BALLOON PHOTOGRAMMETRY FOR CULTURAL HERITAGE

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SS 4: CIPA — Low-Cost Systems in Recording and Managing the Cultural Heritage

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ABSTRACT:

Documentation and measurements on historical buildings are mostly connected with close-range photogrammetry for high resolution in order to analyse the detailed structure of the objects. Classical flight campaigns are expensive, limited by the resolution or restricted. An alternative with immediate access to the data is the use of a helium-balloon based platform with digital camera.

For a project in the southern part of Turkey has been developed a system with a He-Balloon, a digital camera, a control-monitor and a mechanic stabilization. As digital camera was chosen an Olympus Camedia 4040 with 4 Mega-Pixels, which has been calibrated. The Camera was fixed in a triangle frame on 2 axes, so that it had always nadir view. The triangle frame was fixed with 6 ropes below the balloon, and to the ground with 3 ropes, one carried a video and control wire. The video signal of the cameras view was sent to a monitor and the remote control of the camera was also solved by wires.

Then a flight-campaign in August 2002 was made over an excavated historical theatre in the former city of Patara, the former major port of Lycia, located at the mouth of the Xanthos River. In the presentation we want to show you the technical solution and the results of this campaign. The accuracy of the aerial images was better than 4 cm in position and height, the digitising however complex, related to the objects structure. The 3D-Vector data built the base of a fine DTM. Orthophotos have been created in order to add information the digitised results.

1. INTRODUCTION

In photogrammetric application, image acquisition is one of the most expensive steps. Especially if aerial images must be taken, the expenses are always high because of the high-cost of aircraft campaign. In some cases, other solutions for aerial imagery such as kite, balloon and remote-controlled model helicopter or aircraft can be the optimum solution (Leloglu et all). These types of solutions can be used, if the area of interest is small and non-metric cameras are enough accurate for the job.

In this study, a low-cost solution for low-altitude aerial photogrammetry is represented. The system is designed for general purposes of low-altitude aerial photogrammetry. However with some additional parts, the consisting system can be used for special purposes.

2. SYSTEM OVERVIEW

The system contains two main units. As illustrated in Figure 1, these are;

- Flight Unit
- Ground Control Unit

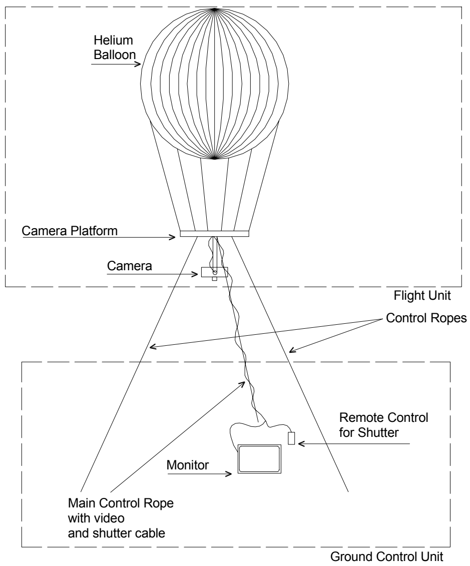

Figure 1. System overview

2.1 Flight Unit

In the flight unit, there are three main parts. These are;

- Helium Balloon
- Camera Platform
- Camera

The balloon is approx. 2.5 m. in diameter and 8 m^3 in volume. As an uplift gas, Helium (He) has been chosen because its non-dangerous properties. Such balloons are available at companies, which make professional outdoor advertisement. 8 m^3 He affect an uplift of 8 kg, so far the weight of all components had to be carefully balanced. Bigger balloons have bigger uplift, but they also need much more He. The chosen volume is just fine for 1 big bottle of gas (has 9.1 m^3). This enables to work 2-3 weeks with one filling.

The camera platform was built in the workshop of GGS in Speyer. The digital camera was fixed at a axe, which itself was connected to a triangle frame, turn able around 2 axes so that the weight of the camera forced the platform, to support always a nadir view of the camera. To reduce the swinging of the platform, a smooth-compensator was built in. Phi and Omega values should be small with this construction, Kappa had to be influenced by the rotation of the balloon.,

The triangle frame of platform was fixed with 6 ropes below the balloon. To the ground it was fixed with 3 ropes, each with 50 m length. One rope was used as carrier for a video and a remote-control wire.

Figure 2. The camera platform below the balloon with the balanced holder of the camera and the ropes

For image acquisition, Olympus Camedia C-4040 has been selected (Figure 3). Nowadays it is very difficult to get high-resolution digital cameras with fixed focus lens. It was a must to use one of the extreme values, either the small angled or the wide angled setting of the lens. The Camedia is known for its good quality and sharpness of the images, resolution is just one aspect.

Figure 3. Olympus Camedia C-4040

The calibration of the camera has been done by BAAP software using the test field in ETH-Zurich. Detailed information on calibration will be given in following chapters.

2.2 Ground Control Unit

Ground control unit has parts mentioned and explained below.

- Monitor
- Remote controller for shutter
- Control ropes

A small portable TV with a video-in plug and battery power was used as a cheap monitor solution. A frame protected the screen against direct sunlight and the control worked fine (Figure 4).

Other part of the ground control unit was the remote controller for shutter. Because of being out of covering distance of interior IR-LED (5 - 10 m.), remote control unit with a wire-output for an external IR-LED has been used (Figure 4).

The last part of ground control unit was the ropes. Ropes, which are light in weight but strong in stability, are selected.

Figure 4. Ground control unit with monitor in the centre, remote controller on the right and battery for the monitor downside of the monitor

3. CAMERA CALIBRATION

The Camedia has been calibrated in ETH-Zurich using the BAAP-software. Because of being a zoom-camera, its calibration has been done both for maximum wide and maximum narrow angles.

For the calibration of the camera, 9 images of the test field from different positions have been used. For wide-angle status of the camera, 30 of 106 control points and for the narrow-angle status 4 of 90 control points have been selected as tie points.

	Narrow-angle	Wide-angle
Number of images	9	9
Number of total points	90	106
Number of tie points	4	30
Number of control points	86	76
Number of Measurements	1432	1806
UNKNOWNS		
Exterior Orientation parameters	54 (6*9)	54 (6*9)
Tie point coordinates	12 (3*4)	90 (3*30)
Additional parameters	10 (1*10)	10 (1*10)
Total	76	154
Degree of freedom	1356	1652

Table 1. Characteristics of the adjustment for the wide-angle status of Olympus Camedia C-4040

At the end of the adjustment, following additional parameters about calibration has been reached.

	Narrow-angle	Wide-angle
Focal Length	20.700859 mm	7.231573 mm.
Principal Point (x0)	0.135214 mm	0.024380 mm.
Principal Point (y0)	0.163940 mm	-0.053714 mm.
Radial Distortion (K1)	0.000210	-0.004906
Radial Distortion (K2)	0.000006	0.000080
Radial Distortion (K3)	0.000000	0.000001
Decentric Distortion (P1)	0.000116	0.000051
Decentric Distortion (P2)	0.000109	-0.000069
Affinity (B1)	0.000041	0.000160
Shear (B2)	0.000028	0.000031

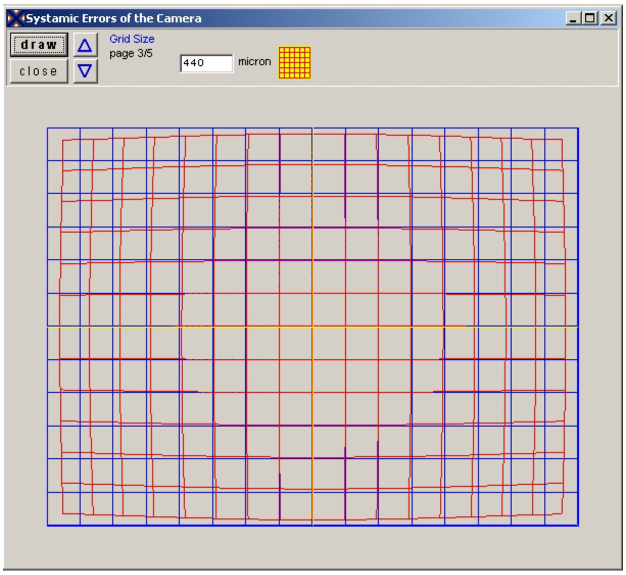

Figure 5. Distortion of wide-angle status (red: current distorted image, blue: ideal undistorted image)

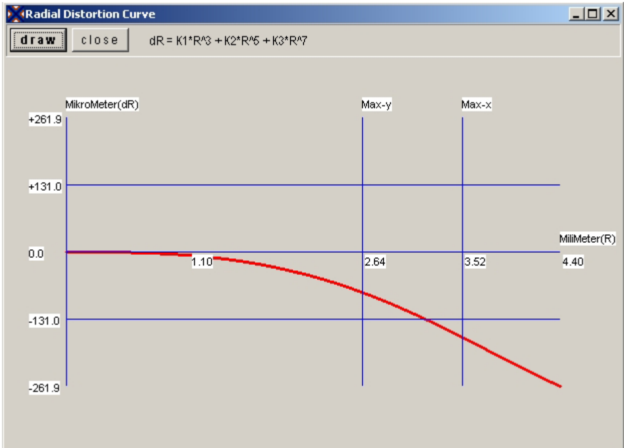

Figure 6. Radial distortion curve of wide-angle status

Figure 7. Total distortion curves along predefined directions (red: x-axis; green: y-axis)

4. PHOTOGRAMMETRIC EVALUATION

For photogrammetric evaluation, Pictran software has been used. Exterior orientation of the aerial imagery was unproblematic due to the position of the camera (almost vertical) and the coordinate accuracy of control point. The control points have been measured with 2-3 mm accuracy in X, Y and ~4 mm. in Z direction. The geometric accuracy of evaluation results for aerial images was about 4 cm.

Exterior orientation was fine also because of the geometric accuracy of control points and their distribution over the images. Using only the ground control points, exterior orientation was already fine but some tie points have been measured for getting better stabilization in the aero-triangulation.

Difficulty of this study was the exterior orientation of terrestrial images. In some parts of the study area, the images had to be taken very closed to the object of interest. That caused, that the single image covers a small area. Therefore many control points on the facades had to be measured. Nearby, the obliquity of the photos forced some additional problems. In that case, the exterior orientation of some facades have been a big work and needed long.

By photogrammetric evaluation, over 100.000 points have been measured three dimensionally. This step was the biggest work of the whole study. The measured 3-D coordinates of the stones and their contours have been transferred in CAD-Software. Editing and some additional cartographic works have been done using AutoCAD.

At the end of the study, following maps with different scale mentioned below have been created.

- Layout plan (1:250)
- Detailed plan (1:100) (Figure 8)
- Drawing of 12 facades (1:50) (Figure 9)
- 5 Profiles (1:50)

5. FURTHER ACTIVITIES

The processing of the data is at least a big work, especially if we use point-based systems. The possibilities of PhoTopoL Software are, to be able to digitise directly lines in 3D and to control them in stereo. This is possible for aerial images as well as for terrestrial photographs. With some limits to resolution and accuracy, also oblique photos can be processed. Further on, the orthophoto production in such a system is possible, which reduces the need to map all lines and increases the information on the map dramatically. An example is given below. Such tools are the key for complex 3D modelling up to the creation of visualisations and animations. This will be tested.
In this frame, the data can be stored in GIS application as well to be part of web-based GIS-application for tourist affairs and as well as for archaeological reconstruction aims.

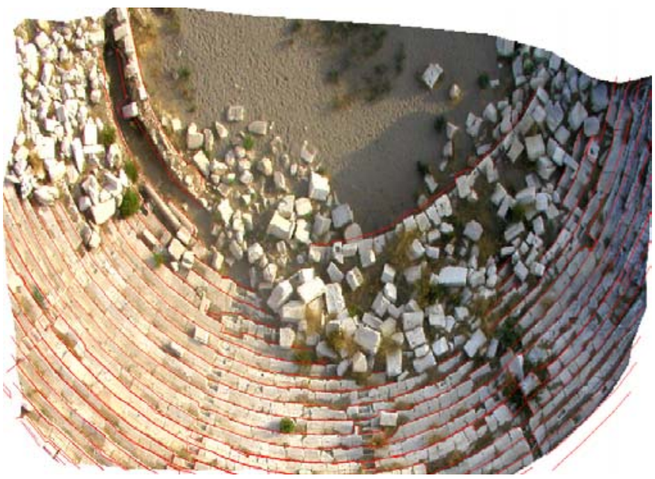

Figure 7. First results of edge mapping in PhoTopoL with computed orthophoto

6. CONCLUSIONS

Evaluation of ancient settlements and cultural heritage has always been one of the most interesting topics in photogrammetry. One of the difficulties by archaeological photogrammetry is the position of the camera. Suitable camera position cannot be arranged in any cases. In this study, a different platform has been used for image acquisition. The interesting point of the image acquisition system is the availability of the covering area in the monitor by the ground operator. This causes more effective work on the field. Another interesting point is the structure of the camera holder, so that it acts likely as a compensator. This causes to take more suitable photos for photogrammetric applications.

In archaeological sites, excavations take place mostly in summer. This causes – especially in Mediterranean part of Turkey- to work in hot weather. Thinking about the contrast on the images, this was a disadvantage. Because of that, image acquisition has been done very early in the morning. Nearby, in those hours, it is very silent and not windy. This is an advantage for using the helium-balloon too.

It is well known that oblique photos have some problem during exterior orientation. But in some cases like facade evaluation etc. this is a must, if any of the additional equipment has been used. Ongoing study is to use the balloon and the camera for façade imaging especially for tall or non-reachable building.

7. REFERENCES

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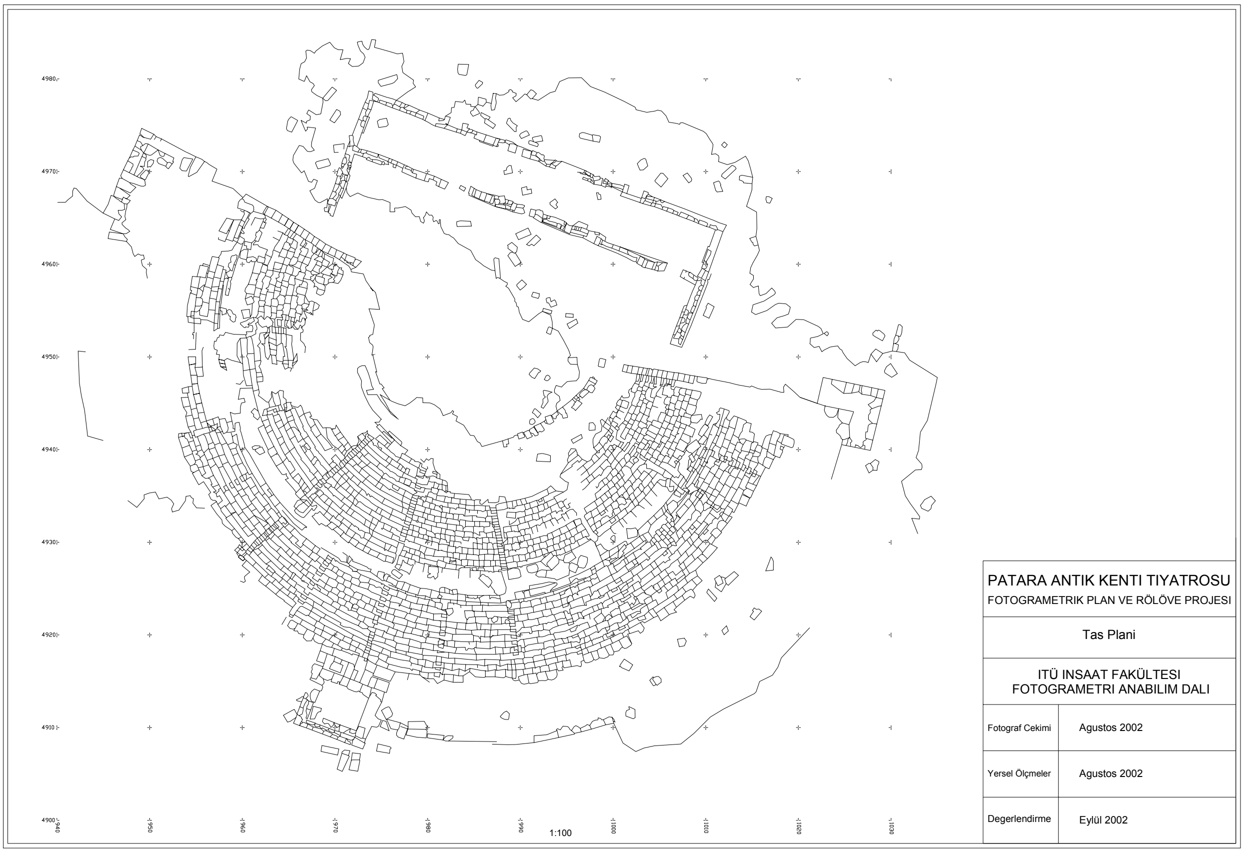

Figure 8. Detailed plan (original 1:100)

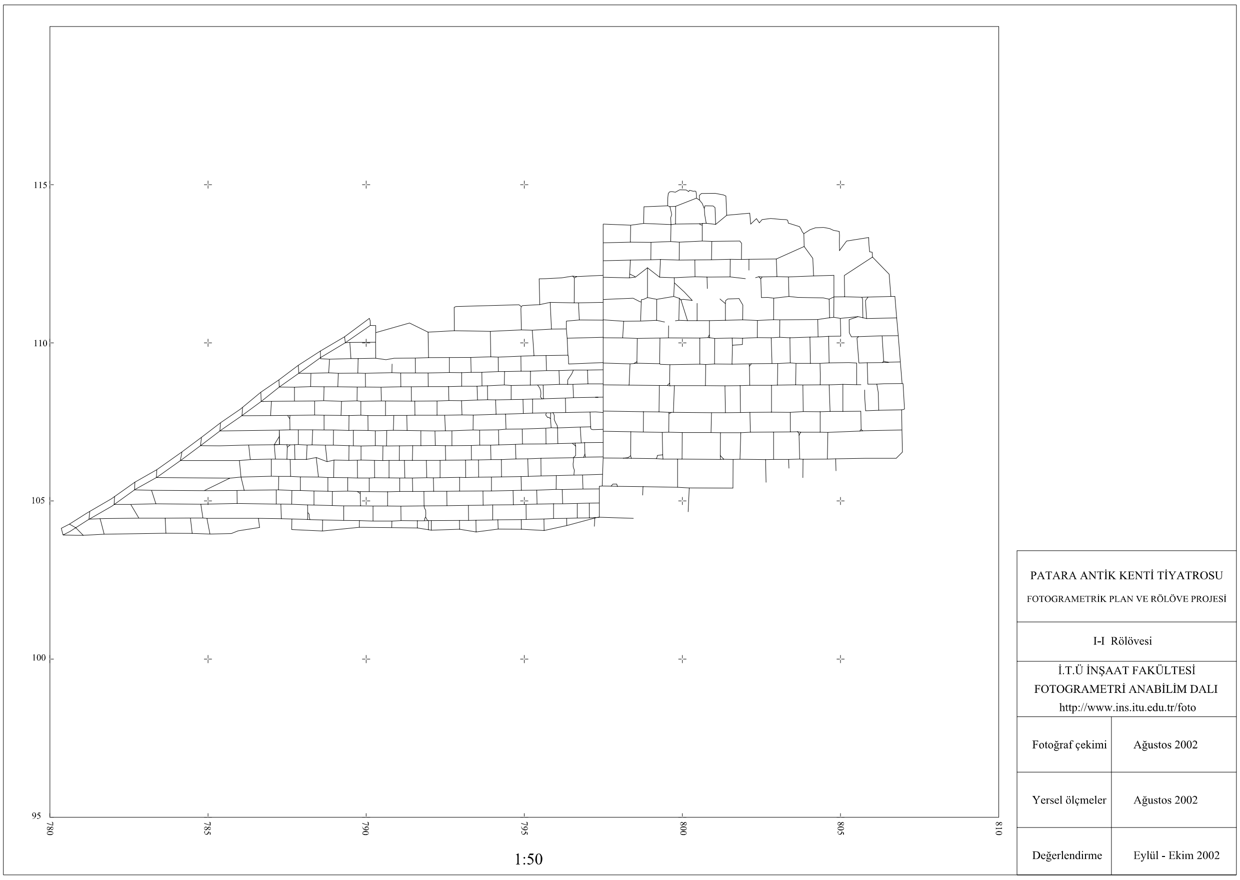

Figure 9. Evaluation result of a facade (original 1:50)