

GALILEO SISCAM APPROACH TO DIGITAL PHOTOGRAMMETRY

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ABSTRACT:

The application of the least squares matching procedure to an analytical stereoplotter is described. The realization of a softcopy photogrammetric workstation based on the same algorithm is presented. Results obtained in terms of accuracy and speed are discussed.

KEY WORDS: Image matching, Digital systems, Image processing, Raster, Photogrammetry.

1. INTRODUCTION

Galileo Siscam has been producing photogrammetric instruments for over than sixty years. During all his activity the company has always chosen new technologies for the realization of its instruments since the early '30 with the Galileo-Santoni analog stereoplotter. In the '70 it was one of first to introduce on the market an analytical instrument the DS based on the prof. Inghilleri's model. With the increasing diffusion of the analytical stereoplotter the company has focused its production on a compact, efficient and easy to use instrument: the Digicart 40 equipped with many software applications oriented to the various fields: cartographic, thematic, architectural.

We have been studying the possibility to automate the restitution task using image processing for some years. This study yields to the presentation of two new products:

- The hybrid stereoplotter: Digicart 40 with an image correlation system that enables to have on the same instrument the traditional data collection and the automatic digital terrain model acquisition.
- The softcopy photogrammetric workstation that allows to make monocompilation using digital images correlation.

2. IMAGE MATCHING

In photogrammetry measures are based on the detection of homologous points on the two images of a stereo pair; using digital images there are several techniques to detect automatically these points. We have tested for a long period the most famous algorithms (cross-correlation coefficients [5], least squares matching [1, 2], features matching [3]) and we concluded that the least squares matching was the most reliable and precise.

To verify the results we applied to our analytical stereoplotter Digicart 40 two digital cameras inserted with two beam splitters in the optical paths that carry the images to the eyepieces (fig 1); in this way the images grabbed from the cameras coincide with the field observed by the operator. The result of the image correlation is used to drive the floating mark to allow a visual check of the calculation result. The lenses that focus the image on the CCD sensor produce such a magnification that a pixel corresponds to 17 μm on the plate. The least squares matching produces the coordinate of the

homologous point with a precision of 1 / 5 of a pixel comparable with the accuracy of a human operator.

During this starting approach we spot some characteristic of the system:

- To get good results the calculation must be started in the neighborhood of the homologous point. Although the algorithm is used in conjunction with a pyramidal approach [6], the maximum distance allowed is 20 - 30 pixels.
- For a correlation with the least squares matching we must perform approximately 1,300,000 floating point operations.
- The quality of the original pictures is not very important for the accuracy of the final result.
- The subject of the picture is otherwise very important for the quality of the correlation. We get poor results when:

- There are many occlusion zones of large dimension.
- There are uniform zones.
- The perspective differences between the two images are relevant.
- A common pattern is repeated in the space (for instance the tiles of the roofs or the rows in the fields).

Taking into account these aspects we have detected the best applications for the automatic correlation:

- Close range pictures of architectural elements yield to poor results because there are significant differences between the two images and consequently there are many occlusion zones.
- We have the same problems with an aerial photo when the flight height is low.
- High flights generally give good accuracy.
- Also with close range photos, if there are not discontinuities of the surfaces, the results are generally good.

As a product of the correlation we have also a figure on the reliability of the results. Using this figure it is possible to classify the points and select those who need to be verified.

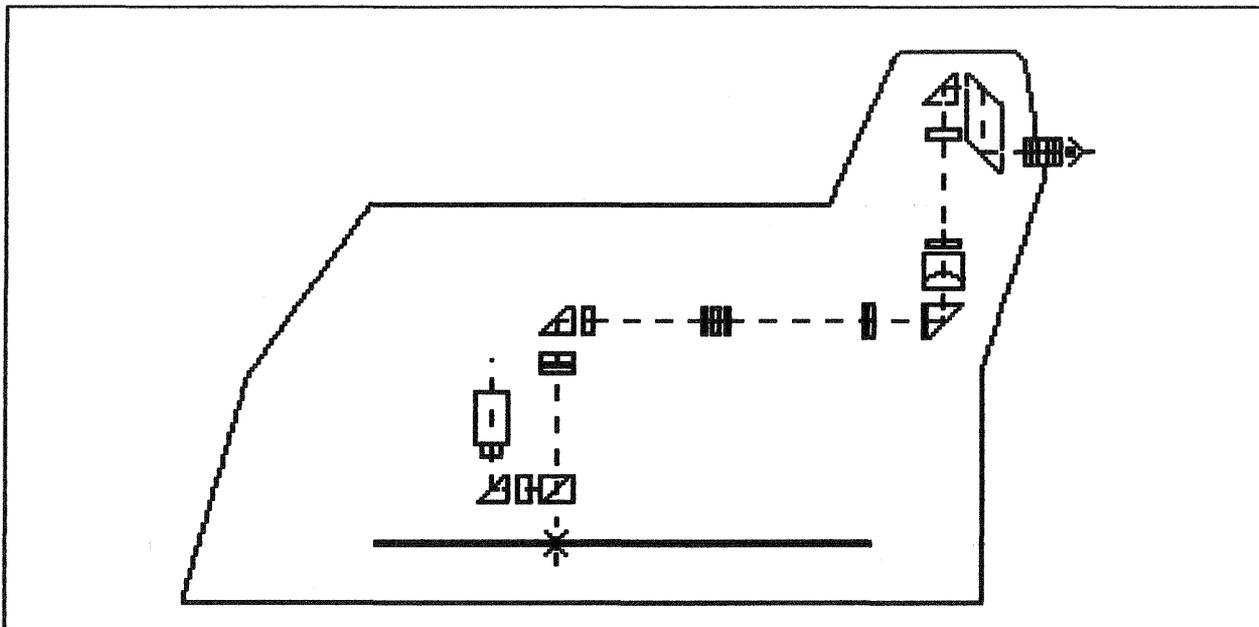


Figure 1. Hybrid system optical scheme

3. THE HYBRID SYSTEM

The automatic collimation based on image correlation can be a great help in the photogrammetric data collection but, till now, it cannot substitute the role of the man. The correlator may become an accessory of a stereoplotter that an operator can use in those jobs when the photo interpretation is not required. Essentially it can be used for automatic digital terrain model acquisition [7].

The operator selects the region where the data is to be collected and the dimension of the grid; optionally a raw DTM (collected with a large grid) can be utilized as input to enforce the convergence of the calculation. After that, the procedure is full automatic, it can be stopped and resumed from the point where it was interrupted several times, only at the end it shows the operator the results in a 3D graphical representation (fig 2, 3 and 4). The nodes of the graphic represent the acquired

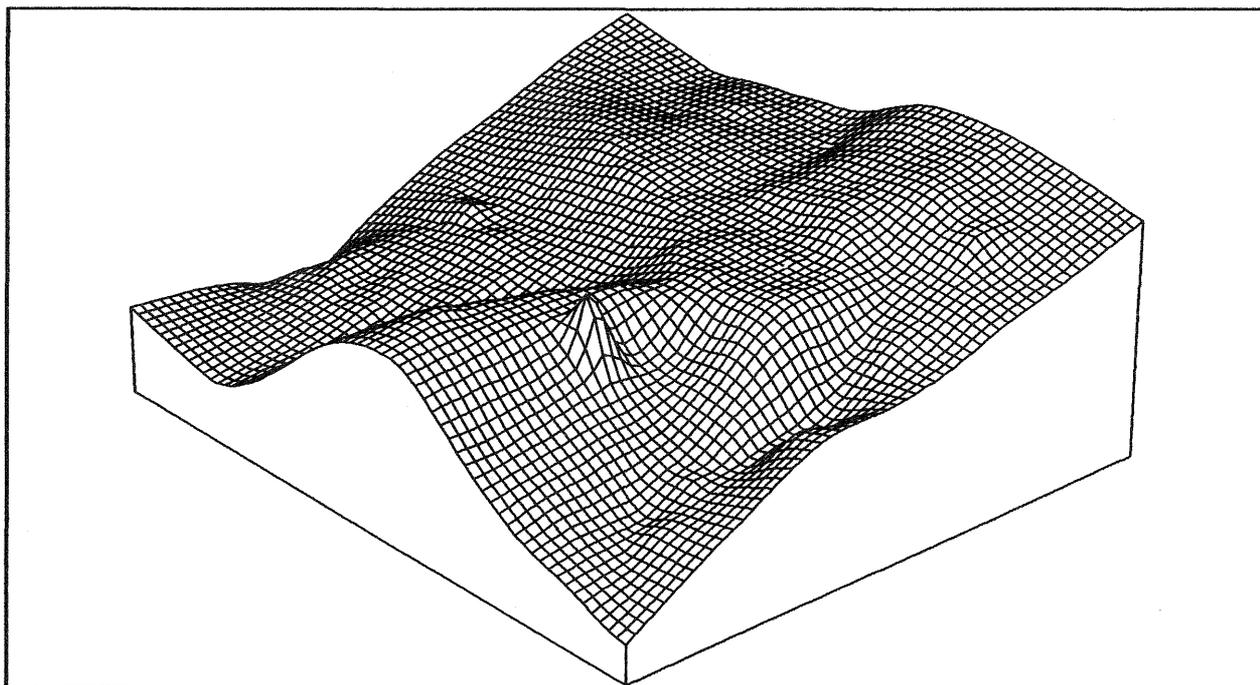


Figure 2. DEM of SICILY stereo pair

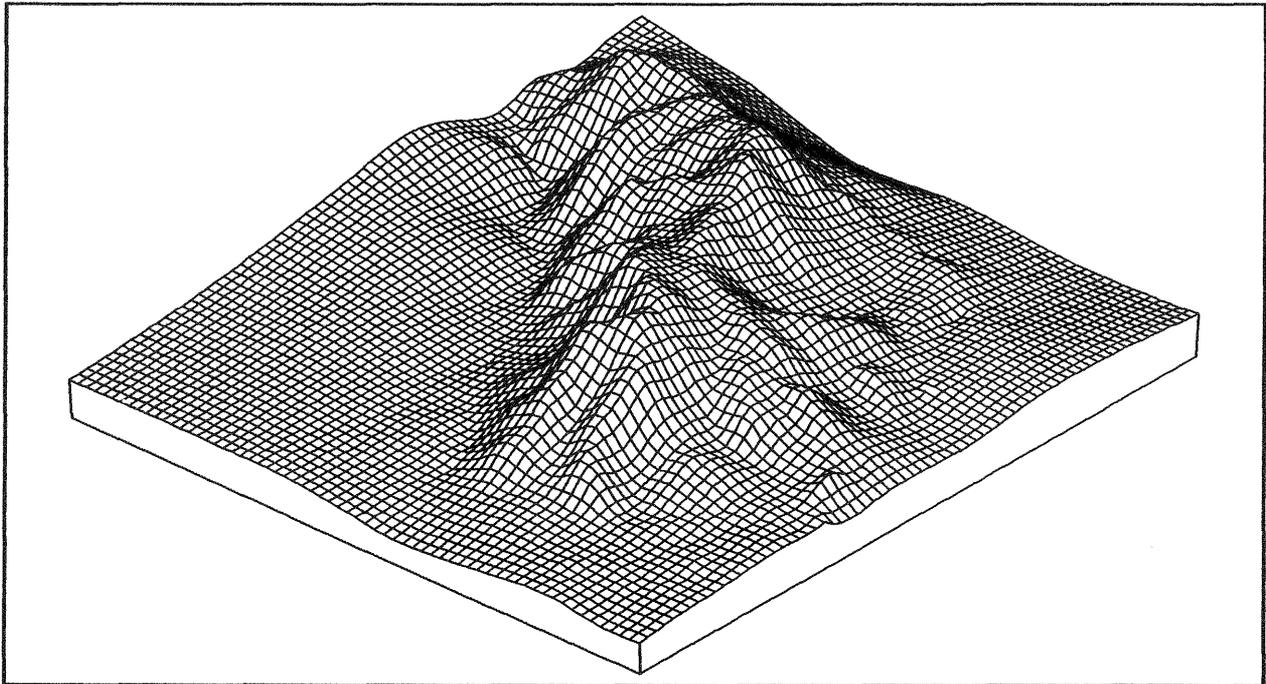


Figure 3. DEM of SARDINIA stereo pair

points, they are marked with a circle whose color is in relation with the reliability of the automatic correlation. The operator can select a node and the floating mark is driven on that point allowing the operator to verify and eventually correct the collimation. The interactive control task is therefore easy and fast. The automatic collimation can help the operator also in the observation of the points for aereotriangulation. The image of each point observed for the first time is stored in a data base; the reobservation of the tie points can be done correlating the stored image with those grabbed from the cameras.

We call this system hybrid because it allows to merge the traditional data collection with the automatic measure. It can be used like a normal stereoplotter and during the operator pause can be utilized for the automatic DTM collection. Only a minimal part of the collected points are to be verified and for this task we can use the stereoscopic view of the instrument.

3.1 Performances of the hybrid system

We have tested the procedure of Digital Elevation Models collection with the hybrid stereoplotter with aerial and close range stereo models.

The photos used in the investigation were chosen as examples of practical applications in photogrammetry. The following image data sets were used:

[I] SICILY : a middle scale aerial stereo pair, (scale 1:14,000), of a hill area in Sicily. A large part of the model is not well textured: this fact, together with weak contrast conditions, makes the matching not always easy (fig. 2).

[II] SARDINIA: a small scale aerial stereo pair, (scale 1:50,000), of a mountainous area in Sardinia. The quality of the images is good, almost all the model is well textured, which makes the matching easy (fig. 3).

[III] VASARI: a close range stereo pair of the Vasari's frescos painted on the vault of a chapel; the whole model is full of details, but the geometric differences are quite large for the presence of overhanging decorations and, at the edges of the model, for the large perspective difference (fig. 4).

Each stereo pair is oriented on the stereoplotter. After the absolute orientation, the following operations are carried out:

- choice of the area in which automatic DEM has to be generated. In this phase we exclude from the calculation the areas where matching results could not be reliable, for example, the urban areas.
- choice of the main scan direction and of the two scan steps (one step along the main direction, the other along the perpendicular one).

These data determine a grid of points in the area of interest. The DEM is generated repeating for each point of the grid the following steps:

- the carriages of the stereoplotter are driven to allow the ccd cameras to acquire the two images in correspondence of the

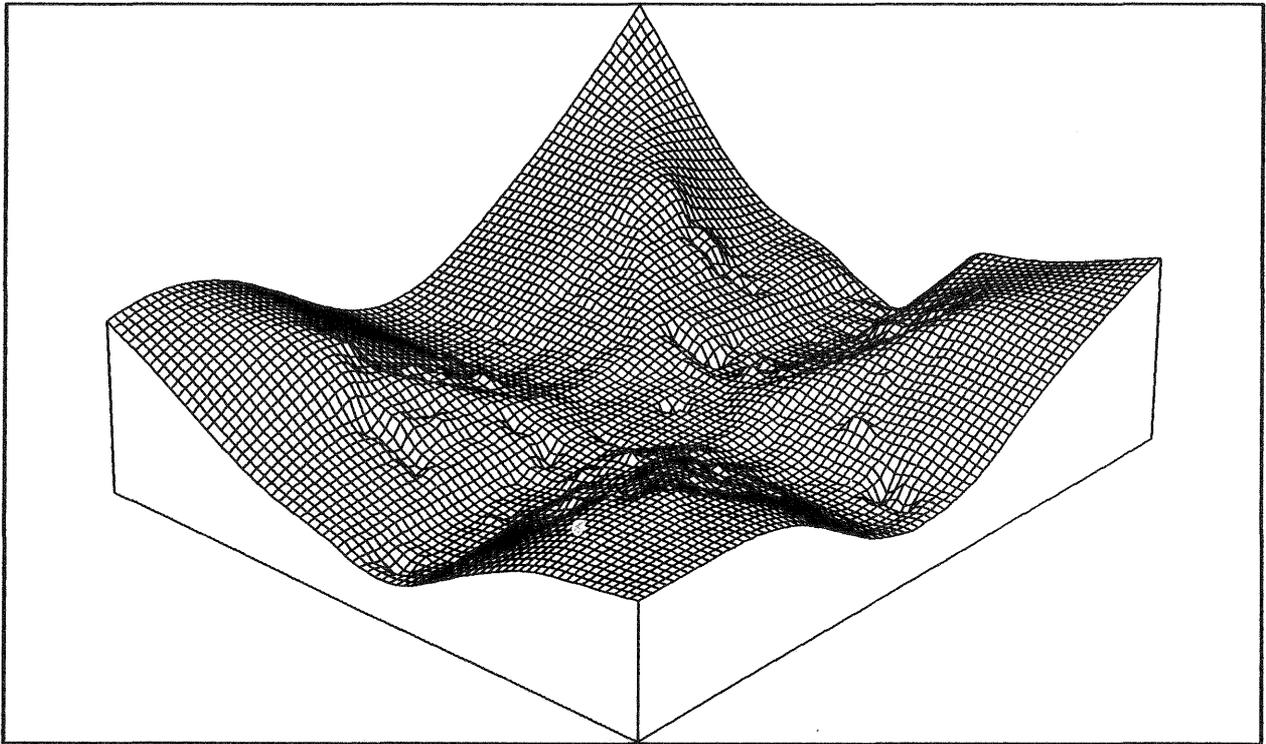


Figure 4. DEM of VASARI stereo pair

following ground coordinates: planimetric coordinates determined by the position in the grid, height equal to a starting value which will be discussed below

- the two images are acquired by the ccd cameras
- fixed a point in the left image (the center of the image), the homologous in the right one is detected by the matching algorithm
- the height of the point is calculated by means of the orientation parameters.

The choice of a good starting value for the height is very important to ensure a high percentage of correct results. In fact, the more the starting height is different from the real value, the farther the homologous point is from the center of the right image, which is the starting point for the least squares matching procedure, and the greater is the probability of error.

This problem specially happens when DEM grid is large, or in cases like our [II] and [III] stereo pairs, where also small planimetric displacements correspond with large change in height values.

Therefore it is necessary to know an approximate value of the real height of each point, to use as starting height for the acquisition of the two images.

For this purpose we use a terrain description done by plain triangles surfaces [8]. In order to obtain this description, before starting automatic DEM procedure, a raw DEM (a very small percentage of the total number of points) has to

be collected by the operator.

The three coordinates of each point of the automatic DEM are stored in a file together with a numerical value giving a valuation of the reliability of the result.

This number is the cross correlation coefficient between the right image, transformed according to the six geometric and the two radiometric parameters calculated with the least squares algorithm, and the left image.

The results of our investigation are shown for each model, dividing the points of the DEM in three classes of reliability :

- Class A : High reliability points, with cross correlation coefficient from 0.8 to 1.
- Class B : Medium reliability points, with cross correlation coefficient from 0.4 to 0.8.
- Class C : Low reliability points, with cross correlation coefficient from -1 to 0.4.

The table below shows the results of the investigation :

DATA SET	NUMBER OF POINTS	GRID SPACING	Percentage of points per class of reliability		
			Class A	Class B	Class C
SICILY	607	10 (m)	75.62	22.90	1.48
SARDINIA	2438	30 (m)	93.15	6.36	0.49
VASARI	3053	10 (cm)	86.67	12.18	1.15

Table I

Obviously, this classifications in groups of reliability must be considered by a probabilistic point of view. The next step in our investigation is the manual control of the heights of the automatic DEM with the stereoplotter.

We verified that, with the selected thresholds, the reliability of the points in class A is really high and the reliability of the points in class C is really low, that is near 90 % of the points in class A are good and the same percentage of the points in class C are wrong. Class B is less significant; it contains either good points not satisfying conditions to belong to class A, either wrong points not satisfying conditions to belong to class C. However, with the thresholds we select for this classification, the greater part of the points in class B are good.

4. THE SOFTCOPY PHOTOGRAMMETRIC WORKSTATION

Another application based on the correlation procedure is the monocompilation system: the softcopy photogrammetric workstation.

We have no more a mechanical-optical stereoplotter, everything is replaced by a computer. The inputs for this system are digital images stored on the disk of the computer. Only one image of the stereo pair is visualized on a high resolution screen, the other, stored on the disk, is used for image correlation. With a mouse the operator moves a cursor on the screen identifying a point on the displayed image, the correlation finds the homologous on the other one and as a result we get the ground coordinates of that point. If the computer is fast enough (at least 8 Mflops to have 5 correlation per second) the movement of the cursor produces in real time the ground coordinates of the points explored substituting completely a traditional stereoplotter.

As a first step it is necessary to perform the model setup as in a traditional stereoplotter. Until the orientation parameters are unknown the use of the correlation is not very reliable (because we have no information about the disparity between the images and the search cannot be limited to the epipolar lines) so it is necessary to select manually the homologous regions on both images. The operator identifies a point on the left image, then selects on the right one, the region that contain the homologous point and activates the matching calculation. As for a traditional stereoplotter the orientation

is subdivided in interior: collimation of the images of the reperes to reconstruct the camera geometry, relative: collimation of at least five homologous points to reconstruct the relative positions the cameras had when the photos were taken, absolute: collimation of at least three points to calculate the roto - scale - translation between the object and the model.

We can use the photogrammetric workstation when the scale is small enough according to the analysis made in paragraph 2. The first application we have implemented is an automatic DTM collector based on a 486 PC using a procedure very similar to that of the hybrid system. The DTM collector does not require the interactivity of an operator so the performances in terms of speed are not of principal importance and so, even a PC, may be enough. Otherwise it is very important for us to have a program that can generate a DTM without the need of a stereoplotter to pair with Orthomap, our package for digital orthoimages generation and processing which needs a DTM for the orthogonalization process.

Presently we are working on the monocompilation aspect of the photogrammetric workstation. This system emulates a traditional stereoplotter using a single image; the operator has only to single out the contour of the objects because the calculation provides to determine the altimetric measures. This is an interactive package, the speed is of primary importance and a PC is too slow therefore we are developing this system on a RISC workstation which gives us a sufficient throughput with its 8 Mflops .

4.1 Performances of the workstation

The accuracy of such a system depends not only on the correlation algorithm but also on the resolution of the images. The collimations the operator performs cannot, of course, be more accurate than one pixel so the final result is highly influenced by the quality (resolution and accuracy) of the scanner we use to transform the traditional photos in digital pictures. High resolution pictures require a large amount of mass storage and impose the use of a powerful computer.

Unlike the hybrid system now we cannot use traditional stereoscopic view to control the accuracy of the collimations so it is necessary to use different techniques. Presently we are investigating the possibility to use a 3D

polarized screen to have stereoscopic view to use for model setup and collimation accuracy control.

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