CLOSE RANGE PHOTOGRAMMETRIC APPLICATIONS USING ASTRI

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ABSTRACT

This paper presents test and results for close range applications using the ASTRI (Analytical STereo Restitution Instrument), the low cost simple system for Analytical Photogrammetry.

1. INTRODUCTION

Architectural Photogrammetry applications should be of high interest in Hellas (Greece) because of the enormous amount of Hellenic cultural heritage concentrated in the country and the Mediterranean area during the last three thousand years.

Unfortunately this interest is not activated very often. It is always a custom in Greece to get advantage of the Photogrammetric approach in cases where conventional methods have no chance to provide the appropriate surveys to the specialists for the conservation and restoration of Monuments and Sites.

Early last year the Municipality of the City of Rhodos entrusted the Photogrammetric Survey of the Medieval Walls to my private firm " Stambouloglou and Associates".

The Walls surround the old city with a perimeter of approximately five kilometres. A deep ditch with 20 to 50 meters width separates the walls and the old city from the modern one.

According to the signed contract two types of Photogrammetric surveys where required. The first was the facades of the Walls in scale 1:200 for the total perimeter and the second was the detail survey of facades in scale 1:50 for some selected areas damaged or in danger of demolition. The requirements of the first type of survey where limited to the description of basic lines, gates, windows, the wall border, and the perimeter of damaged areas. For the second type of survey a detail restitution of the facades was required with all the above lines plus the details of the stonework (practically survey of every stone).

The Medieval Walls are a complex which can be described geometrically with planes and a few curved surfaces. Two approaches where selected for the first type of Photogrammetric surveys in scale 1:200. Rectification for the planes and Stereo restitution for the curved surfaces. Two cameras where used for the photos. An UMK-10/1318 JENA and a CANON 35 mm amateur camera equipped with three lenses 28, 50 and 150 mm. A total of approximately 1000 photos where taken. The first camera was used for the survey in 1:50, combined with the analytical plotter DIGICART-40, while the second for the scale 1:200 with ASTRI. A total amount of 6100 control points where observed and determined using conventional geodetic methods and equipment, the digital theodolite T-1000 WILD equipped with a DIOR 3002 WILD EDM.

The control points were all natural detail points on the Walls surfaces determined from ground stations. An Analytical rectification program using the digitizer and the DLT method gave the solution to the survey of the planes. As an extension to this first approach the new low cost system ASTRI was conceived and constructed for the reduction of data from non-metric, semi-metric and metric cameras for both monoscopic and stereoscopic photos. A description of the ASTRI is given in Stambouloglou 1992.

2. EVALUATION OF THE EXPECTED ACCURACY

The expected accuracy of the Analytical Photogrammetric Restitution is evaluated theoretically with complex or simple formulae depending on the mathematical model and the assumptions used. Complex formulae give the rigorous evaluation of the accuracy concerning all measured data (direct or indirect measurements). Most of the Stereo Photogrammetric applications are very close to the normal case, for which the evaluation of accuracy can be derived with the application of error propagation to the simple formulae :

$$X=\frac{B}{P_x}x_1 \quad Y=\frac{B}{P_x}y_1 \quad Z=\frac{B}{P_x}c$$

where

$$P_x=x_1-x_2$$

Assuming that only the image coordinates x_1, y_1, x_2, y_2, affect the accuracy, one can use the well known simplified formulae for the calculation of the expected accuracy :

$$m_X = m_Y = \frac{Z}{c} m_x$$

$$m_Z = \frac{2Z^2}{Bc} m_x = \frac{2Z}{s(1-p)} m_x$$

The accuracies in the three directions (X,Y,Z) using the above formulae present a linear variation proportional to the object distance (Y), if it is assumed that the Y/B ratio is kept constant (B = base). For terrestrial applications and assuming that we use contact prints from a 24X36 mm format amateur camera with a 50mm lens and given that the image coordinates accuracy is 50 μm we get the following for the mX, mY, mZ (table 1) in steps of 5 m. The use of enlargements (x5) of the same photos can give a corresponding improvement to the accuracy (table 1).

	CONTACTS		ENLARGEMENTS	
Y (m)	mX,mY (mm)	mZ (mm)	mX,mY (mm)	mZ (mm)
5	7	35	1	7
10	14	69	3	14
15	21	104	4	21
20	28	139	6	28
25	35	174	7	35
30	42	208	8	42
35	49	243	10	49
40	56	278	11	56
45	63	313	13	63
50	69	347	14	69

Table 1

3. EVALUATION OF THE OVERALL SYSTEM ACCURACY

The achieved overall accuracy was tested in two steps : the first for the written software and the second for the system (hardware+software). A simulated test field with 49 (7x7) points was used. The simulated data includes all distortions (radial, tangential, shrinkage) and it also takes into account the accuracy for both image and ground coordinates. The orientation of the simulated stereopair was calculated with 25 control points from the 49, while the other 24 were used as check points. The test was performed for many configurations of depth of field. It was found that the method is reliable with a ratio dz/z, (for depth of field to distance to object), greater than 1/100 and it gives results similar to the expected.

In order to compare the obtained results to the expected accuracy the following discrepancies where formed :

$$dX = X - X' \quad dY = Y - Y' \quad dZ = Z - Z'$$

where X,Y,Z and X',Y',Z' are the correct and the ground calculated coordinates of the check points respectively. In addition the mean square error (M.S.E.) of the differences for every axies was calculated :

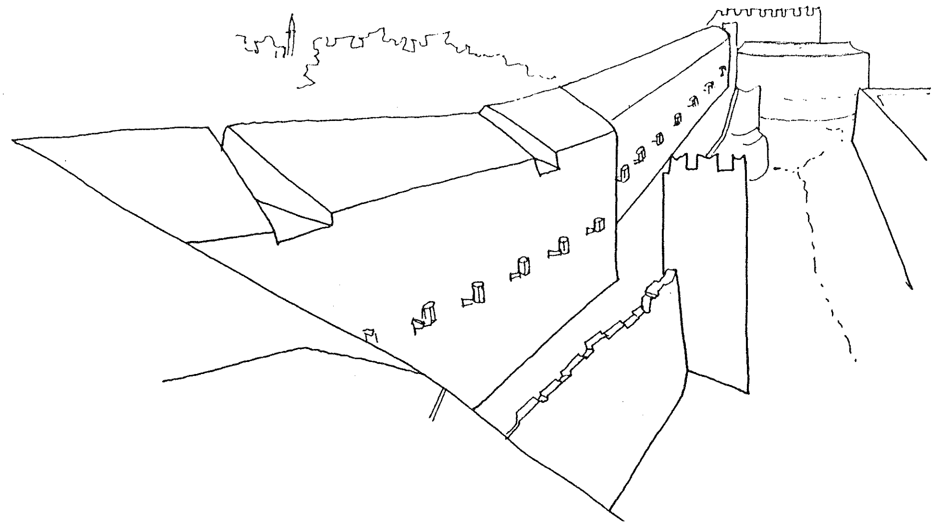
$$\sigma_X = \sqrt{\frac{\sum (dX)^2}{n}} \quad \sigma_Y = \sqrt{\frac{\sum (dY)^2}{n}} \quad \sigma_Z = \sqrt{\frac{\sum (dZ)^2}{n}}$$

Table 2 gives the M.S.E. and the maximum discrepancies calculated for a configuration with focal length 250 mm (5x50) image format 180x130 (5x(36x24)), Z = 40m and dZ = 6 m while the a priori error for image and ground coordinates is 0.050 mm and 0.01 m respectively. A real stereopair with similar configuration was used in order to simplify the comparison of results of simulated and real data.

The pair was chosen among a total of one thousand photos taken for the Photogrammetric Survey of the Medieval Walls of the City of Rhodos. The original negatives of the stereopair were taken with a simple CANON amateur camera equipped with a 50 mm lens. The photos used for the test are 5X enlargements (130 X 180 mm). The photos were taken from a distance of 40 m. The surface of the object presents a depth of field of 6 m. Figure 1 shows the typical shape of the Walls. A set of 19 control points were observed and determined with geodetic method on the object surfaces. From these points a subset of 10 points were chosen to serve as control points while the rest 9 points where used as check points. The respective discrepancies for the three axes dX, dY, dZ and the M.S.E. where calculated as for the simulated pair. The results are shown in table 2.

	CONTROL POINTS			CHECK POINTS		
	Simulated Model (mm)					
MSE	4	4	14	5	5	19
max	8	9	27	11	10	44
	Real Model (mm)					
MSE	6	6	35	19	20	60
max	10	12	69	41	52	95

Table 2



Perspective View

Section

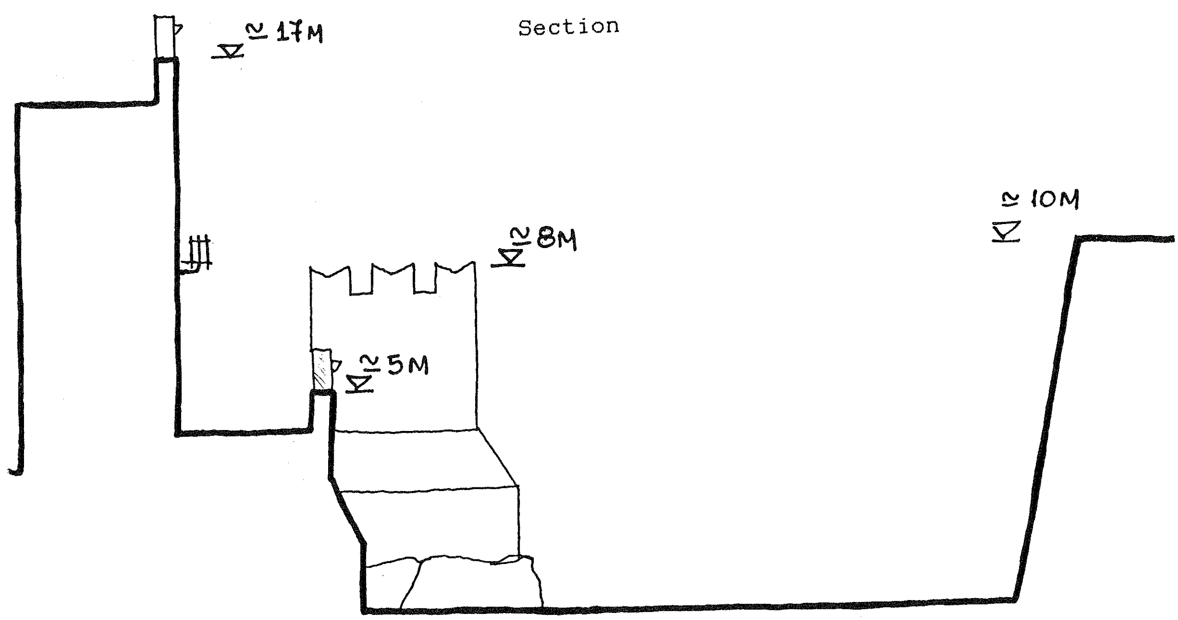


Figure 1

From the study of table 2 it is clear that the results obtained from a typical close range application are compatible with the simulated ones given that the control-check points of the application are natural points and not pre-marked well defined points.

4. CONCLUSIONS

The results obtained in the described application using the ASTRI proved that this new low cost system is a possible alternative for application with low to medium accuracy requirements. Improvements may be acquired with pre-marked control points and larger photo scales.

The amateur cameras may be freely used when combined with a system such as ASTRI The whole combination constitutes an extremely cost effective solution, which easily brings Photogrammetry to the hands of even a non-expert.

5. REFERENCES

1. Karara, H.M. (ed.), 1989. Non-Topographic Photogrammetry. Second Edition, ASP-RS.

2. Stambouloglou, E., 1992. Analytical StereoRestitution Instrument (ASTRI). International Archives of Photogrammetry and Remote Sensing, Vol. 29, part 2.