

PHOTOGRAMMETRY OF ARCHAEOLOGICAL SITE FELIX ROMULIANA AT GAMZIGRAD USING AERIAL DIGITAL CAMERA AND NON-METRIC DIGITAL CAMERA

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ABSTRACT:

Some limitation brought to us by cameras and imaging platforms sometimes can not be overcome as for the case of minimum airplane flight height used as platforms. In other case imaging of larger territories is often irrational, when it is performed from balloons or helicopters. So, there is an often need for combining different cameras and imaging platforms. New digital airborne cameras and non-metric high resolutions digital cameras expands our possibilities for combining this imaging source where we can get to optimal data source without disconcerting accuracy and unnecessary job build-up. In this paper the methodology of combining photogrammetric digital camera Z/I Imaging DMC and Canon EOS 5D will be presented as a source of data needed for photogrammetric product making of complex archaeological location with different photo resolutions.

1. INTRODUCTION

Using photogrammetry in fields of preserving cultural heritage and objects of significant architectural values has a long tradition. Until recently classical photogrammetric equipment was used. It was slow and in terms of making technical documentation it was expensive. With introduction of digital cameras the process became much faster, and raster and vector products reached a higher quality. It is not uncommon to find archaeological sites in larger areas, but some locations are more important than other. What is important is to offer products that are different in quality and content. Combining different platforms and cameras gives us a possibility to optimise a process of collecting images and its further processing, according to final demands. The idea is to use photogrammetric digital cameras for imaging wider territories. However, restrictions of these systems' types (minimum flight height and pixel size sensor) imposes limitation on their application for larger scale imaging. These kinds of restrictions could be overcome by using other platforms with adequate equipment that would enable acquisition of large scale data with tolerable precision.

As platforms, a different light aircrafts (helicopters, balloons) are used, and for cameras the optimal usage is metric and non-metric high resolutions digital cameras.

Using this platform types for imaging larger territories is irrational, because camera image covers smaller area. It also means that using non-metric high resolutions digital camera brings the necessity of accessing their geometric quality and calibration.

The area of experiment was an archaeological site of FELIX ROMULIANA, large archaeological location. Required

technical documentations as results of experiment was a different digital product with different accuracy and resolution. Regarding to project requirements, photogrammetric imaging was performed combining photogrammetric digital camera Z/I Imaging DMC and Canon EOS 5D from the balloon.

2. TECHNOLOGY

2.1 Experiment area

The experiment was performed on archaeological site of FELIX ROMULIANA near Gamzigrad (Serbia). Felix Romuliana in Gamzigrad is thought to have been one of the residences of the Roman Emperor Gaius Galerius Valerius Maximianus, built in the late 3rd and early 4th century (more data to be found at <http://en.wikipedia.org/wiki/Gamzigrad>).



Figure 1. Archaeological site – Fortress

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True importance of Palace, as one of the most important late Roman sites in Europe, was discovered in 1984. Archaeological excavations of wide Palace area are continued to this day.

Wider area covers approximately 180ha, an area of 10 acres is bastion, a complex of a King's Palace covers approximately an area of 1 acre, and the rest of the area is field that surrounds bastion and mausoleum. Archaeological excavation in the fortress has unearthed the remains of a palace with exceptionally fine mosaics, baths and impressive gates. The UNESCO World Heritage Committee decided to place Palace of Galerius on the World Heritage List in June 2007.

2.2 Task

The task was to form digital technical documentation of wider archaeological location area for further archaeological excavations and protecting uncovered construction.

Technical documentation contains several photogrammetric products:

1. Digital terrain model and digital surface model with different resolution and quality.
2. Digital orthophoto with different resolution for palace area and wider archaeological area.
3. 3D animation of archaeological area.

According to importance, experimental area was divided into two sections:

1. Wider archaeological location area – imaged by commercial aerial photogrammetric equipment INTERGRAPH Z/I Imaging DMC, and
2. Area of Palace complex - imaged by digital camera Canon EOS D5 from balloon.

The work methodology is divided considering section division.

2.3 Control points

Local geodetic point network was established in project area. It served for defining a project date and as a base for measuring and establishing control points coordinates. All measuring was performing by Leica TCR 705 Total Station.

A total number of control points were 60; thereof 49 control points in the area of King's Palace and 11 control points covered a wider territory. All control points were signalized by same signal template: 5x5 cm (Figure 2). The template was designed to enable good visibility on images acquired in both photo scales.



Figure 2. Signal template

From a single adjustment adjusted coordinates for all control points were obtained with RMS of 1cm for each coordinate.

2.4 Wider archaeological location area

2.4.1 Photo acquisition

Wider archaeological location area was imaged by digital camera INTERGRAPH Z/I Imaging DMC from Piper airplane. The complete area was covered with two strips and 38 images

in total. Relative flight height was 400m approximately. Photo scale 1:3300 is the highest photo scale for this type of equipment and terrain configuration.

2.4.2 Photo orientation: By using automatic method 659 tie points were measured with 2684 measurements in total. Results of bundle adjustments:

1. RMS of 1.9 micrometers is obtained for image coordinates and
2. RMS of 1.0 cm is obtained for control points.

2.5 Palace area

2.5.1 Photo acquisition: Photogrammetric imaging was performed with Canon EOS 5D digital camera. Camera is equipped with full frame CMOS, chip dimension 4368 x 2912 pixels (12.8 mega pixels). During imaging a wide angle objective was used, focus length 24 mm.

During the imaging process camera was fixed to the helium filled balloon construction.

The main balloon characteristic:

1. Balloon dimensions 2.1x3.2m.
2. Special sail of 5m².
3. Max. height up to 300 m
4. Useful weight to 3.5 kg
5. Special aluminium camera carrier for a Pan/Tilt/Zoom and photography trigger (Pan 359° a Tilt 120°)
6. Lower unit for total camera control
7. Mechanical gyro for stabilizing camera
8. Autonomy in air up to two hours (battery life)
9. Wireless image transmitting 600/1000 mW to 2.4 GHz



Figure 3. Balloon with camera carrier

Balloon is managed from ground with three ropes. The experiments showed that the major problem for this type of projects is stabilization of the balloon. Even the weakest wind could make it difficult to keep the balloon stable. For this reason a special sail was made. It is tighten to the balloon bottom and its role is to guide the balloon in the wind blowing direction. The result was that wind helps stabilizing the balloon instead of opposite. Sail usage means that the wind direction determines the angle of balloon rotation. That is the reason why motor was constructed, for camera kappa rotation with remote command. With these two additions the balloon became more stable and camera managing much more flexible. The outcome is efficient imaging, simplicity, and imaging in no ideal conditions, with wind.

The Palace area was imaged in 1:600 scales by earlier determined flight plan.

2.5.2 Camera calibration

Camera calibration was performed using the 24mm objective. Four independent blocks were used for camera calibration. The blocks were separately adjusted with self calibration. Parameters of radial distortion, principal point, etc. were calculated from significant parameters of self calibration. The conclusion is that there is a high correlation between independent block determent parameters, so the middle parameter values are used for further block adjustments.

2.5.3 Photo orientation

Images were organized into separate blocks of bundle adjustment for four main rooms of the Palace, covered with mosaic. Image coordinates of control and tie points were measured automatically with one pixel accuracy. The most significant results of block adjustment are given by blocks in the table below.

| Block | Photo No | CP No | Tie No | RMS CP (cm) | | | RMS image cord (m) |
|---------|----------|-------|--------|-------------|-----|-----|---------------------|
| | | | | X | Y | Y | |
| Block 1 | 13 | 12 | 1434 | 0.4 | 0.2 | 0.2 | 4.6 |
| Block 2 | 6 | 8 | 605 | 0.3 | 0.3 | 0.2 | 5.1 |
| Block 3 | 10 | 11 | 1121 | 0.3 | 0.4 | 0.3 | 6.1 |
| Block 4 | 7 | 10 | 328 | 0.3 | 0.4 | 0.4 | 6.8 |

Table 1. Most significant results of block adjustment (by blocks)

2.6 Final products

This way gathered data allows a different products making. Given below is a list of products with main characteristics:

1. **Digital terrain model of complete area** of archaeological location – method of stereo restitution was used for measuring break lines, grid points on 5 m resolution and other characteristic points.
2. **Digital orthophoto of complete area** with ground resolution of 4 cm.
3. **3D model of fortress** - All objects are introduced as 3D objects. Using stereo restitution method all features outside the fortress as well as the fortress wall were digitized. The same method was used for features inside the palace, this time with balloon images. All elements of 3D object model were gathered together in a single CAD drawing.
4. **Digital orthophoto of King’s Palace details** – based on balloon imaging and 3D model of objects. Ground resolution of orthophoto is 0.5 cm (Figure 4).
5. **3D animation** – Combining above mentioned products was performed in Autodesk 3Dstudio. Digital orthophoto was pane over digital terrain and 3D model of a complex (Figure 5). Walls were built in several brick-rock combinations, therefore vertical walls were assigned one typical texture (this 3D animation can be seen at http://www.youtube.com/watch?v=_tbqJQcO2bU).

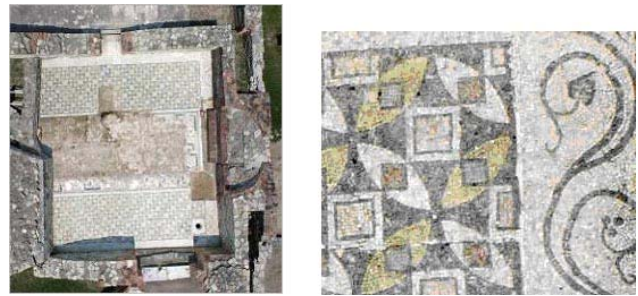


Figure 4. Example of digital orthophoto of King’s Palace

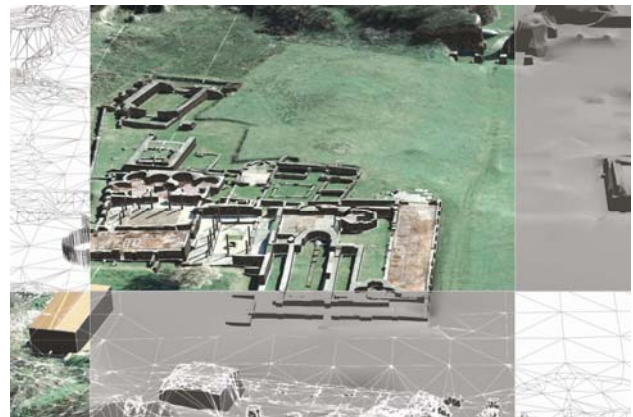


Figure 5. 3D model of King’s Palace complex

3. CONCLUSIONS

Using digital cameras and balloons in photogrammetry isn't new. Appearance of high resolution digital cameras, only extended the opportunity of applying this method. The fact is that new high resolution digital cameras emerge on market, and that the higher performance for this way of imaging is expected to be set as a standard.

Installation of additional components on a balloon, such as a wind control sail and additional motors for camera rotation makes the balloon imaging system applicable in different conditions.

Also, new experiences in combining and filling different source imaging data are precious, because commercial aerophotogrammetric systems have their boundaries in terms of imaging resolution.

Unique datum definition for the project with few different sources enables integration of their results.

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