ANALYTICAL APPROACHES TO THE PROBLEM OF ARCHITECTURAL RESTITUTION

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1. Introduction

A somewhat simple, but important, monument of Athens has been chosen as the object of this experiment. Hadrian's Gate, dating back to the roman era (4th c. BC), was one of the main entrances to the ancient city of Athens and today is one of the best preserved monuments in the modern city centre. The Gate measures 15 m in length and 18 m in height and presents a limited relief. The main objective of this experiment was to investigate various analytical methods of data acquisition and graphic representation of architectural restitutions.

The methods adopted and developed involve both simple and sophisticated equipment and metric as well as non-metric photography. The three approaches are briefly described and are later evaluated in terms of accuracy, time and cost.

2. Analytical Restitution on Stereocord G2

The monument was stereoscopically photographed with a ZEISS (Jena) UMK 1318/100 camera from an approximate distance of 16 m, at a scale of 1:160. Contact paper prints were used on a ZEISS (Oberkochen) Stereocord G2, which is connected via a DIREC unit to a Hewlett-Packard 9845S desktop calculator. For the orientation of the pair three directly measured distances were used instead of control points. In this way the geodetic measurements in situ were reduced to a minimum. The orientation was carried out with the help of programme SDAOE (Ioannidis and Potsiou, 1982), which uses the collinearity and coplanarity conditions and which was slightly modified to accept distances instead of co-ordinates as observations.

For the restitution, the object was partitioned in 24 patches, due to the limitations of the Hewlett-Packard screen for on-line graphics and editing. The main difficulties arose from the fact that several parts of the monument were heavily shadowed or complicated and the scale of the photography relatively small. In many parts special interpretation was required, proving once more the need for an operator specialised in architectural photogrammetric work (Badekas et al. 1987). The co-ordinates of some 10000 points recorded in the HP-9845S were transferred to NTUA's CDC Cyber 171-8 mainframe computer and were off-line plotted on the Calcomp 1044 plotter of the Laboratory at various scales (1:20, 1:50, 1:100). The corresponding fair drawing, after a thorough field completion, appears in Fig.1.

3. Restitution on BC2

The Gate was also photographed stereoscopically with a CANON AE-1 35mm camera, equipped with a 50 mm lens with known distortion characteristics (Georgopoulos, 1981). The photography was taken from a distance of approximately 30m, thus producing a negative scale of 1:600. The negatives were processed on a WILD BC2 analytical plotter, the use of which was kindly made available by the Hellenic Military Geographical Service, (who use it in their currently 1:5000 base map production line).

The orientation on the analytical instrument was carried out with the help of the same geodetic measurements as before. The only difference was that the distances were used to determine co-ordinates, referred to a local arbitrary system, to comply with the BC2 requirements. After the orientation was accepted, the restitution was carried out by the HMGS operator, who had no experience in architectural photogrammetry whatsoever. Around 12000 points were recorded for this task, which do not cover all the details of the monument. The plot was drawn on-line on the WILD Aviotab TA-10 plotter at a scale of 1:50. The plot, as it came out from the analytical plotter, without the necessary field completion, is shown in Fig.2.

4. Monoscopic Analytical Restitution

A simple monoscopic method was chosen and developed especially for the purposes of this experiment, based on the fact that the object has a limited relief. A computer programme was developed in order to perform the resection using as observations, apart from photo co-ordinates, distances measured on the object. For this purpose, 21 distances between 7 points were used. Co-ordinate measurements were carried out on one of the photographs of the metric pair taken for the Stereocord restitution. For this process care was taken to establish the local arbitrary co-ordinate system, in such a way that its XZ-plane was parallel to the main plane of the object (Fig. 3).

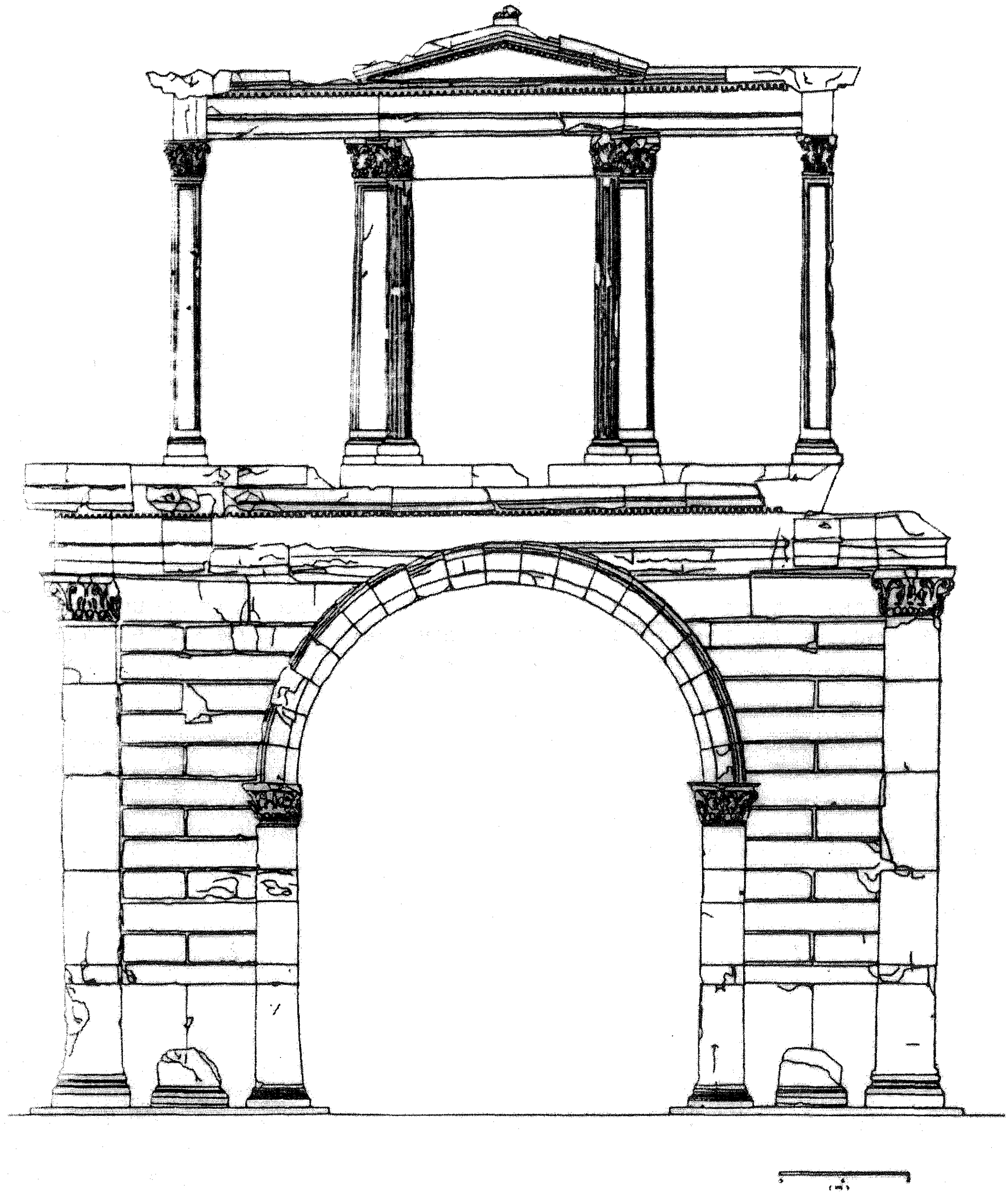


Fig. 1

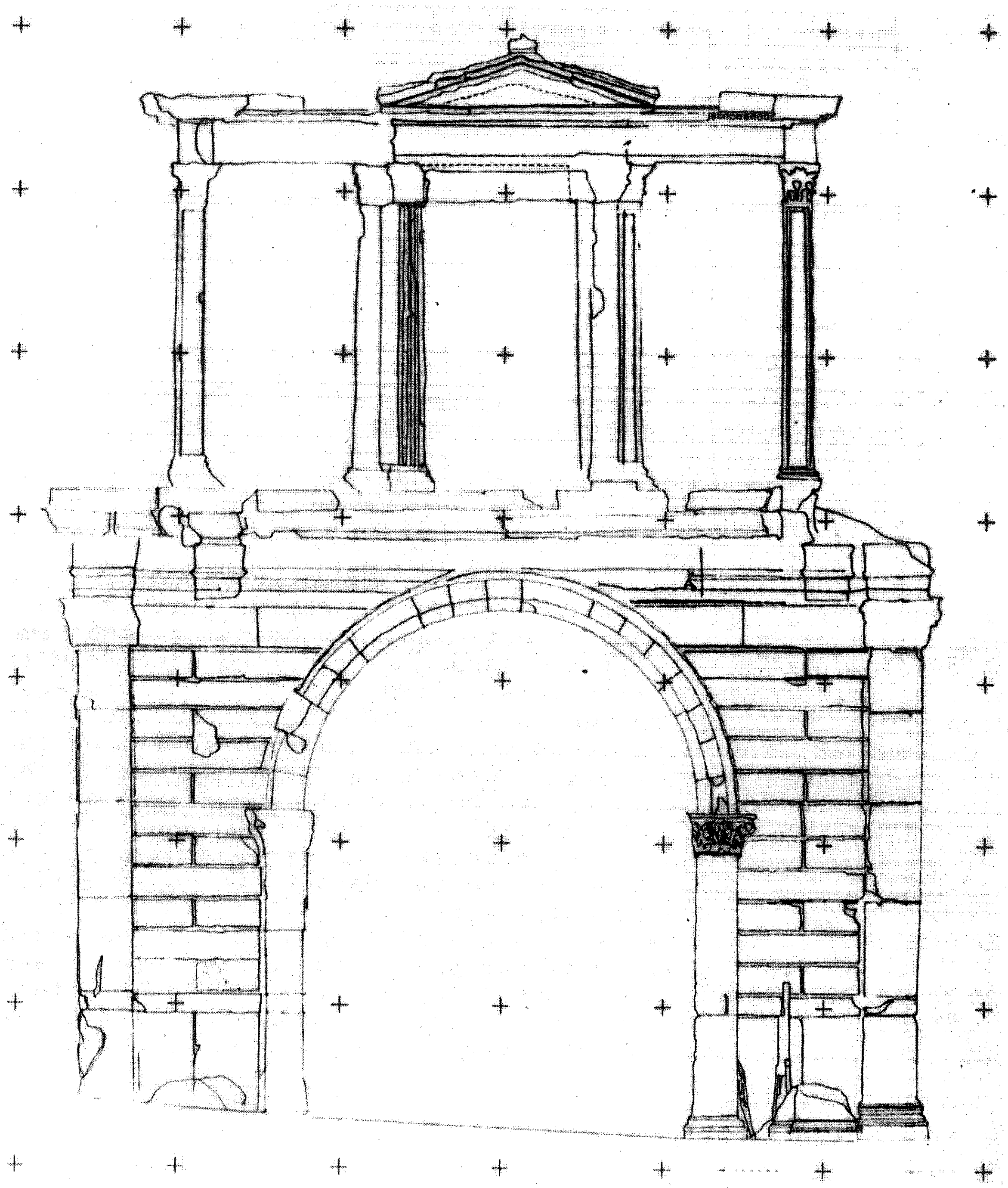


Fig. 2

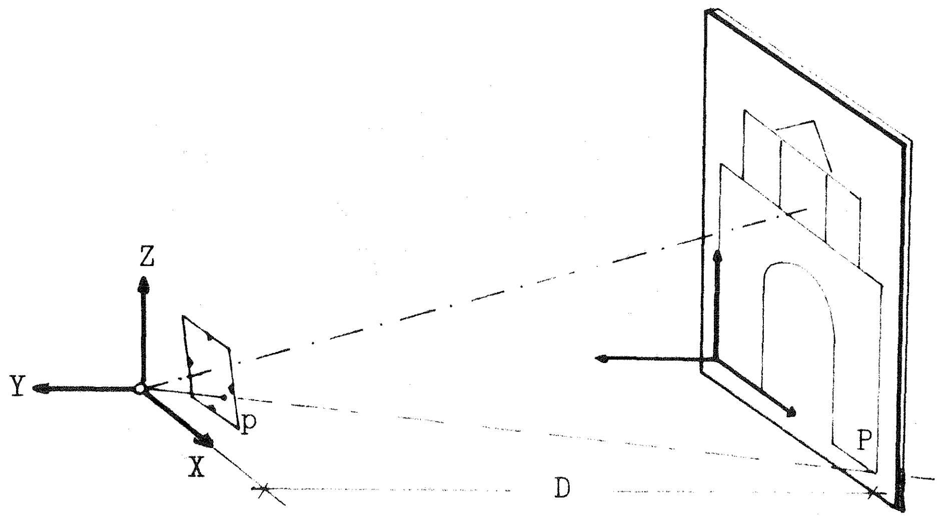


Fig. 3

Having computed the exterior orientation elements of the photograph and the distance from the camera station to a mean plane describing the object, another computer programme was developed to intersect the space vectors produced from the collinearity condition with this plane. For this procedure photo co-ordinates were necessary, which were measured on the STEREOCORD G2 used as a monocomparator and transformed through a 2D-transformation to plate co-ordinates. Some 600 points were observed, in order to give the basic outlines of the object, instead of the complete restitution, for the sake of time saving and comparison. The computations were carried out on the ALTOS 586 microcomputer of the Laboratory and the resulting intersected ground co-ordinates were then plotted off-line on the CALCOMP 1044 plotter at a scale of 1:50. The corresponding plot appears in Fig.4. Observations on 19 check points were also carried out with a CALCOMP 9100 digitiser, in an attempt to bypass the need for an instrument of accurate co-ordinate measurement. The results are discussed in the next section.

5. Discussion

The flow of the described three analytical methods is schematically shown in Fig. 5. It is quite obvious that the three approaches vary in simplicity, in the instrumentation used and, of course, in their applicability. They constitute, however, widely available methods that justify a comparative discussion in terms of accuracy, time and cost effectiveness.

Firstly in terms of time necessary the three methods,

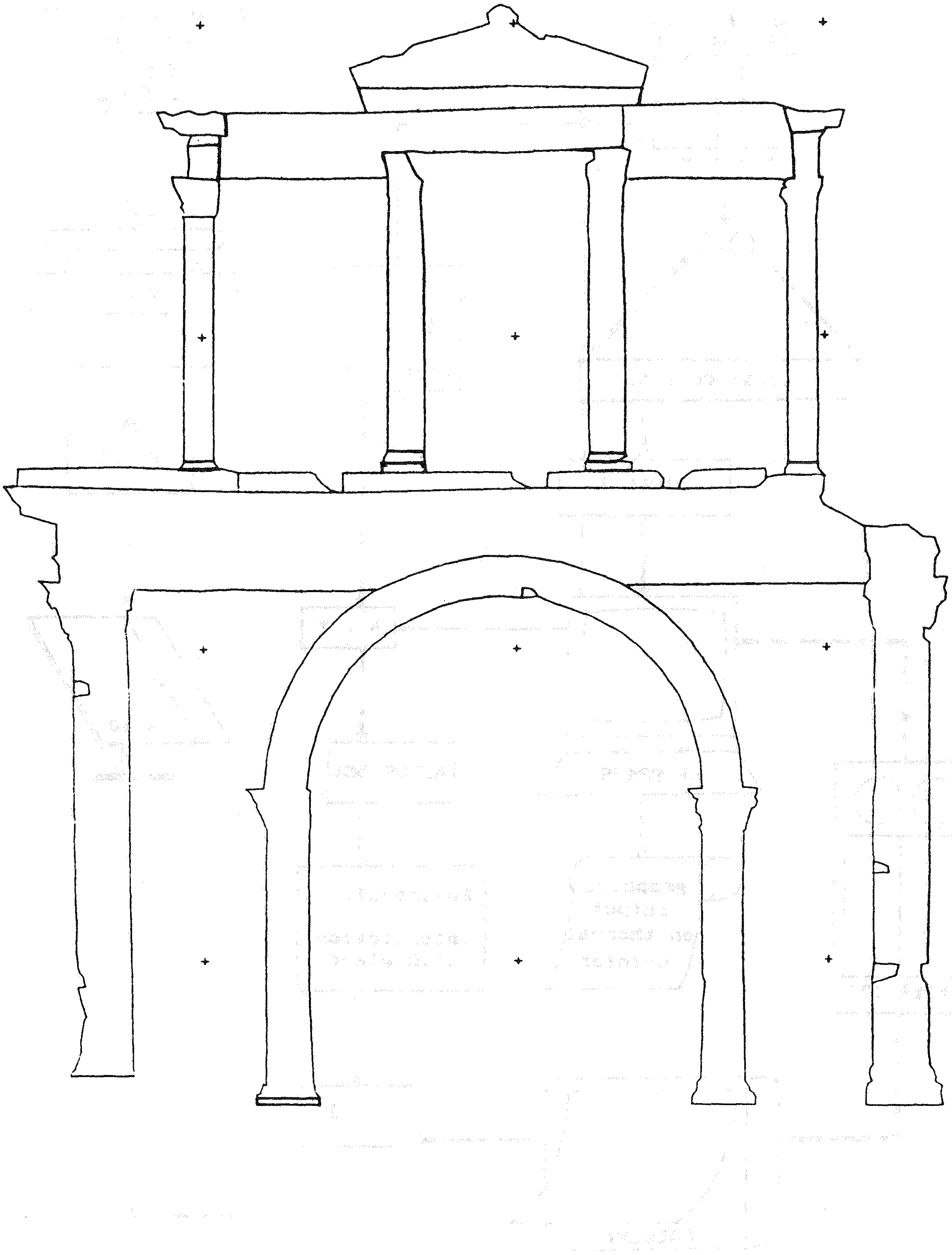
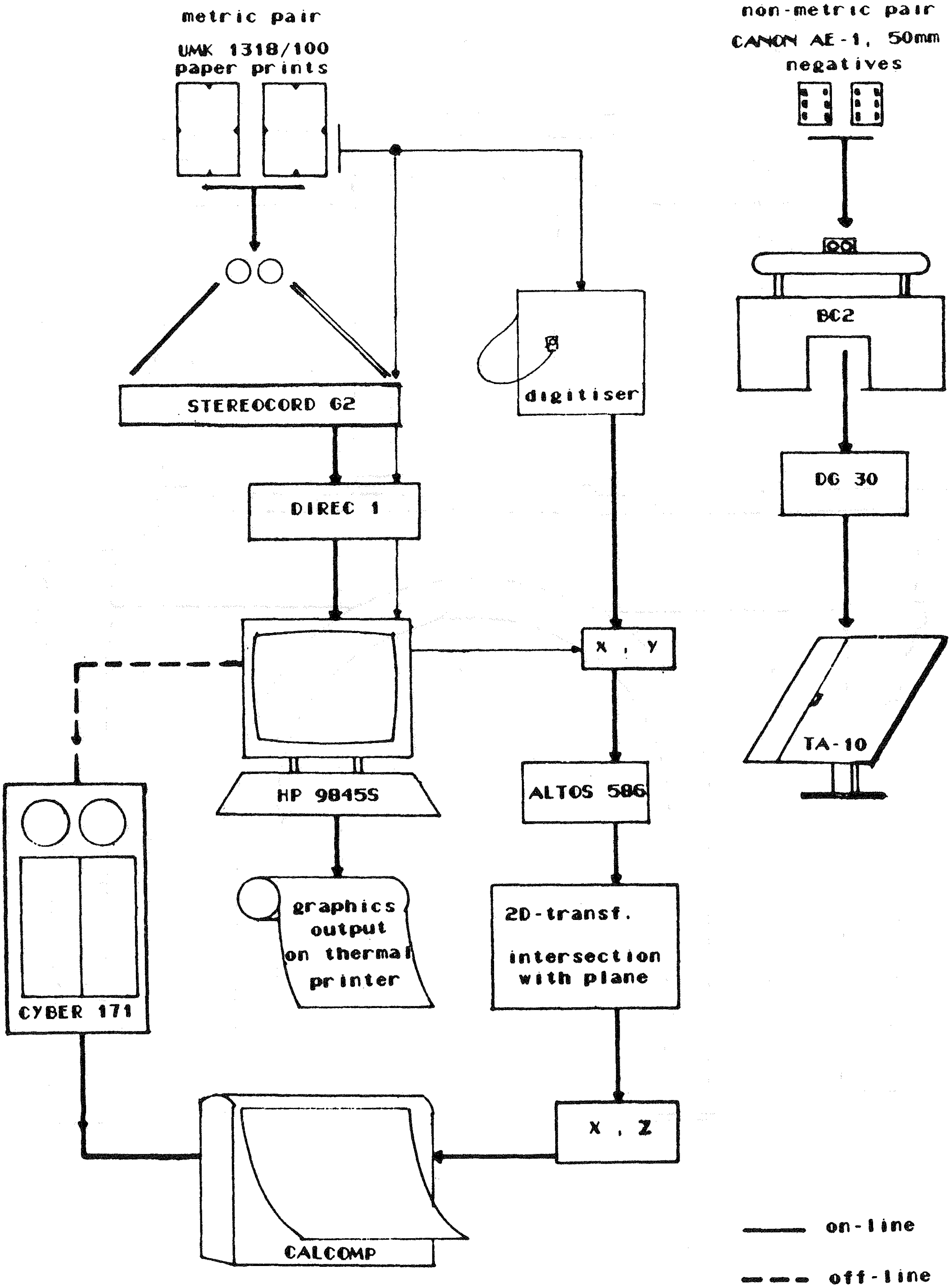


Fig.4



metric pair
UMK 1318/100
paper prints
non-metric pair
CANON AE-1, 50mm
negatives
STEREOCORD G2
digitiser
BC2
DIREC 1
DG 30
x , y
TA-10
HP 9845S
ALTOS 586
CYBER 171
graphics
output
on thermal
printer
2D-transf.
intersection
with plane
x , z
CALCOMP
on-line
off-line

Fig. 5

surprisingly enough, present no variation whatsoever, the main time consuming task being the restitution itself. It should be noted at this point, that the time necessary for the third approach was calculated for the observation of 10000 points on the basis of the 600 observed. Attention is also drawn to the requirement of the monoscopic method to have a great number of distances measured on the object, which is considered as a disadvantage. However, those distances could always be replaced with a few points determined geodetically.

In terms of cost effectiveness, on the other hand, it is obvious that the use of a cheap, off-the-shelf non-metric camera is not going to be able to counteract the excessive cost of an analytical plotter. Thus the second approach is by far the most expensive one. As for the first method, it is obvious that the instrumentation used could be considerd as standard for any photogrammetric Laboratory, as it may be replaced by any stereoscopic instrument with a digital output and a small computer. The third method could be considered as the most cost effective one, as it may make no use of photogrammetric instrumentation at all, apart from the metric camera, as it will be shown later.

Accuracy, the most important attribute of the three methods, was checked in two ways. Apart from the geodetic measurements necessary for the procedures described above, the co-ordinates of 19 additional check points were also determined geodetically. After the restitutions were performed, the resulting co-ordinates of these points were compared analytically. In addition corresponding distances were directly measured on the plots and compared with the real ones. The results of the first check appear in Table 1.

(units in mm)	STEREOSCOPIC METHODS		MONOSCOPIC METHOD co-ords measured with	
	ZEISS G2	WILD BC2	G2	Digitiser
negative scale	1:160	1:600	1:160	1:160
relative rms on the ground at photo scale	15 0.094	19 0.032	13 0.081	16 0.100
absolute rms in X and Z on the ground at photo scale	17 0.106	29 0.048	13 0.081	17 0.106

Table 1. Errors on analytical co-ordinates

It is obvious from Table 1., that the accuracies achieved point to the fact that all methods are equally acceptable, bearing in mind the size of the pointing mark and the negative scale in each case. It should be noted, that the accuracy of BC2 is obviously, and naturally, better almost by two thirds, compared to the other instruments. The relatively small rms errors of the monoscopic methods are due to the fact that the points used for the check were carefully chosen to lie on the same plane. An interesting remark is that with the digitiser a pointing accuracy of 100μm has been achieved. In this way a theoretical check was performed.

A more practical accuracy check was attempted with the help of the previously determined distances between the check points. A number of distances, other than those used for the orientations, were measured directly on the graphical outputs. They were compared with the measured ones and the results are shown in Table 2.

(units in mm)	STEREOSCOPIC METHODS ZEISS G2	WILD BC2	MONOSCOPIC METHOD co-ords measured with G2	Digitiser
Number of distances checked	37	32	13	14
scale of plot	1:20	1:50	computed analytically	
syst. error	-14	-44	0.3	0.6
+/- rms	23	37	18	23
absolute rms	24	41	18	24

Table 2. Errors on known distances

The number of distances in the case of the monoscopic method is smaller, because only those distances were used, that joined check points belonging to the mean plane of the object. The radial displacement, caused by excessive relief, ie. more than 10% of the camera distance, is obvious in the relevant plot (Fig. 4). The large systematic errors are present obviously due to the fact that the plots were deformed, which was expected in a way. Bearing this in mind, one can easily justify the differences in the rms errors between the monoscopic and stereo methods. A comparison of the absolute rms errors of

Table 2. with those of Table 1. shows a remarkable consistency, as their ratio is 1.4 (ie. sq. root of 2) in all cases. This leads to the important conclusion, that whichever way one tries to check these methods, they prove to be within the expected accuracy limits. Hence they are all considered acceptable and recommendable, depending, of course, on the available instrumentation.

References

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