

The Use of Hybrid Surveying Techniques for Documenting the Largest Ancient Theatre in Greece

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SUMMARY

The paper discusses the photogrammetric documentation procedure of the ancient theatre of Dodoni. It is the largest ancient theatre in Greece; its planimetric extents are approximately 100 by 140 metres and its height 25-30 metres. The theatre was built in the 3rd century b.c. and reaches an audience capacity of over 17'000 people.

The partly bad condition and the great extents of the object made it necessary to merge various surveying techniques in order to achieve the defined goal: the full documentation of the interior and exterior of the theatre. Due to the particularity of this study area (big extents, big height differences, parts of the theatre that were hardly accessible) three different cameras had to be employed for performing terrestrial and aerial photography, and additionally a laserscanner had to be used in order to produce the needed high-accuracy DOM (Digital Object Model). Altogether approximately 33 millions of laserscanner points and over 500 images had to be implemented into the workflow in order to achieve the wanted result.

The paper describes the employed methodologies for handling such huge amounts of data in combination with the big number of acquired images, for producing a useful documentation product that would be the source for further stone deterioration analysis. Furthermore, gained experiences, aroused problems and the results of the project, as well as the evaluation of the employed strategies are reported in order to demonstrate the difficulties of such a compound study.

ZUSAMMENFASSUNG

Dieses Paper behandelt die photogrammetrische Aufnahme des antiken Theater von Dodoni. Es handelt sich um das größte antike Theater in Griechenland; seine planimetrische Ausdehnung ist ca. 100 x 140 Meter und seine Höhe 25-30 Meter. Das Theater wurde im dritten Jahrhundert vor Christus erbaut und hat eine Kapazität von über 17.000 Menschen.

Wegen des teilweise schlechten Zustandes und der gewaltigen Größe des Objektes, mußten diverse Vermessungstechniken kombiniert werden um das gewünschte Ziel zu erreichen: die vollständige Dokumentation des Inneren und des Äußeren des Theaters. Aufgrund der Besonderheiten des Theaters (große Ausdehnung, große Höhenunterschiede, teilweise schlecht begehbare Regionen) mußten drei verschiedene Kameras für Aufnahmen sowie ein terrestrischer Laserscanner verwendet werden. Insgesamt mußten ca. 33 Mio Laserscannerpunkte und über 500 Bilder in den Bearbeitungsprozess integriert werden um das gewünschte Ergebnis zu erreichen.

Das Paper beschreibt die angewandten Methoden um solch große Datenmengen verwalten und bearbeiten zu können, damit ein sinnvolles Dokumentationsprodukt erstellt werden kann, welches in Folge zu Restaurationszwecken genutzt werden soll. Zusätzlich, werden Erfahrungen, aufgetretene Probleme, sowie die Ergebnisse des Projektes präsentiert, um die die Schwierigkeiten solch eines vielfältigen Projektes zu demonstrieren.

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1. INTRODUCTION

The ancient theatre of Dodoni (Fig.1) situated in northern Greece was built in the 3rd century before Christ. It was, and still is, the largest ancient theatre in Greece reaching an audience capacity of over 17.000 people. With its length of approximately 140 meters, width of approximately 100 meters and height of 25-30 meters, the photogrammetric documentation becomes a challenging task. This documentation task was necessary, since the theatre is partly in bad condition and unlike other big ancient theatres as the one in Epidaurus or the Herodes Atticus theatre, the used stones do not consist of marble material, and are hence very fragile and damageable.



Fig.1: Ancient Theatre of Dodoni.

2. DATA ACQUISITION

2.1 Laser Scanning

The goal was to document the whole interior and exterior of this theatre in various scales (down to 1:20). Therefore it was necessary to create a very precise, detailed and accurate DOM (Digital Object Model). This was achieved by employing terrestrial laser scanner technology [Kraus (2004)]. The employed Laser Scanner was a Leica HDS3000 [HDS3000 (2006)] and for the interior part of the theatre 6 scan positions were used. Unfortunately, unlike smaller laserscanner projects (statues or small monuments), here the procedure was linked to several problems: this was mainly due to the fact that on the one hand the theatre is huge and on the other hand the scanning density had to be very high (Fig.2) in order to fulfill the technical requirements. Additionally, many occlusions existed in various scans (stones or staircases covered important parts of the theatre in the DOM). The total number of acquired

points through the laser scanning process was approximately 33 millions; a number that reaches the limit of nowadays' processing capacities.



Fig.2: Detailed laser scanner point cloud.

2.2 Image Acquisition

Also, image acquisition was linked to several problems due to the particularity of the object. Thus three different cameras (metric and non-metric) were used:

- a metric WILD P31 (f: 45.21mm)
- a professional medium format MAMIYA Z67 (f: 108.22mm)
- a digital OLYMPUS C70Z (f=38mm)

The intensive winds in the mountainous region where the theatre is located did not allow making use of a balloon to perform the necessary image acquisition from air. Also, the narrowness of theatre entrance did not allow employing a crane to take the images from above. Thus the aerial images were taken from a helicopter (once by holding the camera and once by using a special mount) as well as by using a 4m high pole from the ground. Altogether over 500 (aerial and terrestrial) photographs were acquired and had to be integrated in the workflow.



Fig.3: Aerial photography from helicopter.

The big height differences of the theatre made the aerial image acquisition a very difficult task. Since the scale difference in one single image could be very big, flight planning had to be carried out very carefully, in order not to end up with regions that did not fulfill the specifications regarding GSD (ground sample distance) that should correspond in certain regions to a map scale of 1:20. It was aimed at an overlap of 60% (along) and 50% (side).

3. PROCESSING

The point clouds from the laserscanner were merged together by using common ‘tie’ points; these points were special targets that were automatically located by the processing software in order to perform a smooth point cloud merging process [Vozikis et al. (2004)]. These points were also used for georeferencing the point cloud(s); they were surveyed geodetically and hence had precise coordinates in the Greek reference system.

The outcome of this process was one georeferenced, very dense point cloud. The point density varied from 2mm in regions with intense relief up to 10-15cm in areas where there was not valuable information about the theatre, e.g. areas covered by earth/dust.

This point cloud provided true 3D information. This information had to be transformed into 2.5D, so that the following orthophoto production process could be carried out. The necessary editing processes of the point cloud were done manually since no off-the-shelf software could perform this task.

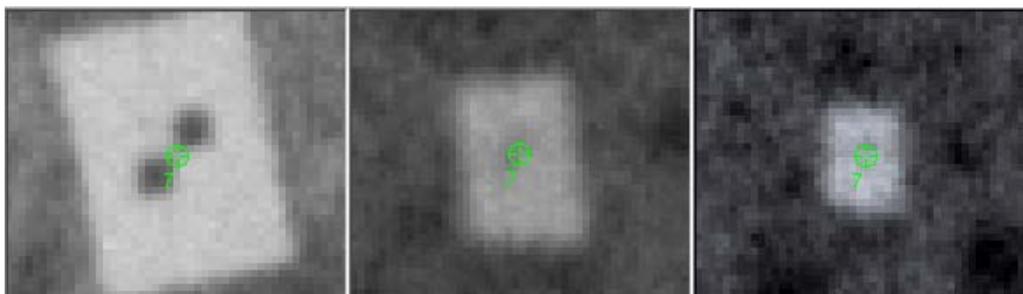


Fig.4: Same region appearing on different images in completely different resolution.

The orientation (triangulation) of the images could not be performed in form of a classical bundle adjustment. On the one hand no initial exterior orientation data was available, and on the other hand the big height differences of the images (that was necessary in order to keep the needed geometric image resolution) did not allow automated tie point extraction processes. Also, image regions (e.g. locations of ground control points) appeared on different images with completely different unequal resolutions (Fig.4). The solution was to combine spatial resection procedures, i.e. method by Mueller-Killian [Kraus (1996)] with bundle adjustment of sub-blocks with manual tie-point measurement.

Once the images had been triangulated/oriented orthophoto creation was started. In order not to avoid double vision, ghost effects and geometric inaccuracies, true-orthophotos (fully rectified orthophotos) had to be created. This procedure required the precise location of breaklines. To extract these 3D breaklines from the stereo models was nearly impossible due to the big height differences of the object under investigation and demanded high performance and concentration of the operator.

Regions of occlusion (for each image) were determined either manually or by employing ray-tracing techniques. In the mosaicking process it had to be paid great attention that for each area in the final mosaic the best suitable image (ortho) was used, by looking at geometry, radiometry and GSD parameters.

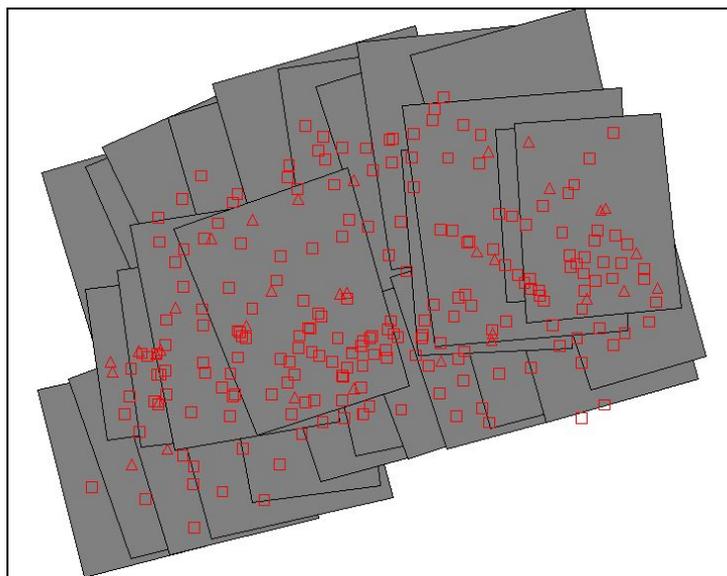


Fig.5: Distribution of aerial images for 1:50 orthophoto scale.

The whole interior of the theatre had to be documented at an accuracy and GSD corresponding to 1:50 orthophoto scale (Fig.5). For a small part of theatre an orthomosaic also of 1:20 scale had to be produced (Fig.6). The geometric resolution of this product had to get down to 5mm or less. This meant that for an area of approximately 10 by 20 metres over 80 images had to be implemented in the aerial triangulation, orthophoto and mosaicking process to produce the part of the 1:20 orthophoto.

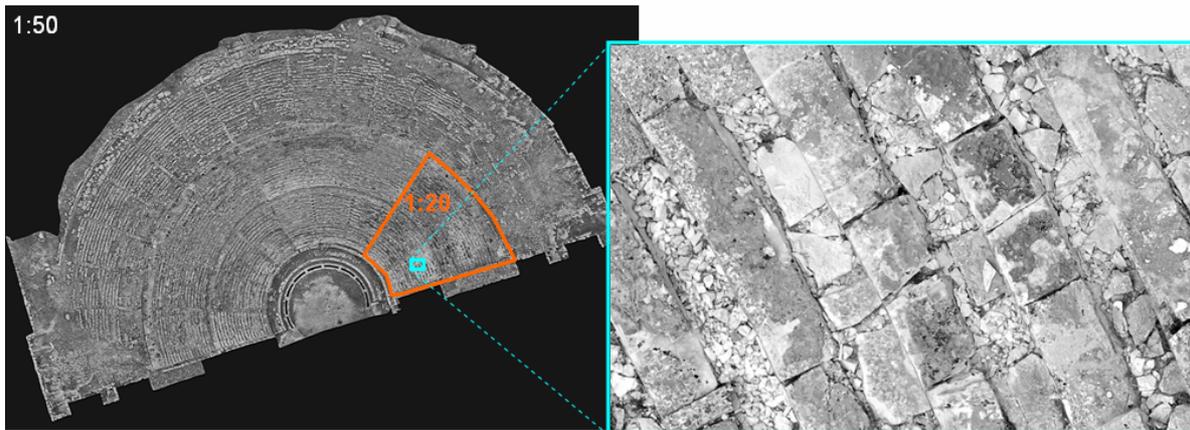


Fig. 6: Orthophoto of the whole theatre, and a subset depicting the level of detail for 1:20 orthos.

Moreover, for the interior of the theatre it was also requested to produce orthophoto faces orthogonal to each tier (Fig.7). The theatre consists of 9 tiers, therefore nine orthophoto faces had to be created. In order to be able to produce this product, again a true-ortho approach had to be applied. Each of these orthophotos was in a separate, different local coordinate system. Correspondingly the laser point cloud had to be rotated and shifted. This procedure could only be performed by self programmed software, since none of tested off-the-shelf programs were able to perform this task with such a huge amount of data. Unfortunately, also the breaklines that were used for creating the ground orthophoto could not be used for the 9 orthophoto faces. Additionally, the stereo overlap for the orthophoto faces was many times not sufficient, hence the breaklines had to be derived from the very dense, rotated point cloud.

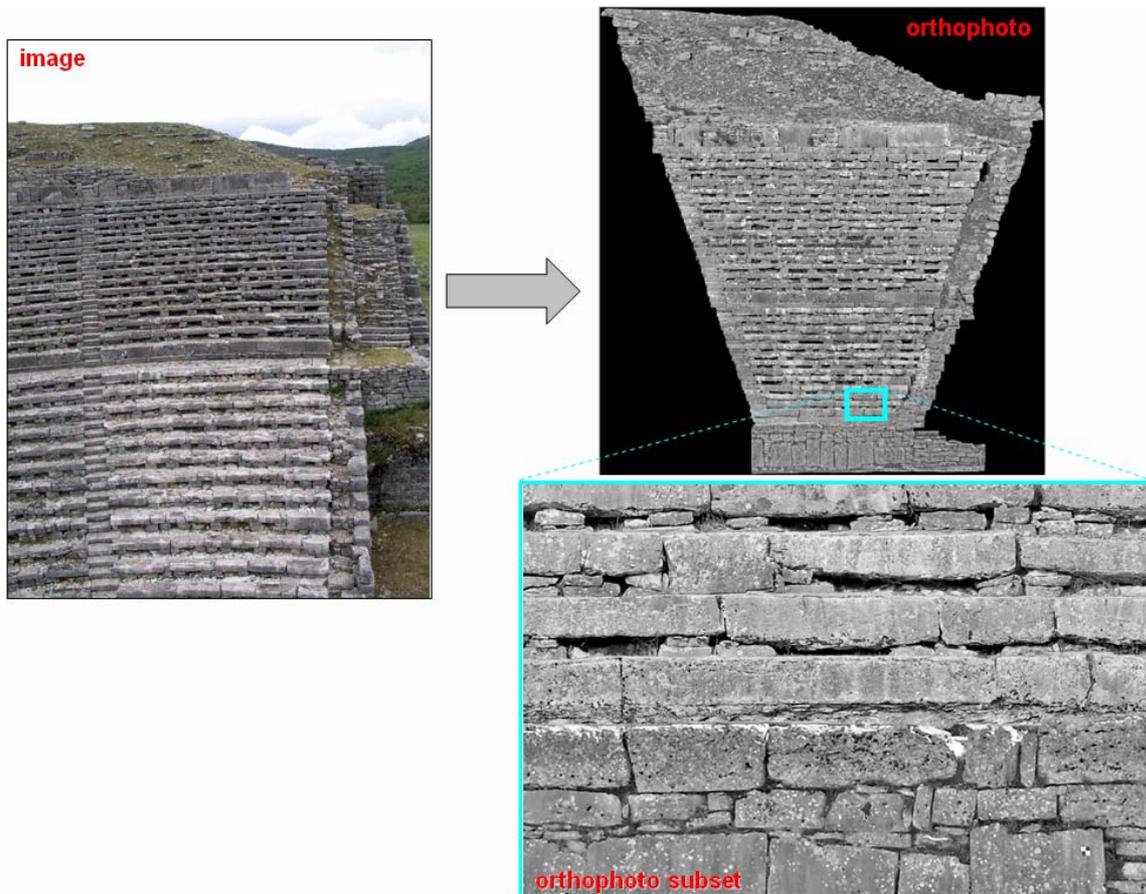


Fig.7: One of the input images, orthophoto mosaic of the face and subset depicting the level of detail.

4. RESULTS AND CONCLUSIONS

This study showed that when dealing with such big projects, the organizing and management is most important of all, and photogrammetric standard procedures cannot be directly applied. Considering the fact that for the whole project over 500 images were used and a laserscanner point cloud of over 33 million points had to be edited, filtered and eventually rotated, important experience was gained. Through this project it also became clear that laserscanning is not the solution to every ‘problem’, and many times the classical photogrammetric stereo approach can be more time efficient.

REFERENCES

HDS3000 (2006): http://www.leica-geosystems.com/hds/en/Leica_HDS3000.pdf, last accessed 10.07.2006.

Kraus, K. (1996): *Photogrammetry Volume 2, Advanced Methods and Applications*, with contributions by J. Jansa and H. Kager. Dümmler Verlag, Bonn, 4th edition.

Kraus, K. (2004): Photogrammetrie Band 1, Geometrische Informationen aus Photographien und Laserscanneraufnahmen. Walter de Gruyter Verlag, Berlin, 7th edition.

Vozikis, G., Haring, A., Vozikis, E. and Kraus, K. (2004): Laser Scanning: A New Method for Recording and Documentation in Archaeology. FIG Working Week 2004, Athens, Greece.

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