FOTOCAD: A SIMPLE PHOTOGRAMMETRIC PACKAGE FOR NON-PHOTOGRAMMETRISTS

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ABSTRACT

In this paper a simple integrated modular software package is presented. The package performs basic analytical photogrammetric operations from camera calibration to automated on-screen restitution. Data collection requires a simple digitizer and the package runs under DOS on a PC compatible without special requirements. The automated restitution takes place in AutoCAD environment, thus enabling on-screen editing. No photogrammetric instrument is required, thus the system is amiable to non-photogrammetrists. An application of the package is briefly presented using non-metric balloon photography, and the results are evaluated in terms of accuracy and effectiveness.

KEY WORDS: Analytical Photogrammetry, Low Cost System, AutoCAD, Software

1. LOW COST PHOTOGRAMMETRIC SOFTWARE PACKAGES

The impressive progress of the computer industry during the last decade has altered the way traditional Photogrammetry was applied until then. Our profession has passed swiftly from the analogue, through the analytical to the digital era.

This process has caused an immense change of attitude towards the way various photogrammetric problems were approached. Speed and accuracy have, no doubt, been greatly improved, but the main benefit lies in the simplification of the various procedures. "Alien" processes, such as camera calibration, relative and absolute orientations, contour interpolation and plotting, are performed simply at the touch of a button. In this way Photogrammetry has become available for the non expert.

Archaeologists, Architects, Geologists and other scientists are now able to extract reliable quantitative information on their own from photographs they themselves have acquired. They just need to perform a few simple measurements on the images (analogue or digital) with the help of a digitizing tablet and the computer takes over. Several software packages have greatly contributed to this end. These packages vary in concept, in complexity, in cost and in usage. In the following a brief description and comparison of the currently known available systems will be attempted.

1.1 Elcovision 10

ELCOVISION 10 is an integrated package offered initially from WILD Heerbrugg and lately distributed by PMS AG. The system includes a Leica R6 35mm reseau camera, which is recommended by the manufacturers for use with it and a digitizing tablet, where all measurements are performed. It allows for photos taken by hand from arbitrary camera stations, although practical experience has shown that near normal case performs better. Interior orientation is carried out with the help of suitable transformations to the original reseau, or, in special cases, according to the already known camera calibration data. Measurements are performed monoscopically on paper prints with the help of the digitizer. The restitution is carried out pointwise on screen within a not so friendly editing environment. There is however the possibility of interfacing the system with commercially available CAD packages such as AutoCAD or Microstation at extra cost and proceed to the editing off-line (Wild - Leitz 1989).

1.2 Rolleimetric MR2

ROLLEIMETRIC MR2, distributed by Rollei Fototechnik GmbH, is a similar package which combines the use of a Rollei semimetric camera (6006, or SLX with reseau plate) of larger format (60x60mm^2) with the software. It claims a similar but more versatile approach, allowing for more photographs to be measured simultaneously on the digitizer tablet. The photo-grammetric operations are executed in a similar way as with ELCOVISION 10.

Moreover the package offers a self-calibration option and a bundle adjustment facility for determining the camera stations and additional control points. The ROLLEIMETRIC MR2 comes bundled with a versatile CAD package, Rolleimetric CAD, for on-screen editing of the restitution, which again is carried out pointwise monoscopically. It should be noted, however, that there is a stereoscopic version of this package, which is called Stereodigimetro FM1, distributed by GEOTOP Ltd, Italy. This combination enables the user to execute more accurate observations and emulate continuous plotting (Rollei Foto-technic, 1987, Fangi 1988a).

1.3 PhoX

PhoX of Studio Presta, Italy, is another photogrammetric software package, which differs in many respects from the previous two described above. It is based on the DLT method and therefore needs a large number of control points. On the other hand it allows the use of any kind of camera (metric, semi-metric or non-metric), or even a combination. It also allows for simultaneous measurements on multiple images on the tablet. Most importantly, it has a direct interface with AutoCAD and the restitution is carried out in this environment, thus exploiting all the editing facilities of a powerful standard CAD package. PhoX is user friendly and extremely easy to learn and use (Fangi 1988b, Fangi 1990, Studio Presta 1990).

1.4 Fotomass

A rather non-photogrammetric approach is offered by this package, which enables the restitution of non-stereoscopic images based on perspective relations. It is offered by SPIRIT AEC, Germany. It allows for restituting from non-metric conventional cameras or video recorders without taking into account their interior orientation. FOTOMASS actually calculates the position of the points observed on predefined planes of the object, which poses certain limitations. It is, however, an easy and user friendly package for limited use dedicated to the SPIRIT CAD package (SPIRIT 1991).

1.5 ARCHIS

ARCHIS of Galileo Siscam is a digital rectification package based on perspective relations on the image. After the rectification the software offers the possibility of on-screen detail digitization, codification and editing. All image enhancement facilities are also offered (Fondelli et al. 1991) .

1.6 ASTRI

The Analytical STereo Restitution Instrument is a low cost simple system for analytical Photogrammetry (Stamboulоglou 1992a and b). The system includes a two-cursor digitizing tablet and the software run on a PC. It allows for monoscopic as well as stereoscopic restitutions using paper prints from all kinds of cameras. The photogrammetric reduction is carried out with the help of DLT and on-line within AutoCAD environment. It is claimed that the system may accommodate applications ranging from Close-Range to aerial Photogrammetry (Stamboulоglou 1992a and 1992b).

1.7 Brief comparison

Although the systems described above are quite different in concept, an attempt will be made to present their relative merits and demerits. At an indisputable expense of accuracy all systems are quite easy to learn and definitely appeal to the non-expert who needs a working tool to produce a plot. They are relatively cheap in price and normally one only needs a commonly equipped PC to run them on. They differ in friendliness and capabilities in minor issues, such as number of necessary control points, maximum number of photographs which may be used at the same time and on-screen editing facilities. A comparison of all these systems is presented in Table 1.

2. DESCRIPTION OF THE FOTOCAD MODULES

The packages briefly described above are addressed to specialised photogrammetric applications, which mainly include architecture, archaeology, recording of traf-

Feature	ELCO 10	ROLLEI	PhoX	FOTOMASS	ARCHIS	ASTRI
Camera type	m-sm	m-sm	m-sm-nm	m-sm-nm	m-sm-nm	m-sm-nm
Min. no of CP	0	3 - 5	10 - 15	0	4-6	6
AutoCAD on-line	no	no	yes	no	no	yes
On-line editing	poor	medium	good	poor	medium	good
Bundle adjustment	yes	yes	no	no	no	no
Max. # of photos	2	20	6	1	1	2
Ease of use	medium	medium	high	high	medium	high
Cost	high	high	low	low	high	low

Table 1

fic accidents, industrial measurements etc. They do not seem to offer to the user the flexibility of a more general approach and, indeed, the ability to use only part of the software.

For several years the Laboratory of Photogrammetry of NTUA has been endeavouring to compile a similar, yet more flexible package. Thus FotoCAD, a modular package was created. The various modules have been developed and tested within students' Diploma theses (Kavadas & Kyfonidou 1988, Argiaditi 1989, Spinou 1990). The structure of the system is presented in Figure 1.

There are three main modules:

a. **FullCal**: The Camera Calibration Module

As the package is intended to be used with metric as well as with semi-metric or non-metric cameras a camera calibration facility was necessary. It offers the possibility of a simple photographic field calibration (Scott 1977, Scott and Georgopoulos 1979, Georgopoulos 1981). The user simply needs to produce photographs of a linear array of targets along the main lines of the camera format. Simple measurements are also needed as input to FullCal. The output of the module are the radial distortion polynomial coefficients and the shift of the origin of symmetry (principal point), which will be used directly as input parameters for the next phase.

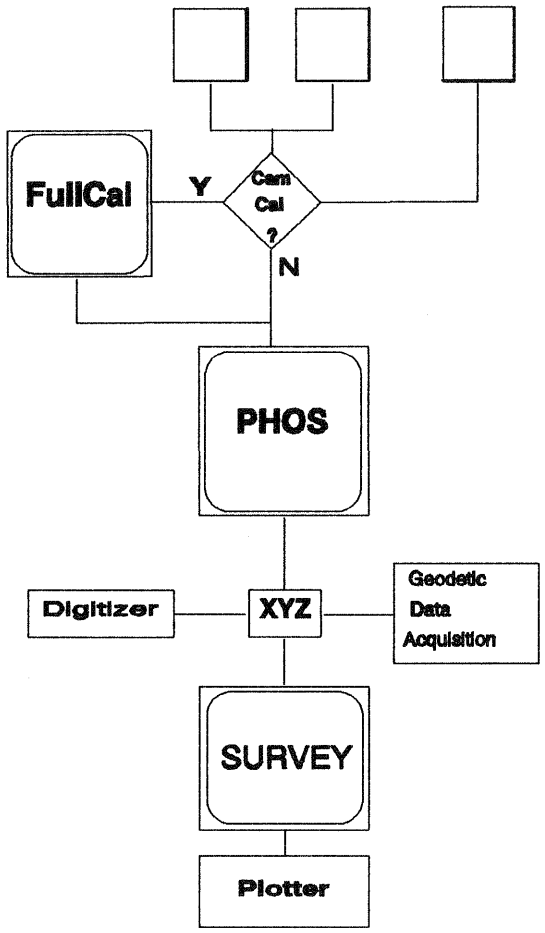

Figure 1

b. **PHOS**: The Photogrammetric Adjustments Module

This module performs basic and advanced photogrammetric operations to image co-ordinates (Kavadas and Kyfonidou 1988). These image co-ordinates may have been measured on a digitiser or a comparator or any other measuring device. Interior orientation is carried out using the relevant information known about the camera. Algorithms based on the collinearity or coplanarity conditions are used for the calculations. The user may select among resection, intersection or relative and absolute orientations. A minimum number of control points with known co-ordinates is required accordingly. Adjustments may be done on single photographs or stereopairs. The result of this module is an ASCII file with the object co-ordinates of all points observed. Appropriate codes for use by the next module are also attached to the points as early as the image co-ordinate measurement stage. A routine allowing for orientation of the photographs without the need for control points is currently under development.

c. **Survey**: The AutoCAD Restitution Module

A simple programme in AutoLISP language has been developed in order to install an appropriate command within the AutoCAD environment, which will automatically produce the plot on the screen for the necessary editing to take place (Argiaditi 1989). The programme uses as input the previously created ASCII file. The various codes attached to each point at the previous stage will determine whether it is a single point, or a line point, or a point of a circle, or of an arc etc. Further development of this module is under way in order to incorporate the 3D information and produce three dimensional drawings.

3. THE PACKAGE UNDER TEST

Since several years the Laboratory of Photogrammetry of NTUA is involved in balloon photography expeditions using a RAVEN TRF 600 balloon (Badekas et al. 1980). FotoCAD was tested using an already existing stereopair from such an expedition over the Minoan Palace of Mallia (1500 BC) in Crete (Spinou 1991).

The photography was taken with a Hasselblad EL/M camera with a 80mm lens (normal) from a height of approximately 230m. The original negative scale was 1:2800 with an overlap of 85%, which resulted to an unfavourable, base-to-height ratio of 1:17. In addition, no control points were determined at the time of the photography (summer 1989) and this made the conditions of the test even more adverse.

A total of 22 control points were determined with the help of a 1:500 survey of the Palace carried out by the French Archaeological School of Athens several years ago. A local co-ordinate system was used and the determination of the control points' plan co-ordinates was carried out on a Calcomp 9100 digitizer with an estimated uncertainty of ± 20cm. Their heights were subsequently estimated from parallax measurements on the stereopair. This determination was by no means ideal, but it would not affect much the resulting accuracy of the height differences.

The camera was calibrated with a photographic calibration in an outdoor test field according to the procedure described in 2a and with the help of the FullCal module. For the observations on the photographs the Calcomp 9100 digitizer was used. The original negatives were printed with four times enlargement, in order to indirectly increase the pointing accuracy of the digitizer. These observations were carried out using a mirror stereoscope simply set up over the pair in order to ensure good point recognition. Apart from the 22 control points a further 1500 detail points were observed and it turned out that no mistake occurred in point recognition.

Using the second module (PHOS) and 9 of the 22 control points the exterior orientation parameters of the two photos were determined. The other 13 control points were kept for checking the achieved accuracy. Their co-ordinates, along with those of the 1500 detail points, were determined using simple photogrammetric intersection provided by module PHOS. The differences of the co-ordinates determined from the initial ones gave a strong indication of the high accuracy and reliability of the method used. In other words the accuracy achieved was well within the expected limits, considering the quality of the initial co-ordinates. In Table 2 these results are summarised.

No of CP's	σX (m)	σY (m)	σZ (m)
9	± 0.15	± 0.15	± 0.43
13	± 0.28	± 0.19	± 0.58

Table 2

Considering the conditions of the photography and the quality of the control points, these results are encouraging. Further investigation into the improvement of the accuracy is already underway.

The ground co-ordinates of the detail points were stored into an ASCII file by module PHOS along with the appropriate codes for the automated restitution. Using the AutoCAD restitution module the plot was produced within the AutoCAD environment. Some editing was necessary in order to rectify certain mistakes of the digitizing stage. The final plot is presented in Figure 2. The time necessary for each of the various stages to produce this plot appear in Table 3.

Action	Time (min)
Digitizer observations (for 100 points)	30
Photogrammetric adjustments - PHOS	15
Restitution - SURVEY	2
Editing - AutoCAD	30
Plotting	3

Table 3

4. CONCLUDING WORDS

The package described above does not claim an award of originality. It is, however, built in such a way to enable modular use by the users. This means that each of the described modules may be implemented independently and irrespectively of the origin of the input data. Thus the FullCal module may be used on its own for the calibration of a camera. The second module may be used for resecting single photographs as well as for determining spatial co-ordinates. Finally the third module accepts input from the previous one, but may well be used with a compatible ASCII file produced in any other way (eg. classical geodetic observations).

Furthermore, it is intended to be used with any kind of camera, be it a metric aerial survey camera or a phototheodolite, or a semi-metric reseau camera or even a non-metric camera. Thus its uses are only limited by the user's imagination, as the package could be implemented in cases of small aerial surveys and in close range applications.

It is believed, that it provides an ideal integration of the traditional pointwise photogrammetric restitution with the powerful editing facilities of today's standard CAD software, promoting at the same time the idea of automation.

Finally, it is considered to be a positive solution to today's demands, which are simplicity, ease of use, economy and effectiveness. FotoCAD ensures quick productivity for non-photogrammetrists, thus making Photogrammetry available to them. It could be stated that it is a decisive contribution to a **new concept** approach (Georgopoulos 1990), which will change Photogrammetry as we have known it up to now.

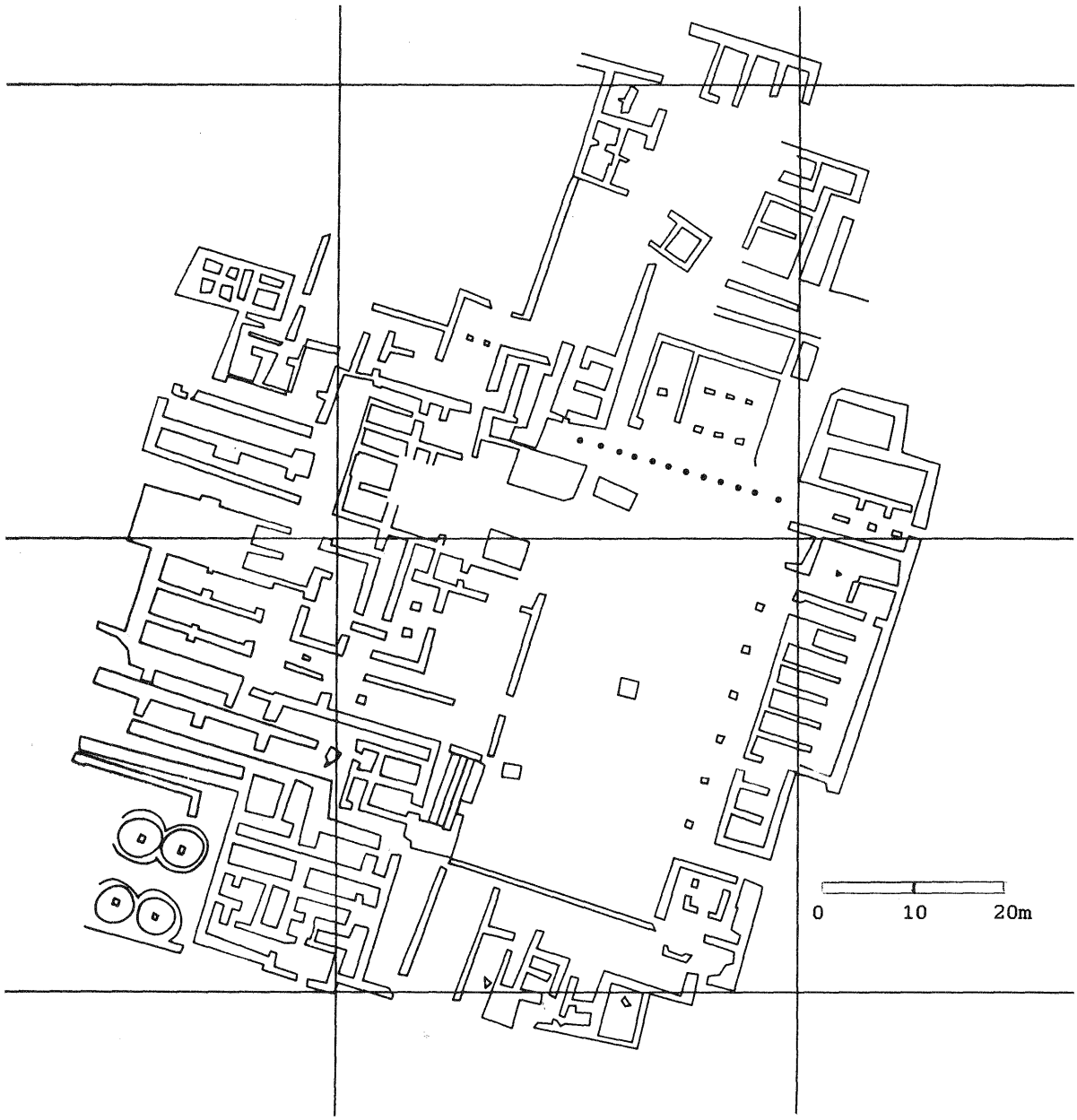

Figure 2

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