ARCHEOLOGICAL PHOTOGRAMMETRY WITH SMALL FORMAT CAMERAS : THE SURVEY OF THE FORUM VETUS IN SARMIZEGETUSA (ROMANIA)

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ABSTRACT

This article deals with instrument and methods specially developed by the authors for mapping a roman forum in Sarmizegetusa (Romania).
The data capture system consists of an automatic standard format camera, and an easy-to-carry adjustable support allowing a maximum height of 6 metres shooting.
The use of 24mm x 36mm photographs meets low costs and map accuracy constraints in archeology.
The map of the forum was worked out through mono and stereoplotting combined with topographic data processing.

RESUME

L'article présente un instrument et des procédés photogrammétriques originaux qui ont été mis au point par les auteurs pour la réalisation du plan d'un forum romain à Sarmizegetusa (Roumanie).
Le système de prise de vues est constitué d'un appareil photographique motorisé de format standard et d'une potence réglable en hauteur (6m. maximum) facilement transportable.
L'utilisation de clichés au format 24mm x 36mm satisfait l'économie d'un levé archéologique, tout en respectant ses contraintes de précision.
Le plan du forum a été établi à partir du traitement des données topographiques combiné aux opérations de redressement photographique et de stéréorestitution analytique.

INTRODUCTION

The E.N.S.A.I.S. Laboratory of Photogrammetry in Strasbourg managed by Pierre Grussenmeyer, and Franck Perdrizet, researcher in geomatics and surveying techniques in Montpellier, are used to carrying out studies in the scope of archeology and architectural heritage.

Sarmizegetusa (Romania) was the ancient capital of the roman province of Dacia founded by Emperor Trajan. Nowadays the modern village is located near and on the ruins which are scattered over a large area. The site includes some major monuments : amphitheater, two forums, including the ancient one called forum vetus (fig.1) by archeologists.

With a 1/100 scale allowing a full plot on a $1m^2$ sheet, it was decided to survey accurately the stonework of the structures which had crumbled down, in order to help the specialists in architectural reconstruction.

Photogrammetry soon appeared to be the only way to see the numerous and irregular shapes ; nevertheless, the features of the forum would also be surveyed through angles and distances.

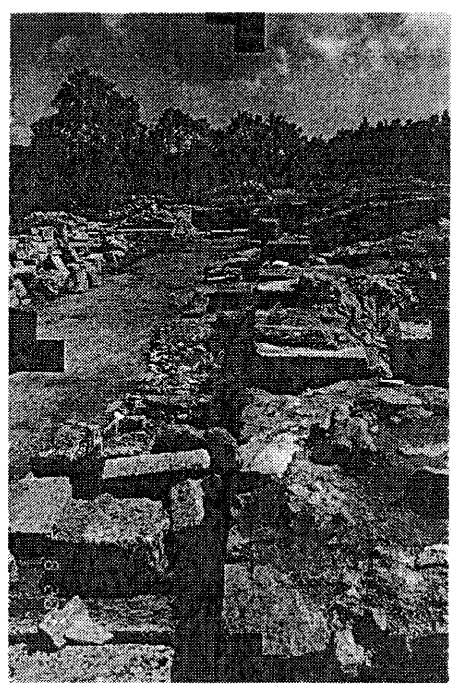

Fig.1 : view of the forum vetus

1. THE DATA CAPTURE SYSTEM

As no aerial view was available and there was no relief overlooking the site, we planned a close-range coverage (fig.2) with a camera set at the end of a portable L-shaped bracket built by ENSAIS (fig. 3).

Fig.2 : nadiral photograph on a monument

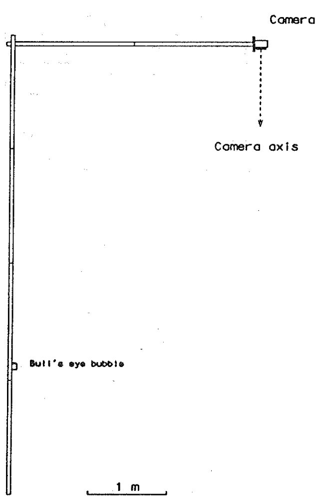

Fig. 3 : the portable L-shaped bracket

A Ricoh KR 10 M reflex camera (24mm x 36mm format) was turned into a measuring tool after some enhancements : calibration on a set of targets for a blocked focus at the test field of ENSAIS, and accurate setting of 4 fiducial marks (designed by PMS AG, Switzerland).
The mean radial distortion graph of the lens (28 mm focal length) was drawn up with the Orient Software.

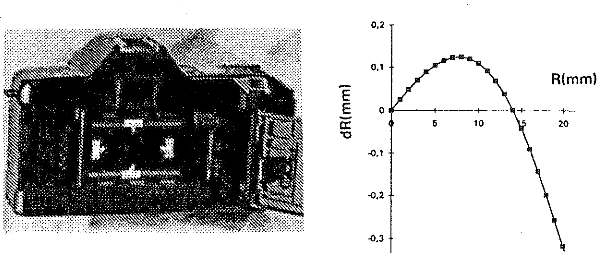

Fig. 4 : the Ricoh KR 1OM camera with its four fiducial marks and the radial distortion graph

The camera is screwed onto a small plate at the end of a single solid angled support (bracket) made of assembled pieces of metal allowing a maximum shooting height of 6 metres (value chosen for best efficiency).
The consequent 1/210 image scale is most suitable for precise work with enlargements of up to 1/50.

With pieces shorter than 1.50m and a total weight under 20 kg, the bracket can be easily transported by plane.

Camera height above ground	coverage area (m x m)	image scale
4 m	3,4 x 5,1	1 : 140
5 m	4,3 x 6,4	1 : 180
6 m	5,1 x 7,7	1 : 210

Tab.1 : fields and scales allowed by the data capture system with a 28mm focal length

The bracketing option of the Ricoh camera enables 3 snap-shots to be taken in a row with 2 versions slightly more or less exposed than the standard one, in order to improve the chance of getting the best contrast.

Two or three people are necessary for handling the bracket while the operator releases the shutter with an infrared remote device.

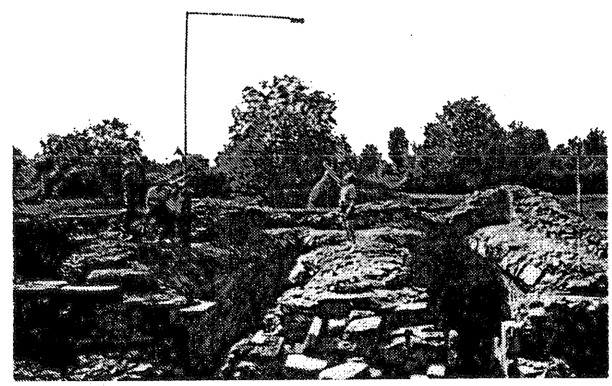

Fig. 5 : surveying the curia

The verticality of the camera axis needs not be perfect since its true spatial position will be computed during the bundle adjustment before the stereoplotting ; the support set up is estimated with a bull's eye bubble and the spatial position of the camera can be easily adjusted with a screw.

Meanwhile, before starting the survey, one has to check what is really recorded by the camera when vertical, by means of targets on the ground.

For this reason, but also for a quick retaking of a possibly missed photograph due to the hazards of the operations, photographs must be processed in the field : black and white Agfapan 100 Asa films were used.

Where colors were required to help interpretation, a second coverage was made with Ektachrome 200 Asa slides which were stored later on CD Rom with Kodak CD Photo system [Hanke, 1994] for possible further processing.

2. COVERAGE PLANNING AND STEREO-PREPARATION

The photogrammetric survey consisted of views to be worked on separately (about 80 photographs) or by stereoscopic pairs (about 70).

The problem of organizing such a patchwork found a rational solution with a rectangular network.
Then we divided the field into parts which would be exploited in basic views, and we chose the way to connect each one to the others, that is to say, to find out the best compromise in the positions of the control points.

According to the technical characteristics of the camera, a few geometrical patterns had been prepared in order to cope with any situation likely to occur. On a given part of the site, the most suitable pattern was then chosen and repeated in a sequence for as long as necessary .

The geometrical patterns were marked out on the ground by spots staked out at regular intervals; when operational, they were equipped with targets. The network was set with regard to the ancient square town-planning (two major perpendicular axes : "cardo" and "decumanus") .

Flat areas were recorded on single views (fig. 6) with little overlapping (10 to 20 %).

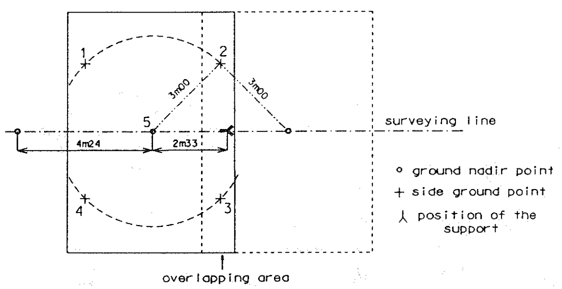

Fig. 6 : pattern used for the central yard

A stereoscopic coverage (60 % end lap and 20 % side lap) was used for ruins with important relief (up to a few meters). After signalizing and measuring the 3D positions of the targets, the survey was worked out into strips along the prominent structures and along excavations, in order to avoid hidden parts (fig. 7) .

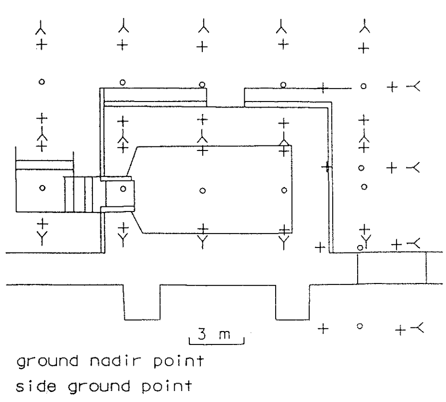

Fig. 7 : targets location and ground nadir point on the eastern tribunal

3. PHOTOGRAMMETRIC PLOTTING

3.1 Bundle adjustment with the ORIENT software

Before starting the plotting, a photogrammetric triangulation method was needed for balancing the set of control points over each strip . The method used is derived from aerial triangulation. We used the ORIENT software from the Institute of Photogrammetry and Remote Sensing (Vienna University of Technology), [Kager, 1991].

The strips were recorded in the ZEISS Planicomp P33 analytical stereoplotter with the ATM program.

number of negatives (24mm x36mm) camera Ricoh KR10M	24
number of points for the adjustment	184
number of control points	35
control points r.m.s.e. (x,y,z)	<0.01m
tie points : r.m.s.e. (x,y) r.m.s.e. (z)	 <0.02m <0.03m
number of observations	995
number of marked observations	14
adjustement standard r.m.s.e.	8 μm

Tab. 2 : results of the bundle adjustment with ORIENT, (curia area , four strips)

The parameters of the calibration were computed before and after the field work on a set of targets at ENSAIS, in order to check the stability of the camera.

Calibration of the Ricoh KR 10 M camera					
R_0=14mm	c(mm)	x'_0(mm)	y'_0(mm)	a3	a4
pre-calibration	28.128	-0.002	-0.165	-0.401	0.065
calibration after field work	28.117	-0.004	-0.136	-0.366	0.049

Tab. 3: inner orientation and radial distortion parameters

The equations used for the adjustment of the distortions in Orient are :

$$\begin{cases} dx'_0 = a_3 \frac{x'_i}{R_0^3}\left(R^2 - R_0^2\right) + a_4 \frac{x'_i}{R_0^5}\left(R^4 - R_0^4\right) \\ dy'_0 = a_3 \frac{y'_i}{R_0^3}\left(R^2 - R_0^2\right) + a_4 \frac{y'_i}{R_0^5}\left(R^4 - R_0^4\right) \end{cases} \quad (1)$$

where $R^2 = x_i'^2 + y_i'^2$ and $dR = \sqrt{dx_i'^2 + dy_i'^2}$ (2)

The radial distortion equation is :

$$dR = \frac{a_3}{R_0^3} R\left(R^2 - R_0^2\right) + \frac{a_4}{R_0^5} R\left(R^4 - R_0^4\right) \quad (3)$$

The distortion graph is shown on fig.4 .

3.2 Stereoplotting

The stereopairs, black and white negatives or color slides, were at first orientated with the well-known PCAP software. The stereoplotting was operated in the Microstation environment on a Zeiss Planicomp P33 equipped with an additional eye-piece. Photo-interpretation relied on F. Perdrizet's archeological background.

It has provided much architectural 3D information where classical surveying was not effective enough.

3.3 Monoplotting

Black and white independent views were rectified by classical optical projection, then digitized one by one at their accurate location thanks to the images of the ground control targets.

An image rectification software can also be implemented with a CD-Rom unit.

Either method is very efficient, on flat areas only.

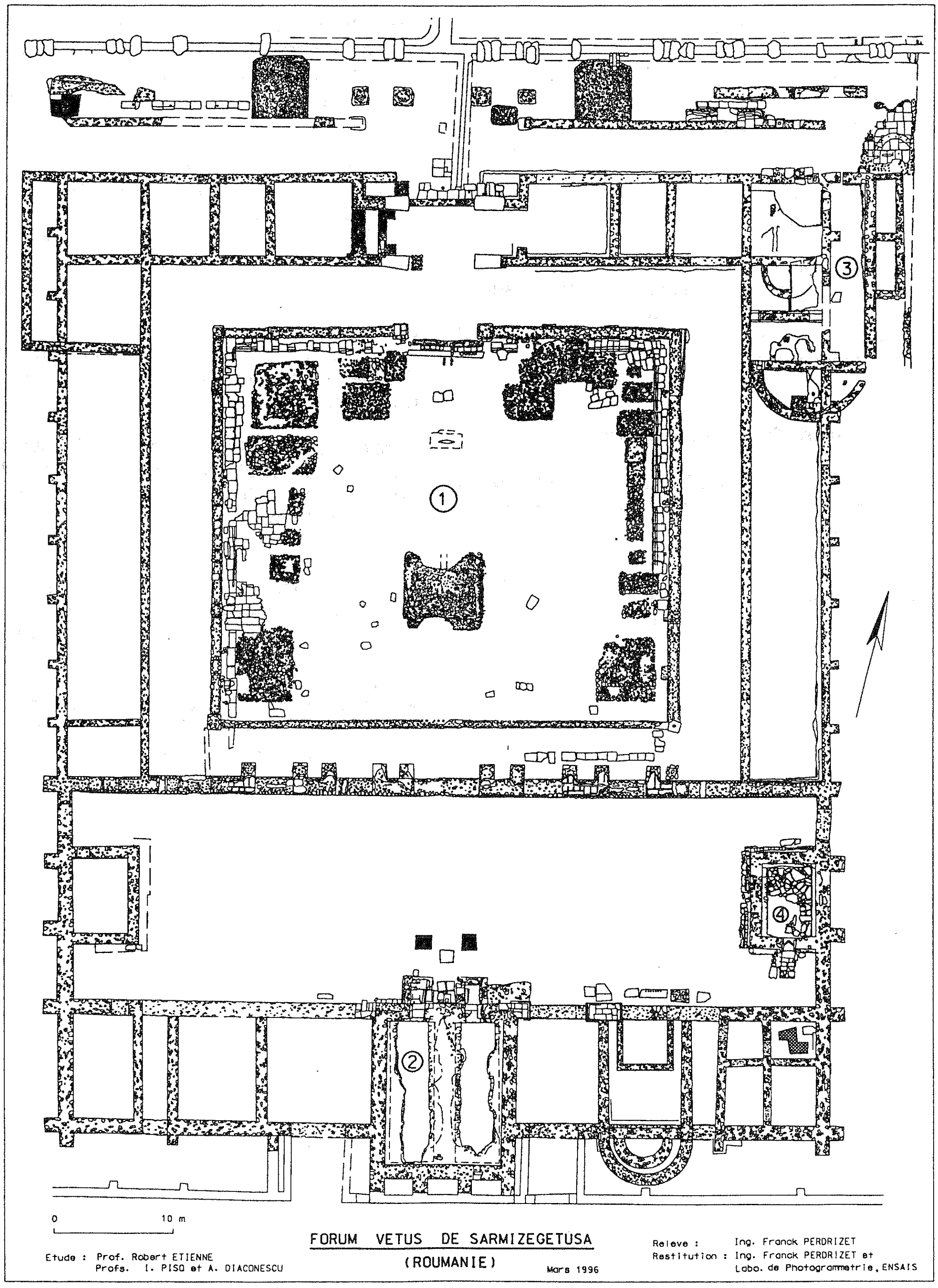

Fig. 8 : final map of the forum vetus : central yard (1), curia (2), aedes fabrum (3), eastern tribunal (4)

3.4 Final map

Mono and stereoplotting, together with topographic data processing resulted in files to be merged into a unique map (fig. 8) with the help of the referencing network.

Many overlapping areas and graphic redundancies preserved the integrity of the process. Adjustment computation and a last check mission ensured the final accuracy of the map (ground r.m.s. about 2 cm).

CONCLUSION

The choice of a small format camera was made on economical and practical grounds. A conventional photogrammetric camera and its equipment often seems unaffordable when budgeting an archeological survey. In this case, a less sophisticated instrument can be suitable provided its characteristics and its deviations from the theoretical model are known.

It was proved that a careful use of the camera within its limits and a thorough monitoring of the various processes can fully take up the challenge, not only from a costs and schedules point of view, but also in terms of map accuracy and quality.

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