LOW COST SURVEYING SYSTEMS IN ARCHITECTURAL PHOTOGRAMMETRY

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0 Abstract

In recent times quite a few new photogrammetric sytems, especially in architectural photogrammetry, have been introduced to the market. The main difference to the older existing surveying systems is, that the new ones are not very expensive. This paper tries to give a survey concerning these low cost systems. It wants to outline the principles of photogrammetric evaluation, and give some examples.

1 Introduction

This paper gives an overview on existing low cost photogrammetric systems. The reason for the coming up of these systems, is the need of a general accessibility of photogrammetry, especially in architecture. For many users conventional analytical plotters are too expensive. Often, the performance of those systems is not necessary. There are low cost solutions required, which are cheap, flexibel, compatible, versatile, and easy to use. Therefore all of the systems, which will be presented in this paper, are menu driven and use hardware which is compatible to IBM personal computer and standard plotters. This overview cannot be complete. The author has tried to describe different principles by means of a number of representive systems.

2 Monoscopic Image Measurement

Monoscopic measurement of image coordinates requires rather simple instrumental devices (Fig. 2.1), and therefore offers an important presupposition for low cost photogrammetric systems. On the one hand, these systems don't offer the opportunities of conventional stereo photogrammetry, on the other hand monoscopic image measurement fits very much to multi-image-triangulation, carried out by simultaneous bundle adjustment. Within the multi image bundle adjustment a self calibration of the used cameras can be done. This increases the reachable accuracy of these systems and allows the use of non-metric and partial metric cameras [WESTER-EBBINGHAUS 1985]. Control information is not restricted to three dimensionally predetermined object points. It is possible to introduce geodetic measurements like distances, directions etc.. Low cost devices for monoscopic image measurement are high resolution monocomparators with image carriers for negative film (Fig. 2.2), digitizing tablets (Fig. 2.3), and computer monitors with digital image processing hardware (Fig.2.4).

3 Stereoscopic Image Measurement

Due to the stereoscopic viewing of the images, this kind of measurement requires more complex measuring instruments than the above mentioned monoscopic principle. Besides the advantages of stereo viewing however most of these systems don't offer the option of a multi image orientation. This makes simultanous camera calibration more difficult. If no calibration is possible at all, only metric cameras can be used in connection with such a system. The systems can be divided into stereocomparators (STC) and analytical plotters. For the latter a subdivision into Image-Space-Plotters (ISP) and Object-Space-Plotters (OSP) is possible. Measurements with either instrument can be done on an image carrier with negative film, a digitizing tablet, and a monitor with digital image processing hardware (Fig. 3.1).

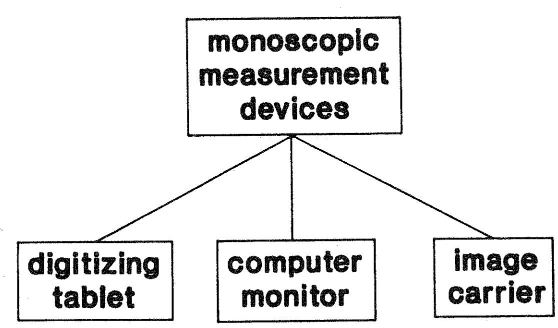

Fig. 2.1 Devices for monoscopic image measurement

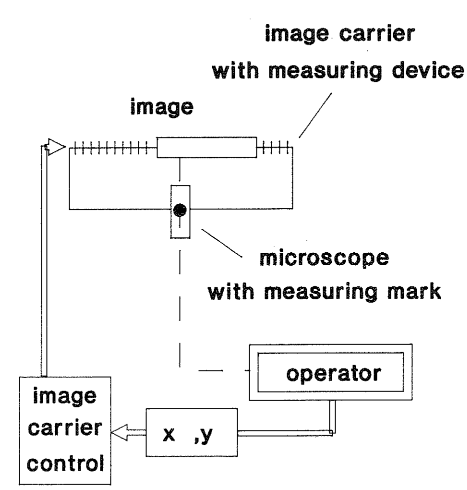

Fig. 2.2 Measurement principle of a monocomparator

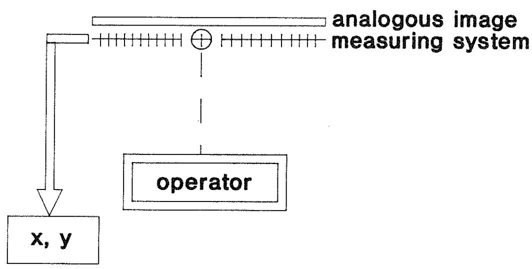

Fig. 2.3 Measurement principle of a digitizing tablet

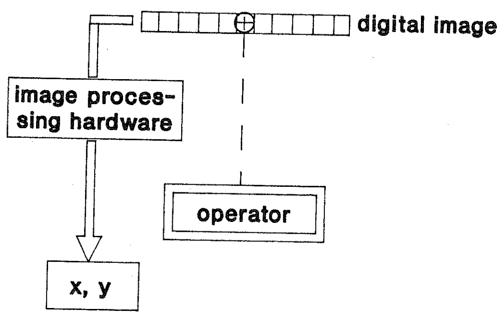

Fig. 2.4 Principle of measurement on a monitor

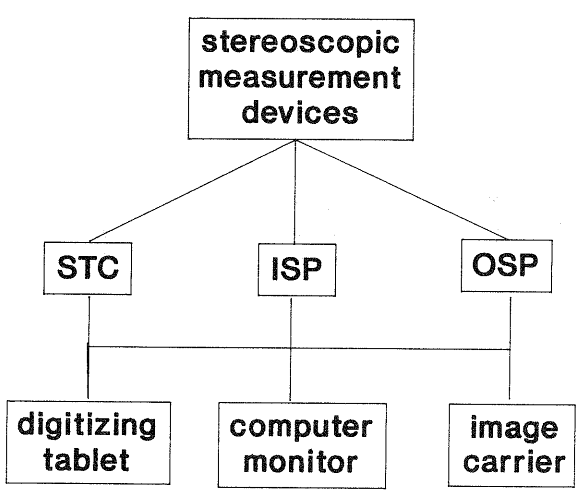

Fig. 3.1 Devices for stereoscopic image measurement

3.1 Stereocomparators

Stereo comparators are the simplest instruments of this category. In contrast to the analytical plotters there is no computer controlled preservation of the image (relative, absolute) orientation during the data acquisition process. Therefore for every point measurement both image carriers have to be positioned manually in x and y (Fig. 3.1.1). The measured image coordinates serve as input for the calculation of spatial coordinates.

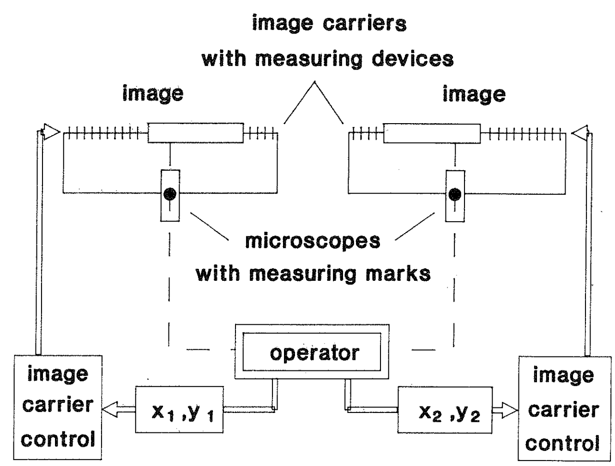

Fig. 3.1.1 Priciple of data acquisition with a stereocomparator

3.2 Analytical Stereoplotters

Analytical stereoplotters are the more expensive stereoscopic systems. During the data acquisition process the image orientation is preserved computer controlled. Therefore only three image carrier movements have to be carried out manually. If the orientation is performed using a bundle adjustment, a simultaneous camera calibration is possible [WESTER-EBBINGHAUS 1987]. In contrast to stereocomparators, the output of analytical plotters are three dimensional object coordinates. There are two categories with different kinds of positioning values, the image-space-plotters and the object-space-plotters.

3.2.1 Image-Space-Plotters

Image-space-plotters work similar to stereocomparators. In addition they are equipped with an computer controlled y-parallax compensation, which is calculated several times per second, to preserve the image orientation (Fig. 3.2.1.1). Therefore only x and y of one image carriers and the x-parallax between both have to be controlled manually, while the stereoscopic viewing is preserved. From the measured image coordinates and the parallaxes spatial coordinates are calculated, using the predetermined orientation parameters.

3.2.2 Object-Space-Plotters

Object-space-plotters work in the same way as the well known analogous stereoplotters. Four computer controlled servo motors are required for their realization in contrast to image-space-plotters, which only need a computer controlled y-parallax adjustment. The measured variables are spatial object coordinates (X,Y,Z). That means that the measurments are directly done in the object space reference system. The x,y image carrier movenments of both photos to preserve the image orientation are calculated several times per second, using the predetermined orientation parameters (Fig. 3.2.2.1).

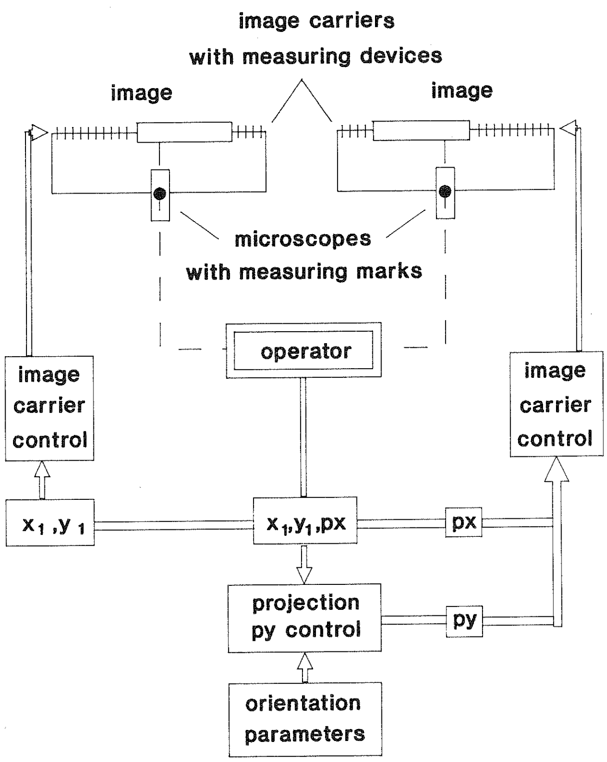

Fig. 3.2.1.1 Principle of data acquisition with an image-space-plotter

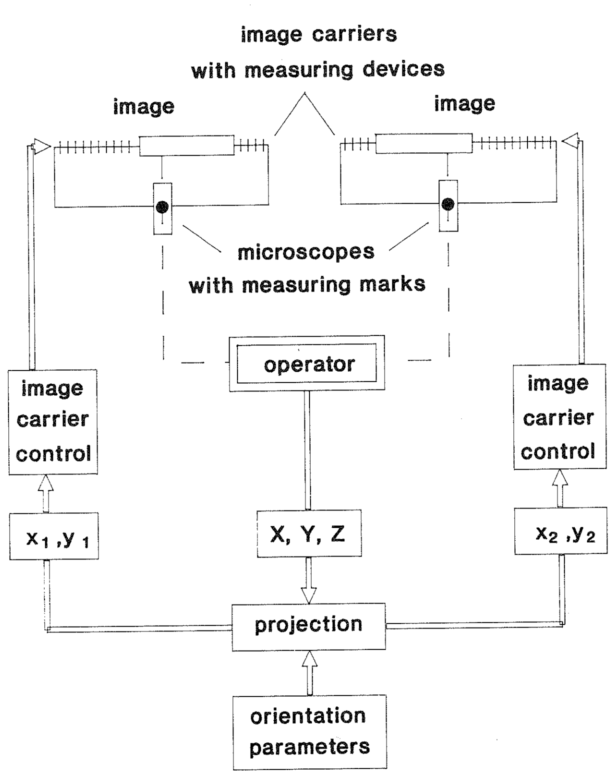

Fig. 3.2.2.1 Principle of data acquisition with an object-space-plotter

4 Overview on Low Cost Systems

Recent developments in close range photogrammetry such as multi-image bundle triangulation, new devices for image measurement and computer control have created the presuppositions for the development of low cost photogrammetric systems. Especially in architectural photogrammetry, quite a few systems have appeared on the market in the last years. They cover the whole spectrum of analytical photogrammetry as described above. Often réseau cameras are used in connection with them. This enables the correction of image deformations, caused by film shrinkage and non-planarity of the film. A few of the systems are listed below. A division is made according to chapters two and three of this paper.

4.1 Systems with Monoscopic Image Measurement

4.1.1 Elcovision

The Elcovision system provides software to compensate image deformations, by calculation the réseau correction. The used camera has to be calibrated beforehand, because no self-calibration during the bundle adjustment is performed. Up to 12 models can be calculated simultaneously with a bundle adjustment program. The monoscopic evaluation of the two-image-model afterwards is supported by graphical functions and can be viewed on the monitor.

4.1.2 Foto 3D

The Foto 3D system [WIEMANN 1992] uses non-metric cameras. The orientation procedure differs from that described in the above systems. Instead of calculating relativ and absolute orientation or computing a bundle adjustment, Foto 3D uses a 3D to 2D projective transformation, which is comparable with the direct linear transformation [ABDEL-AZIZ, KARARA 1971]. It doesn't need any information on the interior orientation parameters of the used camera, but the coordinates of the exposure station and 4 controll points per image have to be known. The user can choose between multi and single image evaluation.

4.1.3 MR2

The MR2 system compensates image deformation with a calculated réseau correction. A multi image orientation with simultaneous camera calibration is done with the bundle adjustment. After the bundle orientation the multi-image evaluation process is carried out usually with four images, and the coordinates of all measured points including standard deviations are calculated with spatial intersection. They can be viewed on the screen and can be manipulated with some graphic routines. A single image rectification is posible as well.

4.1.4 PHIDIAS

In addition to the standard hardware as described in chapter one, the PHIDIAS system [BENNING, EFFKEMANN 1990] consists of a scanner, and the personal computer needs 2MB RAM and a 150 MB hard disk. It uses digitized images. The analogous images are scanned with a 300 dpi flat-bed-scanner. Software for the calculation of the réseau correction to compensate image deformation is available. The orientation parameters and coordinates are calculated with the bundle adjustment. Two photos are used for the monoscopic image evaluation, and the coordinates of the measured points are calculated with spatial intersection. If the user is working with plane areas a single image solution is possible. The measurements are displayed on the screen by superimpositioning of vectors.

4.1.5 PhotoCAD

PhotoCAD allows the compensation of image deformation by calculating the réseau correction. The system offers a two image solution, which means that no bundle adjustment is computed. Therefore the used camera has to be calibrated in advance. After the numerical orientation process the evaluation of the object is done with two images. It is supported by graphical functions and can be viewed on the monitor. A single image evaluation is possible as well.

4.1.6 Comparision of Systems with Monoscopic Image Measurement

One of the main characteristic of the systems described above is the use of photos which are not limited to the normal case of stereo photogrammetry. MR2, PHIDIAS, and Elcovision use the bundle adjustement method for a simultaneous calculation of the orientation parameters, and Foto 3D computes all parameters using the projective approach, requiring three dimensional control points. Only MR2 and PHIDIAS allow simultaneous self calibration of the camera. Due to the simultaneous calculation of all parameters the overall accuracy of the final evaluation is significantly increased. All systems work with standard personal computer hardware, but PHIDIAS needs 2 MB RAM, a 150 MB hard disk, and a 16 inch or larger monitor. In table 4.1.1 the above mentioned systems are listed in alphabetical order with some important characteristics. The prices are software prices. All additional hardware is of extra cost.

4.2 Systems with Stereoscopic Image Measurement

4.2.1 Alpha 2000

The Alpha 2000 belongs to the categorie of object-space-plotters and works in connection with two IBM compatible 386/25 personal computers. The first is used as a system unit with the control, calibration, and orientation software. The second, which needs 8 MB RAM and a 210 MB hard disk, works as application computer. An optional superimposition module provides the capability to overlay digitzed data on the visual photographic stereo model. Furthermore there are some software options for application and data compilation tasks available.

4.2.2 ASP 2000

The ASP 2000 is considered to be portable. The systems provides a method of measuring lens distortion and calculating radial and tangential parameters. The exterior orientation is calculated using a bundle adjustment from up to 12 points. During the digitizing process the collected data is displayed on a colour monitor.

4.2.3 DVP

The DVP (Digital Video Plotter) [NOLETTE, CAGNON, AGNARD 1992] uses digitized stereo images instead of film it. The digitizing is done with conventional desktop publishing scanners (resolution: up to 600 dpi). Two stereo images are displayed on the screen. They

	Price [1000 US $]	Resol. of meas. system [μm]	addit. observ. in Obj. Space	Interf. to CAD Systems	Simult. camera calibr. possible
Elcovision	10-15	25	yes	yes	no
Foto 3D	5-10	25	no	yes	-
MR2	10-15	25	yes	yes	yes
PHIDIAS	15-20	25	yes	yes	yes
PhotoCAD	5-10	20	yes	yes	no

Table 4.1.1 Systems with monoscopic image measurement

are viewed through a mirror stereoscope mounted in front of the monitor. After the orientation process the measurements are done with a cursor controlled floating mark. The already evaluated image parts are marked in both images by superimpositioning of vectors.

4.2.4 Stereo System of "Fachhochschule Bochum" (FH BO)

This system [HEIMES, PURUCKHERR 1990] is a development of the "Fachbereich Vermessungswesen, Fachhochschule Bochum" It falls under the categorie of object space plotters. The exterior orientation for a pair of images is calculated using the bundle method. A 2D- and a 3D-graphic package enable the system to display the collected data on a monitor during the data acquisition process. A single photo rectification ist possible as well.

4.2.5 FM1

The FM1 is a stereocomparator, which is especially designed for users of the multi images system ROLLEI MR2. It is mounted on a digitizing tablet and runs with the complete software of the MR2 system. Therefore it enables users of the above system to a stereoscopic evaluation of images.

4.2.6 MPS 2

The MPS 2 [UREN, THOMAS 1990] is somehow the low cost version of the ASP 2000, and it is portable as well. The system employs the same software as the ASP 2000, so it differs from the latter only in terms of hardware design (size, accuracy, usable image size, see table 4.2.1).

4.2.7 PA 2000

The PA 2000 has a built-in two-way illumination mechnism, which allows measurement of positive film and prints. The whole data acquisition program including the orientation sofware is controled by an external graphic tablet. During the evaluation of the model the digitized data is on-line visible on the graphic screen. Furthermore there are some graphic functions available, which can be selected on the digitizing tablet.

4.2.8 STEREOBIT/20

STEREOBIT/20 [CAMBURSANO, DEQUAL, ZONCA] is an image-space-plotter and equipped with two stepping motors for the parallax control. The model or ground coordinates can be visualized on a video display. An interactive graphic software enables the user to do a revision of the collected data and allows the plotting of evaluated models. An optional software module (8000 US $) gives the opportunity to compensate image deformations like film shrinkage and non-planarity of the film.

4.2.9 Visopret 10/20

The Visopret 10 and 20 are stereocomparators. The Visopret 10 is equiped with a zoom

	Price [1000 US $]	Resol. of meas. system [µm]	image size [cm]	float. mark [µm]	weight [kg]	Interf. to CAD Systems
Alpha 2000	60-70	1	23x23	5-50	230	yes
ASP 2000	60-70	1	23x23	20	45	yes
DVP	30-40	42	23x23	42	6	yes
FH BO	40-50	5	23x23	100	120	yes
FM1+MR2	15-20	25	24x24	100	15	yes
MPS 2	30-40	4	7x7	25	20	yes
PA 2000	50-60	5	24x24	90	100	yes
STEREOBIT/20	30-40	10	23x23	100	45	yes
Visopret 10	30-40	10	23x23	40	75	yes
Visopret 20	20-30	10	23x23	40	55	yes

Table 4.2.1 Systems with stereoscopic image measurment

stereoscope, while the visopret 20 uses a reflecting stereoscope. They are equipped with a two-way illumination mechnism, which allows measurements using film and prints.

4.2.10 Comparision of Systems with Stereoscopic Image Measurement

Comparing the above mentioned systems, one can see that they all differ from each other quit a bit. It is therefore difficult to consider one system better than the other. Nevertheless the subdivision into stereocomparators, image-space- and object-space plotters should be noted. Especially the evaluation of contourlines is done in the simplest way with an object-space-plotter. In general the choice of a system depends on the application one has to do. But all systems have one thing in common. Due to their low prices they make photogrammetry affordable for people who are not able to pay the price of a standard analytical plotter. In Table 4.2.1 they are listed in alphabetical order with some important characteristics. The prices include hardware and basic software to run the systems.

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