 23 x 23 cm
- imagescale: 1:15000
- year of flight: 1997

The stereographically evaluated model area covers a surface of approx. 32 km2. The details were interpreted in an area of 18.4 km2, which includes the urban area of Ephesos with its city walls, the sanctuary of Artemis and the Ayasoluk with St. John's Church and the castle.

Due to this special purpose the photographs do not provide any geodetically measured controlpoints signalised in the course of the flight. For analysis it was therefore necessary to select natural controlpoints in the pictures, characteristics such as edges of roofs, traffic-line markings etc. were used, which then had been measured in the field by GPS (Global Positioning System). Therefore it was possible to implement the aerial photos in the Ephesos Reference Frame 1998 (ERF98) in which all other surveying in Ephesos is made. The ERF98 is defined by the global reference frame (ITRF94). Measurements for the bundle adjustment as well as the entire further mapping were undertaken with an analytic plotter. Following the bundle adjustment a medium standard deviation of ±18 cm at position and ±25 cm at height (internal accuracy) resulted for the tie points (points visible in two or more photographs but without ground control).

3. DATA AND ANALYSIS

In the course of stereographic analysis the whole visible situation (vegetation, traffic zones, buildings, waters, etc.) was measured. In order to create a digital terrain model (DTM), a point grid by 20 x 20 m resp. 80 x 80 m (varies due to the character of the ground) as well as breaklines were measured. So a very detailed recording of the terrain structure was achieved. Apart from photogrammetric regular points and breaklines, terrestrial as well as GPS surveyed points and breaklines were also involved in order to gain the digital terrain model. This procedere proceeding a substantially increased accuracy, especially for areas in close neighbourhood to archaeological sites. Finally, about 80 000 points were used to derive the DTM..

4. ORTHOPHOTO MAP

Four orthophotos were generated from the aerial photographs with the help of the new terrain model. Then, these orthophotos were combined to one single orthophoto map (Figure 1). The resolution of the digital orthophotos is limited by the scale of

the aerial photos (1:15000) and by the resolution of the scanner (15µm). The colours of the infra-red images were converted by means of a colour transformation- and intensity matrix, with additional parameters of practical experience into images of natural colouration[*].

Again this map, including the revised photogrammetric line analysis and the city map, the latter generalised to a scale 1:5000, resulted in a GIS (Geographic Information System). Contour line, inclination and shaded relief maps were derived from the terrain model.

One aim was to create a layer of the archaeological resources for the orthophoto map scaled 1:5000. For that purpose the digital city map of Ephesos had to be generalised. This map was generated by surveying and by digitising existing paper plans (scales between 1:50 and 1:200). The plans were tied up through measurements of control points in the field; then the digitised plans were converted by a neighbourhood transformation (Hardy, 1972) (multiquadratic interpolation); thereby an optimal absolute infitting under maintenance of inner geometry of the drawings was obtained. Figure 2 shows the area of the East gymnasium with generalised vectordata and the underlying orthophoto in natural colouration.

Infra-red pictures are often used for photo interpretation work, because of their special properties. The emulsion of the film is sensitive to the spectrum of near infra-red light and represents it in red colour. The vegetation emits strong infra-red rays and therefore allows to distinguish between different plants. Because of the strong influence of the ground conditions on the vitality of the plants, it is possible to see them at the colour gradation in the photos.

To verify the aerial photo interpretation an area south of the Arkadiane was chosen, which is a colonnaded street leading from the theatre to the habour. Here the Byzantine city wall (in Figure 3, drawn in blue) encloses a rectangular area[**]. Archaeological excavations took place: at the gate on the southside of the Arkadiane, at the street leading south, at the westgate of the Agora, at the so called gate "Medusentor" and at the street leading east to west. On the aerial photograph a rectangular place is visible, showing a circular monument in its centre, the place is surrounded by a pillared hall. The square measures on its sides 85 m and the diameter of the central circular building is to 20 m.

5. WATER CONDUIT

In ancient times Ephesos was supplied by several great water conduits. One of them starts in the south at a place called Değirmendere, it has a total length of 43 km (Öziş, Atalay, 1999).

Starting point for the following computations was the consideration that ancient water conduits often follow the topography. There is the question, if it is possible to model approximatly the course of the water conduits by applying a mathematically defined terrain surface of DTM. If it is

succesful, it could optimize fieldwork and model areas where no architectural remains are left.

In this case an elevation of 62 m on the aerial analysis was messured at the aqueduct Arab-dere-kemer, which is the nearest to Ephesos. By following the calculated run of the water conduit in the direction to Ephesos on the DTM and by assuming a fall of 0,5 Promille[***] for the calculations, the course as shown in Figure 4 comes out. This results corresponds well with an elevation of 60 meter over the sea proved by Forchheimer (1923) the water conduits on the north side of the Bülbül Dağ.

5.1 Errors

Which errors can occure by simplification?

  a)   By the calculation every valley is driven in the full length without any aqueduct, therefore a greater distance has to be covered and more difference of altitude "is used".

  b)   b) Also a terrain saddle, which in ancient times was used to shorten the distance by digging a canal or a tunnel, therefore construction expense was reduced.

Both errors are model errors, which are leading to the assumption of a water conduit lying too deep in the area of interest.

What are consequences of errors in altitude necessarily lead on the model, and what are the consequences of changes of the landscape on the determination of the position of the water conduit?

  c)   c) In a very steep area of 50% inclination as it occurs on the north slope of the Bülbül Dağ, an altitude error of ±1m and an error of position of ±2 m has to be calculated.

  d)   d) If you have now an inclination of 10%, 1 m would amount to an uncertainty of the position of ±10m.

  e)   e) Having an even area, it is not possible to estimate the line course only in presumtion of an incline.

Those cases show very clear by the importance of the stochastically model for DTM, to be able to value the reliability of the results. For the model calculations in this place discussed only the starting point and the terrainmodell were assumed. If there could be introduced more points, that define the water conduit in the field and are surveyed, the calculations could be improved.

REFERENCENS

Forchheimer, Ph., 1923. Wasserleitungen, In: *Forschungen in Eph*esos *Band III*, Wien, pp 233.

Hardy, R.L., 1972. Geodetic applications of multiquadratic analysis. *Allgemeine Vermessungsnachrichten 79*, Herbert Wichmann Verlag, Karlsruhe, pp. 398-406.

Hueber, F. 1997. Gebaute Geschichte. von Zabern, Mainz am Rhein.

Öziş Ü., Atalay A., 1999: Fernwasserleitungen von Ephesos, In: H. Friesinger - F. Krinzinger (Hrsg.), *100 Jahre Österreichische Forschungen in Ephesos. Akten des Symposions*, Wien 1995, pp 407.

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[*]   Carried out by Prof. Dr. Dipl.-Ing. J. Jansa, Institute of Photogrammetry and Remote Sensing, TU-Vienna.

[**]   F. Hueber, Ephesos (1997). Gebaute Geschichte (1997) pp. 51.: "Der Platz südlich des Viersäulenbaues ist heute an der byzantinischen Stadtmauer zu erkennen, die seine Außenwände als Teil der Befestigung mitbenutzte. Sonst sind von diesem Platz nur noch einige Säulenbasen der Kolonnaden erhalten."

[***]   Öziş, Atalay (1999) prove a incline of 5 per mill, this shoud be an errat, because my estimation of the elevation difference from the spring to the aqueduct including the length of the water conduit results a value of about 0,5 per mill.

Schindler A. 1906, Bemerkungen zur Karte. In *Forschungen in Ephesos Band I*, Wien, pp.235.

Figure 1: Orthophoto map

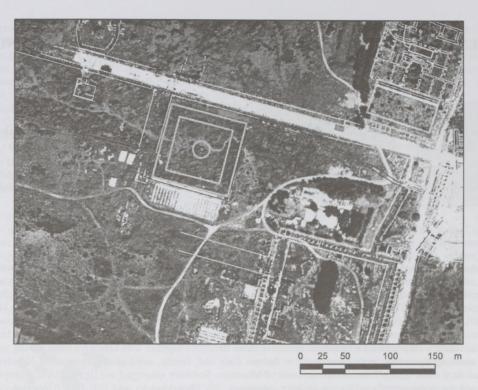Figure 2: Generalised city map and orthophoto in natural colouration

Figure 3: Aerial photo with interpretation (green)

Figure 4: Calculated run of the water conduit