"STEREOBIT /20" AND "RESEAU". A NEW PHOTOGRAMMETRIC ANALYTICAL SYSTEM FOR SEMIMETRIC IMAGES: IMAGE ACQUISITION AND PRACTICAL EXAMPLES.

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ABSTRACT

GALILEO SISCAM, the main Italian producer of photogrammetric instruments, in cooperation with the Politecnico of Turin, has recently introduced a new complete system for the use of semimetric images.

Image acquisition is based on the well known ROLLEI 6006, the reseau camera with 11x11 calibration crosses or the more recent PENTAX PAMS 645P, a "quasi-metric" camera with a mechanical flattening device and a special reseau with only 9 crosses. Both cameras are of a low cost, easy to use, and equipped with a full set of lenses and optionals.

Photogrammetric plotting is performed by means of the new motorized STEREOBIT/20 a rigorous analytical plotter with only two parallaxe controls.

In order to verify, in practice, the advantages attainable with the calibration of semimetric images by means of the RESEAU software, a series of simulations and experimental tests have been carried out; results and some comparisons between different semimetric images are presented and discussed.

1. INTRODUCTION

In recent few years we have witnessed a growing interest in photogrammetric techniques, also by those operators in the survey sector who, by tradition, have always paid particular interest to the description of the shape but were oblidged to neglect the metric aspect because the available instruments were inadequate.

The main reasons for this growing interest in photogrammetric techiques are:

- the low cost of the photographic equipment (semimetric cameras) compared with the cost of current terrestrial metric cameras;
- the low cost and easy handling of the systems designed for semimetric images in comparison to the traditional photogrammetric analytical plotter;
- non-experienced operators need to know only a few practical rules which permit the restitution of the objects by means of monoscopic (ROLLEI MR2, WILD ELCOVISION) or stereoscopic collimation (STEREOBIT): the highly advanced software with its transparency enables the operator to solve all the problems connected to orientation and plotting.

The appearance of some types of semimetric

cameras made it necessary to furnish users with an analytical plotter that combines the accuracy of the classic photogrammetric plotting (in the sterescopic collimation of points and in the survey of continuous lines) with the economy and facility of use, bothof which are necessary to render the whole survey system competitive with other simplified methods.

A fruitful collaboration has existed for many years between the Politecnico of Turin and the GALILEO SISCAM in Florence in order to study and create hardware and software instruments for photogrammetric surveys.

During the planning phase for these systems, it was found necessary to take both scientific needs and the facility of use by those operators who have only a minimum of practical experience, into consideration. The work carried out during the last two years with STEREOBIT and the RESEAU software has been undertaken for this purpose. This system makes it possible to utilize the images taken with the semimetric ROLLEI 6006 camera with an accuracy higher than that of other systems which have been available until now. (CAMBURSANO, 1990)

In the following sections, and after a brief description of the semimetric cameras, the results obtained by the latest version of the RESEAU program from various semimetric images elaborated in our Department, are presented.

For a description of the new STEREOBIT/20 please refer to the paper presented by CAMBURSANO, DEQUAL and ZONCA in this same session.

2. THE SEMIMETRIC CAMERAS

It might be convenient to recall briefly the basic idea behind semimetric cameras. They aim to combine easy handling, flexibility and the space saving advantages of the amatorial camera with the metrical characteristics of the traditional photogrammetric cameras.

The semimetric cameras differ from the common camera as follows:

- they are equipped with a grid ("reseau"): the coordinates of all the reseau crosses are known with a high degree of accuracy. This grid is superimposed by contact on the image when the picture is taken and allows the reconstruction of the internal orientation and the correction of some deformations of the film;"
- they are equipped with a certificate of calibration which contains all the information about the coordinates of the principal point within the reseau reference system as well as the principal distance and the value of the geometric distorsion of the lens system. Every combination of camera body, reseau and lens has its own particular certificate. Much of the calibration data is obtained by photographic calibration of the camera. The coordinates of the reseau crosses come from a direct measuring operation with a resolution of at least 1 µm.

The function of the reseau is to show what the effects of the flatness errors of the film and of the deformation of the photografic support are upon the geometry of the taken image at a certain number of points.

It is possible to correct such deformations and rebuilt the exact geometrical shape by determining the differences in position between the observed crosses and the calibration values. This approach allows one to use enlarged paper prints and measuring systems for non-calibrated coordinates.

It was found convenient to use 4X enlarged images of the original negative film: when measuring with the instrument resolution of +/- 10 μ m the results are the same as if an image had been used in its original format with a coordinate measuring system of a resolution of +/- 2.5 μ m.

The calibration carried out by observing the reseau crosses also permits the correction of all the systematic instrument errors (eg. orthogonality, linearity of the guiders, encoders, etc.): the read coordinates in correspondence to the reseau crosses are affected by those errors which, however, are completely eliminated during calibration.

Obviously, the corrections are interpolated inside the meshes.

The greater the number of reseau crosses, the more precise the reconstruction of the internal geometry of the taken image becomes.

On the other hand, a dense reseau overlaid on the image creates considerable disadvantages for the operator because important features of the object might be covered and cause considerable disturbances during the stereoscopic observation.

It will be necessary, therefore, to find the right balance between the density of the grid and the necessity to reconstruct the internal geometry of the image in order to achieve sufficient precision at every point of the photographic image.

The cameras used in the tests represent, in a certain way, two solutions which could be called extreme: the dense grid (121 crosses) of the ROLLEI 6006 camera and the new PENTAX PAMS 645P, with a grid of only 9 crosses.

2.1 THE ROLLEI 6006 CAMERA

This well known semimetric camera derives from the similar amatorial camera and is provided with a grid of $11\times11 = 121$ crosses at a regular distance of $5\times5mm^2$ that cover an area of $50\times50 mm^2$; centered on the original format $60\times60 mm^2$ of the film. This camera can be used

1) The team directed by Prof. S. DEQUAL, has been financially supported by the Italian Ministry for University and Research (MURST 40%)

with all the standard available accessories (filters, extension tubes, lenses of different focal lengths, etc.), and can use normal negative or positive films.

The calibration certificate gives the coordinates of the principal point, the principal distance and the radial distorsion curve of the lens. This curve represents the mean of the radial distorsion along the four semidiagonals, and is defined by the formula:

$$DR = K1r^{3} + K2r^{5}$$
 (1)

where:

r indicates the distance from the principal point

K1,K2 are the coefficients of the interpolating polynomial

Calibration data has been established for focusing objects at hyperfocal distance. For shorter distances a table indicates the principal distance variations, while nothing is given about the stability of the principal point or about the variations of the distorsion curve.

2.2 THE PENTAX PAMS 645P CAMERA

This derives from the amatorial model PAMS 645.

It is a multi mode TTL automatic exposure

reflex camera equipped with a PENTAX lens

reflex camera equipped with a PENTAX lens with a focal length of 45 mm in the standard version. Other lenses are available with focal lengths ranging from 40mm to 305 mm. Shutter speeds vary from 1/1000 to 15 s and B. The film (220,120 or 70 mm roll film) is moved by motor drive to give single exposure or continuous operation at a rate of one frame per 0.7c 0.7s.

All major functions from exposure control to display panel are microprocessor controlled.

External information (exposure factor, film sensitivity, exposure count, etc) useful for the operator is provided by means of a LCD digital display.

A standard model is equipped with a reticule of 5 crosses of which 4 are positioned on the centers of the edges and one in the centre of the photogram.

The extreme scarsity of crosses in the image used for controlling and correcting the negative effects of flatness errors of the film, is compensated by the presence of a mechanical flattening device which presses the film against the reseau glass plate in the moment when the shutter is activated. Thus, the effect of the flatness errors of the film on the geometry of the image is minimized. This error is by far the most insidious and can be eliminated only with great difficulties because of the considerable error variability from point to point on the image. It is





Figure 1 - Reseaus of 5 and 9 crosses of the PENTAX camera

therefore not easy to establish continuous models across the format of the photograph.

On the other hand, the film shrinkage effect can be considered, as a variation of the X and Y-scales, homogeneous over the whole of the image. According to this hypothesis, only a few points are needed in order to correct this kind of deformation.

Using a grid of low density drastically eliminates the inconviencies brought about by having many inner crosses on the image during the stereoscopic observation of the model and will, obviously, speed up the calibration process.

A grid of 9 crosses has been used in the experiments with the PENTAX PAMS 645P; this grid is derived from the 5 cross standard reseau by adding another four crosses at the vertices of the image. This solution is more consistent with the method and techniques in treating semimetric images, since in this case every point of the photogram is contained within three reseau crosses. The need to extrapolate information, a process which is always dangerous, is thus avoided.

The usable surface of the image is 49.4x39.6 mm², and normal negative or positive films can be used.

The calibration certificate provides the coordinates of the reseau crosses, the coordinates of the principal point, the principal distance and the distorsion of the lens system.

According to ISPRS indications, the Gaussian radial distorsion is:

$$DR = K1 \cdot r^3 + K2 \cdot r^5 + K3 \cdot r^7$$
 (2)

where:

r is the distance from the principal point

K1,K2,K3 are the coefficients of the interpolating polynomial.

The decentering distorsion effects have also been calculated according to the indications of ISPRS. Finally, there is another important particularity: the lens of the camera is focussed fixed.

3. DESCRIPTION OF THE TESTS.

The experimental tests and their results presented here have been planned in order to verify the correct functioning of the new procedures of the RESEAU package in the handling of the images taken with different metric and semimetric cameras and the comparing of the accuracy of the results obtained with these images.

Measurements have been carried out with the STEREOBIT/20 analytical plotter, installed in the analytical photogrammetry Laboratory of the Department.

A three dimensional test area was created, formed by 30 points, located within a space of approx. 10 m of length, depth and height.

The coordinates of these points have been measured applying the traditional geodetical methods, which gave all standard deviations not exceeding +/- 1 mm in all directions.

Figure 2 shows the three-dimensional distribution of the signals within the test area and the shape of the signals. Establishing the internal points with equal distances in all three directions permits one to simulate critical conditions which are precisely those which turn up when the object develops considerably in depth.

The cameras used for taking the pictures were:

- the ZEISS JENA UMK 1318 metric camera
- the ROLLEI 6006 semimetric camera
- the RENTAX PAMS 645P quasi-metric camera.

Table 1 gives the scale of the photograms and the base/distance ratio of the stereo-pairs.

The absolute orientation of all the stereoscopic pairs were carried out using twelve points of the test area. The remaining points were used as check points.

Table 2 shows the results of these orientations: mean, minimum and maximum discrepancies calculated on the points used for the absolute orientation.

The following figures show the histograms of the discrepancies (absolute values) on all points. of the test area.

4. ANALISYS OF THE RESULTS AND FINAL CONSIDERATIONS

One can see that when referring to the results obtained from the orientation and plotting tests performed with different combinations of instruments and type of images, summed up in table 2 and figure 3:

- the results of the test executed using metric images and the DIGICART/40 analytical plotter confirms the inner metric quality of the test area. The mean value of the discrepancies over all the control points is about 1 mm and maximum discrepancies do not exceed 4 mm;
- the same experiment using the STEREOBIT/20 points out discrepancies 3

times larger than those obtained in the previous test. This fact proves once again that the smaller measuring resolution of the STEREOBIT/20 (+/-10 μ m) compared to the DIGICART/40 (+/-1 μ m)does not affect the results of orientations and restitution to the same degree;

 the tests performed with semimetric images from PENTAX and ROLLEI cameras gave





CAMERA	Focal lengh (mm)	Camera-signals distance (m)		Photogr. scale		Taking stereose	base/dist.	
		min.	max.	min.	max.	base (m)	min.	max.
UMK	100	11.00	21.00	1:210	1:110	4.00	1/5.25	1/2.75
ROLLEI	40	11.00	21.00	1:525	1:275	4.00	1/5.25	1/2.75
PENTAX	45	11.00	21.00	1:467	1:244	4.00	1/5.25	1/2.75
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CAMERA ANALYTICAL PLOTTER	DXm (mm)	DYm (mm)	DZm (mm)	DXmox (mm)	DYmax (mm)	DZmax (mm)
UMK DIGICART40	1	1	2	2	4	4
LIMK STEREOBIT20	.3	.3	6	6	7	. 11
ROLLEI STEREOBIT20	4	3	6	9	7	15
PENTAX STEREOBIT20	5	6	7	13	1:0	15

Table 2

discrepancies which are quite similar (about+/- 5 mm in the three coordinates) with a maximum value of 10 mm (see table 2). The same considerations can be made as far as the results obtained on the check points are concerned ((figure 3). This fact shows the effectiveness of the PENTAX camera concept: the presence of a flattening device counterbalances the low number of reseau crosses with the considerable time saving advantage during the calibration phase. The presence of only cone cross inside the PENTAX image also drastically reduces the disturbance caused by the presence of non stereoscopic points inside a stereoscopic model and the risk of

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hiding important features of the photographed object. At the same time it is necessary to pay attention to what is going on during the taking of the images with a 9 cross grid the possibility that even only one of the crosses will not be visible can endanger the exact determination of the calibration parameters in a huge part of a photogram;

by comparing the results on the check points obtained with semimetric and metric photograms it appears that the lack of precision between semimetric and metric images is in a ratio of 2 to 1. The mean discrepancies observed with metric images on the test area are about +/-4 mm with a



Figure 3 - Histograms of the discrepancies

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standard deviation of +/- 0.5 mm. On the other hand the mean of the discrepancies rises to +/-7 mm with a standard deviation of +/- 1 mm when using semimetric images.

As far as the aim of this work is concerned, it is possible to say that the new PENTAX PAMS 645P camera with a 9 cross reseau and a mechanical flattening device, gives the same metric quality as the widespread ROLLEI 6006 semimetric camera with its own 121 cross grid.

The solution proposed by PENTAX is between the classical photogrammetric terrestrial cameras and the ROLLEI semimetric camera. Therefore the authors propose to underline this aspect by using a different name for this type of camera and call it, for instance, a "guasi-metric" camera.

The authors also want to point out that the results obtained with the STEREOBIT/20 are of very good quality and give the user a photogrammetric full system with an optimal cost/performances ratio.

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REFERENCES.

CAMBURSANO, DEQUAL, MALAN, RINAUDO, 1990. Calibration and restitution package for semimetric images on DIGICART 40 and STEREOBIT. GEODETICAL INFO MAGAZINE, vol.4, n.3.

CAMBURSANO, DEQUAL, ZONCA, 1991. "STEREOBIT/20" and "RESEAU". A new photogrammetric analytical system for semimetric images: theory and software. XIV Symposium CIPA - DELPHI.

H.M.KARARA 1989. Non-Topographic Photogrammetry (2nd ed.). ASPRS

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