

CLOSE-RANGE PHOTOGRAMMETRY WITHIN A COMMERCIAL CAD PACKAGE

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ABSTRACT

Metric applications with commonly available image processing or graphics packages are often reported. Not specifically designed for photogrammetry, these tools have a limited range of uses and, not least, require a good photogrammetric understanding to avoid oversimplification or blunders. As a more rigorous low-cost approach, the tools of widely-used commercial graphics packages may be combined with suitable software to produce 'autonomous' units capable of reliable photogrammetric work. Here, software introduced into the AutoCAD R14 environment allows mapping from stereopairs with monoscopic pointing. Two adjacent windows are used for the overlapping raster images where homologue image details are alternatively digitised as points, lines or polylines; in a third, the 3D vector output is directly produced via space intersection. Users may work with the collinearity equations or DLT. Rectification of planar detail is also included. The system is seen as a useful low-cost photogrammetric system for mapping in close range and can be considerably expanded. Furthermore, the important educational uses of such systems also need to be stressed.

1. INTRODUCTION

It is often recognised that photogrammetry in architectural documentation should be as simple and low-cost as possible in order to further expand its footing in this area by attracting more users of modest budget. As a rule, the structure itself of man-made objects allows corresponding details to be reliably identified on overlapping images. Coupled with the usually not strict accuracy requirement, this renders stereoviewing dispensable. Several, relatively simple, commercial systems for terrestrial photogrammetry are indeed based on monoscopically measuring multi-image configurations with various options and degrees of sophistication (RolleiMetric, Elcovision, PhotoModeler, 3D Builder, Phidias, Kodak Dimension Software, FotoG, Dipas etc.), well documented in literature and the web.

However, it is even simpler and less costly for users to exploit familiar software packages already in use for non-photogrammetric purposes. In this context, simple photogrammetric applications often arise in practice based on commonly available image processing or CAD packages suitable for certain photogrammetric tasks. For instance, these can be used as 'monocomparators' for digitisations of image detail or for vector and raster rectification purposes. Yet these tools have not been specifically designed for photogrammetry; hence, their range of applications is severely restricted, often calling for tedious approaches. Not least, a good photogrammetric understanding is necessary to avoid oversimplification or, simply, mistakes.

A convenient low-cost compromise would be to integrate suitable algorithms into widely-used commercial graphics packages, a modification adding to them a further 'module' for rigorous (within limits, of course) photogrammetric procedures. It is of no lesser importance that such a tool, which may be used by everyone on a PC, is also valuable for academic education in photogrammetry; indeed, this has been one of the motives behind the project. In such a context, AutoCAD R14 has been considered. User-system interface is programmed in Autolisp and Visual Basic with ActiveX technology. The additional software allows photogrammetric mapping from a stereopair (viewed simultaneously in separate neighbouring windows, each with its 'autonomous' graphics tools) with monocular observation. Tools for 2D rectification are also included. These two dis-

crete tasks (analytical rectification of images for nearly-planar objects and 3D mapping from stereopairs) involve certain common techniques but, basically, two separate methodologies are adopted. In its current form, *AutoFoto R1* is regarded as a useful low-cost tool for close range photogrammetric work yielding acceptable accuracy (Glykos, 1998). Its expansion to incorporate further functions and its adaptation to the most recent AutoCAD release are at this stage under investigation.

2. MAPPING FROM STEREOPAIRS

2.1 Setup

The user opens a new drawing and chooses '3dsetup' via the pop up menu, command prompt or toolbar icon. A new drawing is loaded based on the '3d_foto.dwt' template which activates a basic environment of the process. This file introduces three viewports – one for each image and one for the 'model' drawing – and layers to be used next, with the 'block' references of the fiducial, homologue and control points. Through this same command the drawing is given a name, while an '.ini' file is created in the same path to store useful information about the project. Whenever a drawing is re-opened, '3dsetup' (loading all tools for 3D mapping) must be re-run. Next, *AutoFoto* commands allow to insert the two images in all formats supported by AutoCAD: the left image in the left viewport stored in layer 'Lfoto'; the right in the right viewport (layer 'Rfoto'). Then one must decide between the conventional (central perspective) and the DLT (projective) approach.

2.2 The collinearity approach

2.2.1 Interior orientation The basic inner orientation parameters (camera constant, principal point and radial lens distortion) have to be known beforehand as no calibration software is provided at this stage. Algorithms for full calibration, or partial for estimating radial distortion (Karras et al., 1998), are to be introduced. Affine transformations fix the relations between the AutoCAD and the two image coordinate systems. Fiducial or reseau points (or corners in amateur cameras) are observed in both images with no limitation regarding number. One can easily move the points with the AutoCAD commands for precision pointing

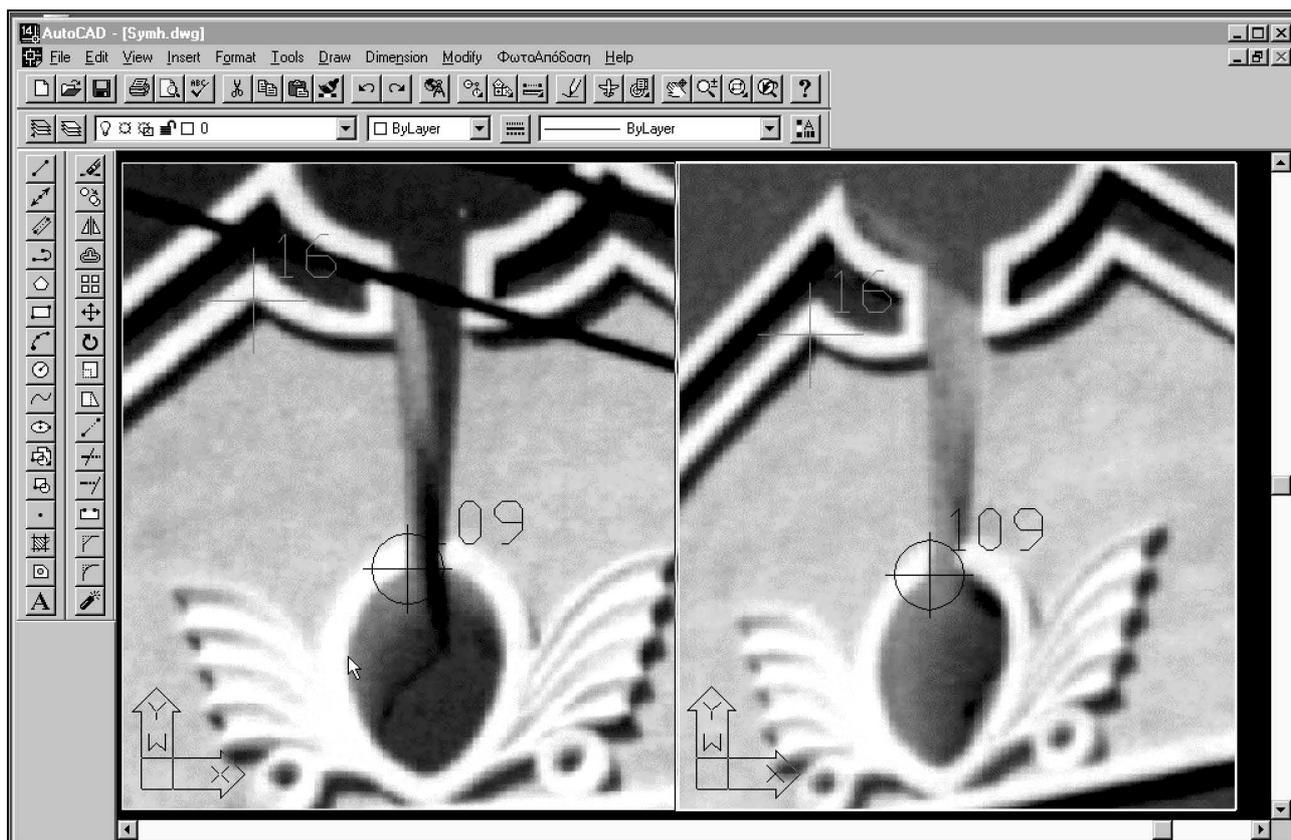


Figure 1. Measurement of homologue and control points in the two image windows.

but should delete them through the AutoFoto command. After the adjustment, based on a reference file, the result form displays the values of the coefficients, RMS error, and residuals v_x and v_y . Results are stored automatically in the working path ('.aff.'), while the 12 transformation coefficients and the x , y reference coordinates are also stored in the '.ini' file. If less than 3 points are measured, the user is warned. In case of only 3 points, user is notified about the lack of redundancy.

2.2.2 Exterior orientation The two usual alternatives are available in AutoFoto for exterior orientation of the stereopair: relative/absolute orientation and space resection.

Relative orientation. Here both homologue and (common) control points are alternately measured in both images using the AutoFoto commands (Fig. 1). Point coding has to be identical in both images, with no limit on the number of points used. Homologue points are block references of block 'Homologue'; an attribute stores their code number. The same holds for control points (block 'Control'). A homologue point must be deleted with the AutoFoto command; control points with either AutoFoto or AutoCAD 'delete' commands in both images. Given the inner orientation parameters (including radial lens distortion, if known), relative orientation is solved for via the coplanarity condition with at least 5 homologue and control points (warning and 'no redundancy' messages are provided). Estimates and standard deviations of the five unknowns, RMS error and image residuals for homologue and control points are displayed in a result form (Fig. 2). Users may directly experiment with the solution by excluding control and/or homologue points from the residuals list. After a number of unsuccessful iterations (default is 10) the user is notified of no convergence.

Absolute orientation. Next, the 7 absolute orientation parameters are estimated if ground coordinates of at least 3 control points have been given through the form or a file. Full but also planimetric and vertical control is accepted. Here again, the result form shows parameter values with standard deviations, RMS error and X , Y , Z residuals. Adjustment may be resumed with varying control point selections. Accepted solutions for the stereopair orientation are stored separately ('.rel') and seen on a form with the finalised values as well as the resulting 12 exterior orientation elements; the latter are also written in the '.ini' file. Alternatively, local 'object-related' systems may be established without ground control. In this current version, one needs: known distances for scaling purposes; points on a vertical plane which is fitted, thus fixing the two rotations in space; and lines defining the horizontal and/or vertical direction on the vertical plane. The exterior orientations in this system are again saved in the '.ini' file.

Space resection. Here control points, not necessarily the same, are measured on the images through the AutoFoto commands (each is a block reference of block 'Control'). Points may be conveniently moved or deleted with AutoCAD commands. The process, similar to the above, may be repeated with desired selections of points and the final solution is stored separately ('.ext') and in the '.ini' file.

2.3 The DLT approach

The approach is suited for amateur images with unknown interior orientation as it rests on the projective (direct) relation between any 2D coordinate system, here the AutoCAD system, and the 3D object system. This is described through 11 projective coefficients (which correct possible affine deformation). At least 6 non-coplanar control points must be inserted for each image with the AutoFoto com-

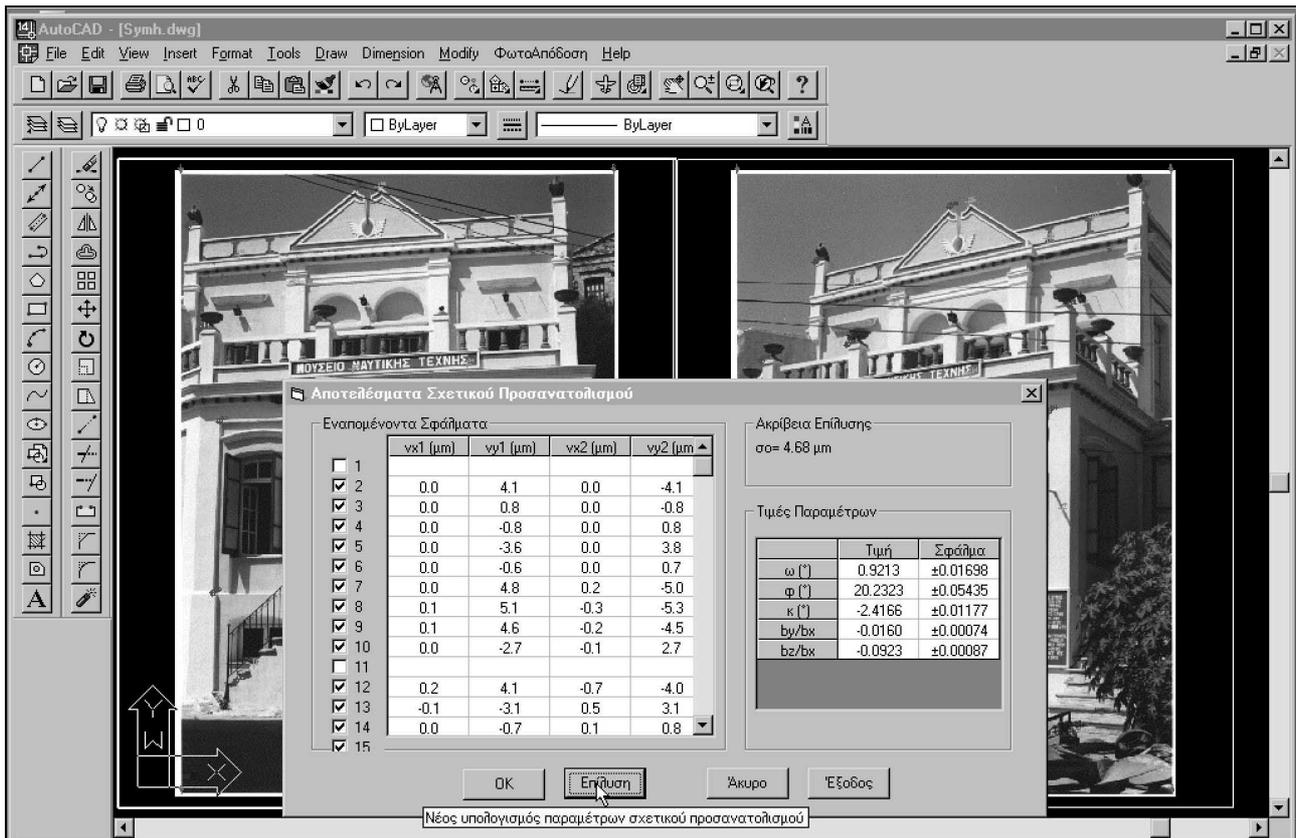


Figure 2. Result form of relative orientation with estimated parameter values, standard errors and image residuals.

mands. A result form displays parameter values, RMS error, residuals. Here again, solutions with combinations of control points are possible. Results are stored separately ('.dlt'); the '.ini' file is updated with all 22 DLT coefficients.

2.4 Space intersection and mapping

Having established and stored all parameters connecting image plane and object space, the user proceeds to digitisation of image detail for 3D object reconstruction, which will be the result of homologue rays intersecting in space. With the AutoFoto '3D mapping' command and the appropriate selection of 'collinearity' or 'DLT', the mapping toolbar appears while a message informs the user about the 'maximum acceptable error of intersection' on the image plane (in μm). For each object point, its precision of intersection is automatically checked against this value, as a measure intended to prevent the user from blundering or matching badly corresponding points. The 'threshold' may be accepted as a default $4 \times \sigma$ – whereby σ denotes (according to the adopted approach) the precision of relative orientation, the mean precision of the two space resections or that of the DLT solutions – or changed.

The toolbar allows users to map lines, polylines or points, or to erase and modify them. In the mapping process, the user first 'clicks' on the left image to indicate the approximate area of the point. The program zooms automatically on this area for precision pointing. The homologue point is given in a similar way, and the 3D point coordinates are estimated (if precision falls below the 'threshold', the user repeats the point or ignores the warning message). Five layers are available for digitised detail; the current layer is chosen from the toolbar. The toolbar allows viewing either the two images or, to check results, the model object.

Objects are drawn in layer Lfoto_'Number of layer' for the left image, in Rfoto_'Number of layer' for the right; model objects are in Cmodel_'Number of layer'. The elements of each line, polyline or point are interconnected by 'xdata'. In the editing process, therefore, a user has to select only one element; the program locates the other two. Thus, all elements may be erased if an object is selected either in the left image, the right image or the model. Furthermore, users may ask the program to 'recompute' a model point, after having moved it on the left or the right image.

3. RECTIFICATION

Finally, in the single-image approach all tools for mapping in 2D and the Block reference of control points are loaded into the new drawing with the '2dsetup' command. The image, to be used as 'background' for 2D data extraction, is stored in its specific layer ('Image'). Detail may then be digitised in different layers as lines or polygons with AutoCAD commands. Rectification takes place through the 8 projective transformation coefficients determined from at least 4 well-distributed control points and stored in a '.rec' file. The drawn details are rectified in a new layer.

4. CONCLUDING REMARKS

The presented software *AutoFoto R1* is an enhancement of AutoCAD R14 allowing photogrammetric mapping in 3D from stereopairs for the generation of CAD models. Only rigorous photogrammetric algorithms have been employed; thus, performance depends on the usual parameters: image scale, quality and resolution; accuracy of interior orientation, control point quality, stereopair geometry. For instance, the images in Fig. 2 have been taken with a 20°

convergence using a 35 mm camera and normal lens, resulting in a negative scale ~1:400. Enlarged paper prints were scanned at a resolution producing a 8 μm pixel size on the negative plane. Control point accuracy was estimated as 1-2 cm. With nominal focal length, and ignoring both principal point and radial distortion, relative orientation yielded an RMS error better than $\pm 5 \mu\text{m}$ (± 0.6 pixels); for absolute orientation the RMS error was < 3 cm.

Within its obvious limitations, the system presented here is believed to have several advantages:

- Based on a popular graphics package, it gives users an opportunity to apply photogrammetry within a familiar environment. Such approaches – which do not attempt to attract users (notably architects and engineers) to photogrammetry and its own commercial systems but rather ‘bring’ photogrammetry to them – may prove fruitful in expanding its fields of application.
- In this sense, requirements are indeed modest as regards software, hardware, RAM, hard disk space. Anyone at a PC can use such a system.
- Being by definition ‘open’, such systems may be constantly enriched with further photogrammetric software. Relatively simple examples may well include:
 - variations for defining local object systems without geodetic control;
 - full camera calibration or estimation of lens distortion from straight lines (Karras et al., 1998);
 - rectification through vanishing points or linear features (Petsa, 1995);
 - monoplottting using a DEM, already programmed within AutoCAD R14 (Grammaticopoulos, 1999);
 - vector development of regular surfaces (Karras et al, 1996).

A more ambitious task is the accommodation of windows for multi-image configurations and of bundle adjustment (or ultimately the consideration of stereoviewing facilities);

on the other hand, one may also consider the exploitation of available drawing aids (‘snaps’, ‘ortho’) in 3D mapping and the introduction of absolute and relative constraints among lines in space.

- All three above points (general purpose graphics environment; low cost; ‘openness’) imply that similar approaches are obviously suitable for educational purposes. Large numbers of students may practice and experiment with basic photogrammetry within the very same packages they use for applications in other fields (e.g. cartography, architectural design, 3D modeling). Furthermore, it is realistic to expect that in this sense users may bring new ideas regarding additional tools or functionality. The educational aspects of such systems should by no means be underestimated.

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