Automatic Measurement of Plate Coordinates in order to Obtain Automatic Plotting

Baj Angoletto Elena*, Casalini PierLuigi**, Lombardi Stefano*, Tonazzini Anna***
* Ist. Geod.Top.Fotog., Fac.Ing., Univ. of Pisa, Italy
**Ist. Scienze dell'Informazione, Univ. of Pisa, Italy
***Ist.Elaborazione dell'Informazione, CNR, Pisa, Italy
Working Group II/2

1. Introduction

This paper discusses the problem of obtaining a completely automatic restitution of particular takes in terrestrial photogrammetry (3).

The aim is to determine automatically the plate coordinates of corresponding points on a pair of stereoscopic photograms.

At present, the most common tendency is to define and design image correlators (1),(2), i.e. sophisticated instruments generally designed ad hoc, which substitute the stereoscopic vision by adequate photoelectric and electronic systems. Essentially, these systems provide a rapid and accurate sensing of parallax by scanning and subsequently correlating corresponding imageries.

The approach taken here is completely digital, using the typical image processing system, and analysing separately the two photograms. The system adopted consists essentially of: 1) an analog-to-digital converter (digitizer), which converts each photogram of the stereoscopic pair into digital information, 2) a digital computer, 3) a TV monitor for data display, and 4) a plotter for mapping.

2. Photogram taking techniques

The problem was approached in stages and our study was limited to terrestrial takes obtained with special artifice, i.e. by projecting a bright plane raster onto the surface to be taken. The raster is made up of two series of parallel straight lines intersecting each other at 90° at points called nodes. The nodes projected on the object enable us to identify in the stereoscopic pair corresponding points in cases where the homogeneity of colour and the lack of light and shades of the photograms make this operation difficult and at times impossible.

Similarly, the characterization of the points to be restituted by mathematically definable forms (the nodes of the raster) facilitates automatic measurements by the computer.

Moreover, the raster can be considered a photogram (pseudophotogram) obtained by a particular take of the object. In fact, we can make the following considerations:

1) projecting the plane raster from a point P onto the object, a deformed and spatial raster is obtained whose nodes represent a discretization of the object (it is assumed that the raster is permanently printed on the object);
2) taking the object from the same point P with a camera whose optical axis is oriented as that of the projector, an undeformed image of the raster is obtained.

It is obvious that a projector having the same characteristics of the camera has to be used. It must have fiducial marks to locate the principal point and the principal distance must be known. It must also be constructed with the same precision of the camera. We define such a projector a metric projector (4).

In this way the classical stereoscopic pair of photograms can be replaced, without losing any information, by the original raster and by one single photogram taken from a point different from that of the projection. The advantage is obvious, the plate coordinates on the pseudophotogram are predetermined and are therefore known with great precision.

Thus, while in the case of two stereoscopic photograms it will be necessary to measure the plate coordinates of corresponding points on two photograms, in our case only the plate coordinates of the imageries of the node of the raster on the single photogram are to be measured. The measurements have to follow an exact order, so as to allow a correct matching with the nodes of the pseudophotogram.

In the following paragraphs, the term "raster", with reference to the processing of the photogram mentioned above, will mean the deformed image on the photogram of the original raster projected on the object.

3. Automatic measurement

In this section we describe the procedure which measures the rectangular coordinates of the nodes of the raster in a coordinate system of the image plane (5). Figure 1 gives a block diagram of this procedure.

The ordering criterion adopted for a correct matching consists in locating the nodes of the photogram sequentially from left towards right along the successive horizontal lines of the raster (which appear in general deformed) scanned from top downwards.

a) Digitizing

The analog information contained in the photogram has to be digitized (6),(7) for processing on a digital computer. An image scanner samples and quantizes the values of photometric transparency or density of the image in grey levels, which are subsequently stored in a matrix A(i,j) (Table 1).

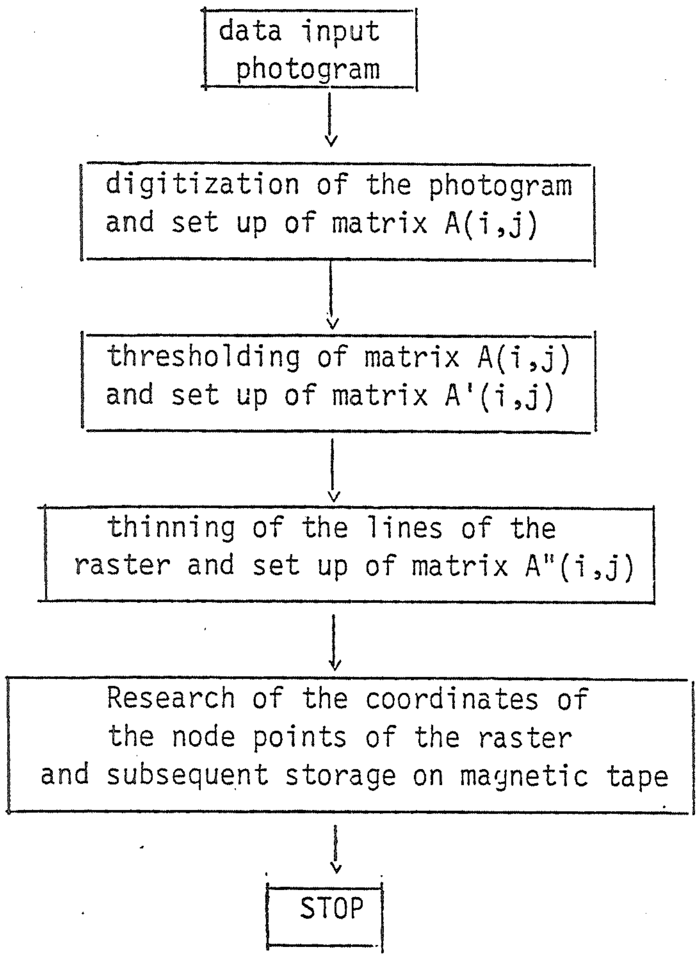

Figure 1

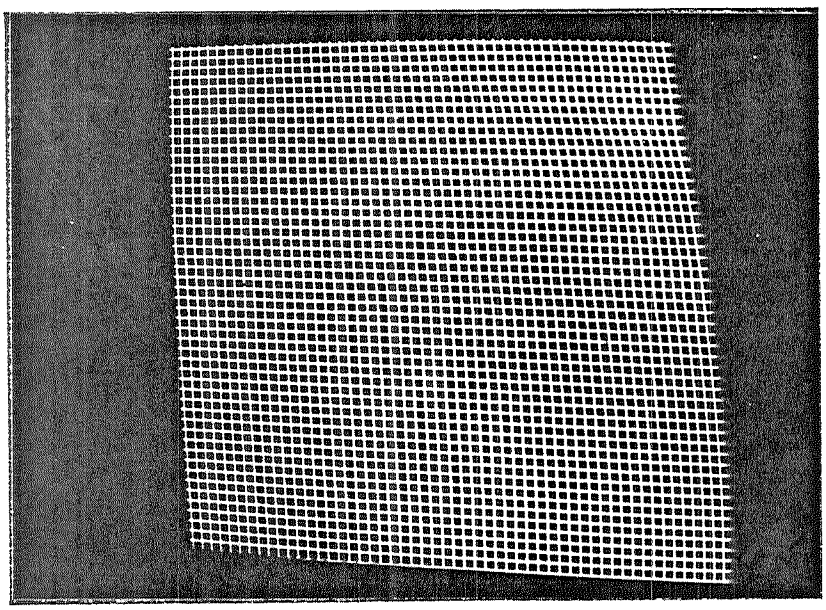

Table 1

Digitized Image

The measurement of the coordinates of the nodes in the matrix coordinate system is facilitated by a pre-processing of the matrix itself.

b) Thresholding

The procedure of thresholding (8) associates to the background of the image the value '0' and to the lines of the raster the value '1', so as to distinguish clearly the lines from the background. A statistic analysis of the histogram of A(i,j) (Table 2) is carried out, a threshold "L" is determined and a second binary matrix A'(i,j) is set up such that

$$A'(i,j) = \begin{cases} 1 & \text{if } A(i,j) \geq L \\ 0 & \text{otherwise} \end{cases}$$

(Table 3)

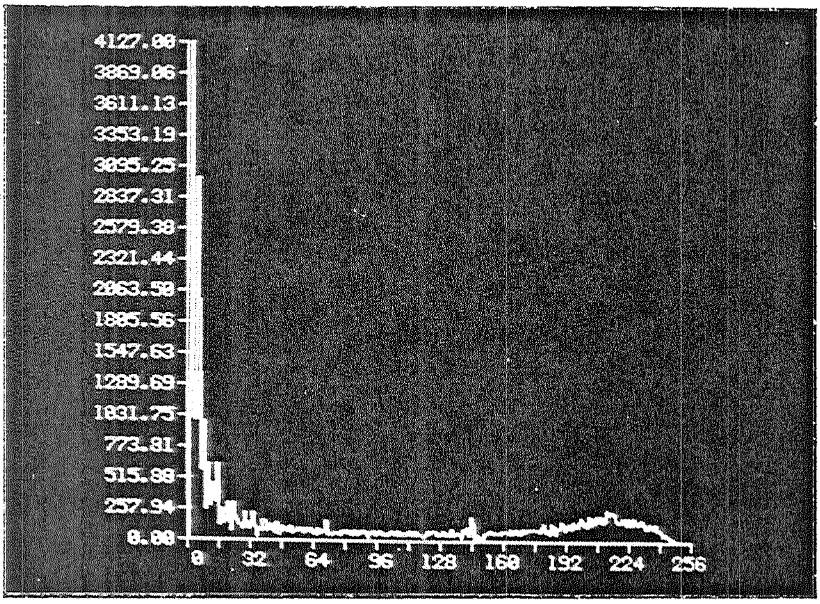

Table 2

Histogram

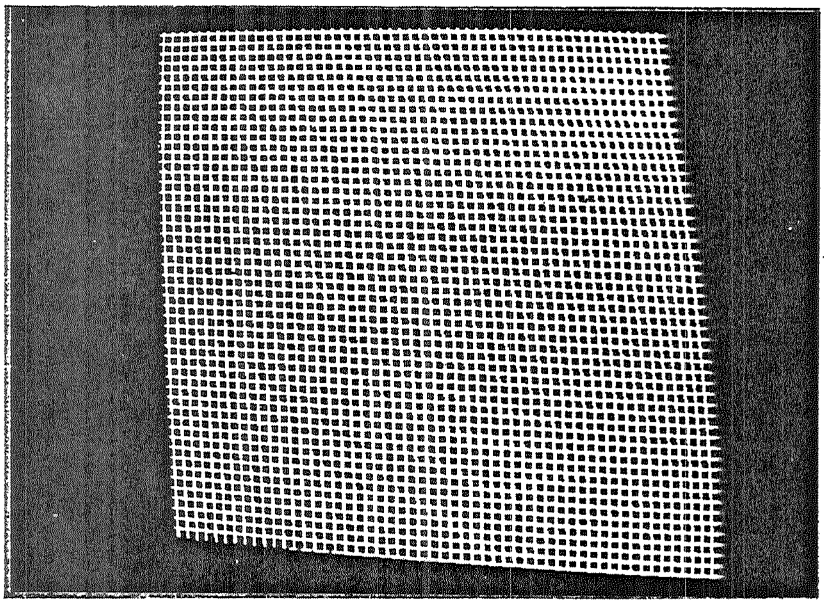

Table 3

Binary Image

After the thresholding procedure each line of the raster is represented in matrix A'(i,j) by a stripe of variable thickness, which is generally made up of several adjacent points (pixels) of value

'1'; so the areas of the node will become very extensive and hence not well definable.

It has to be noted that sometimes, owing to the difference in surface light density of the various parts of the raster, the use of one single level of threshold for the whole matrix A(i,j) may cause a change in the information content of the image, producing in this way geometric distortions and consequent loss of accuracy in the subsequent phases of processing. This can be avoided by using image restauration techniques before the thresholding procedure, such as contrast enhancement and/or edge enhancement.

c) Thinning
This procedure (8) aims at reducing the thickness of every line to one single pixel, replacing practically every stripe produced by the thresholding procedure with its central line. A new "thinned" matrix A"(i,j) is set up (Table 4).

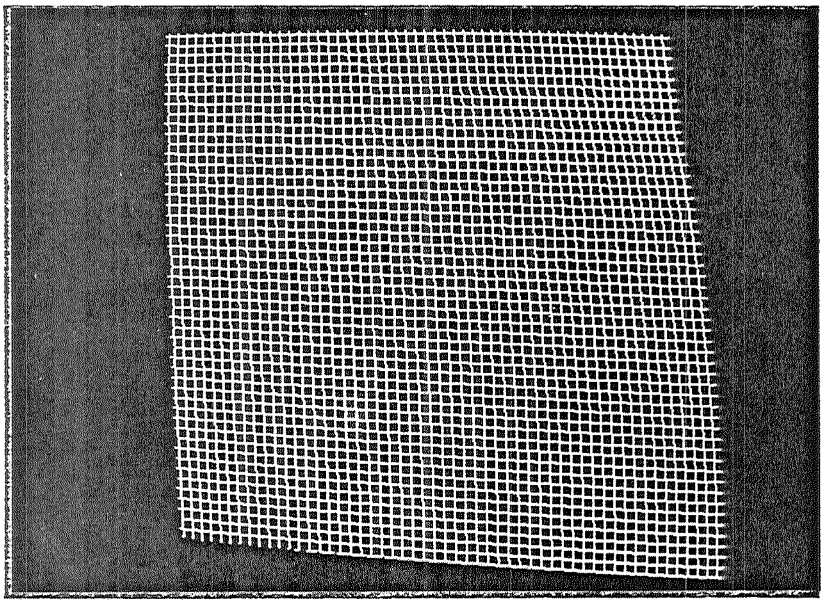

Table 4
"Thinned" Image

In the ideal case the node should be made up of the only pixel of intersection of one horizontal and one vertical line, and it is hence easily identifiable by analysing the 8 adjacent pixels.

However, generally in practice, if the deformation of the raster is great, the nodes will still be constituted by an area of pixels of value '1'.

Each of these pixels is, in any case, well characterized by the fact that the sum of the values of its 8 adjacent pixels is always ≥3. The node point will be represented by the barycenter of this node area.

d) Algorithm for the measurement of coordinates of the nodes
The block diagram of Figure 2 shows the three phases of the algorithm.

Phases 1 and 2 consist of two consecutive convolutions between the thinned matrix and a 3x3 window of value '1' elements. Each convolution consists practically in summing to each pixel of the matrix the values of the 8 adjacent pixels.

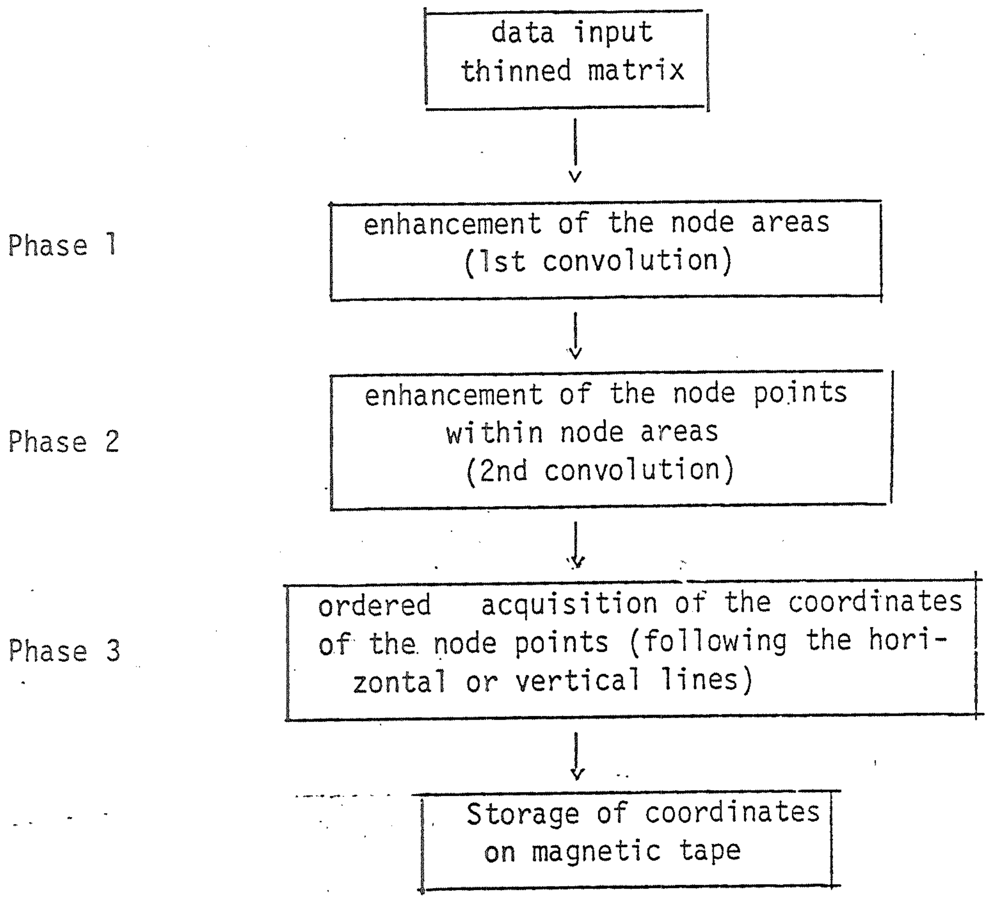

Figure 2

The first convolution enhances the node areas as areas constituted by pixels of value ≥3.
The second convolution enables us to identify, within each node area, the node point as the relative maximum point.

Then we mark in the original matrix the node pixels by a value 'n' different from '0' and '1'. In the third phase, we proceed to the identification of the subsequent horizontal lines and to the consequent ordered acquisition of the coordinates of the node points in the lines.

For every line, the matrix is scanned to identify the leftest element (initial element). The line is followed, analysing for each of its elements encountered during the course an appropriate right neighbourhood, as shown in Figure 3. The analysis of the positions of this neighbourhood is made in the numeric order indicated in the second column of the figure.

offers a resolution of 0.1 mm in both directions of scanning (dimension of the pixel), and is capable of digitizing photograms of a maximum dimension of 20x20 cm, to be reproduced in matrices of 2000x2000 pixels.
It has to be noted that I.E.I. is implementing a system (array camera) which offers accuracy up to 15 micron for photograms of any dimension.

In order to show the performance of our method, let us first consider an ideal case of a raster projected on a plane surface which is homogeneous and uniformly illuminated and normal to the axis of the projector.

The plate coordinates of the nodes automatically measured are compared with those measured by a high-precision monocomparator (± 2 microns) which can be considered errorless. The results show that the mean square error of automatic measurement in x and in y is smaller than 0.05 mm., i.e., smaller than the maximum error associable to the procedure of image digitization. It can be reasonably claimed that, at least in the ideal case, the errors of the phases of the procedure compensate each other.

However, the authors believe that it is necessary to carry-out a more thorough study of the degree of accuracy of every phase which, as it has already been mentioned, is related to the surface light conditions and to the deformation of the raster.

The overall accuracy of measurement does not correspond, however, to the actual degree of accuracy of the point restituted. In fact, in order to calculate the coordinates of the object, we use, for every node, four plate coordinates, namely the x, y coordinates on the pseudophotogram, which can be considered errorless, and the x',y' coordinates on the photogram.

Strictly speaking, in this calculation, only one automatically measured coordinate can be used. Obviously the accuracy of the restitution procedure, with respect to measurement, will be substantially increased.

5. Conclusions

The automatic measurement method proposed here, together with the particular techniques of taking adopted, consitute the first result obtained in a more extensive research towards the complete automation in photogrammetry restitution procedure.

At this first stage, it is already possible to identify the advantages and disadvantages of the method as well as some of its possible interesting applications . We have mainly the following disadvantages:

1) limitation to close-range photogrammetry and to slightly

illuminated objects, at the moment;

2) necessity of having a metric projector in combination with a metric camera.

The advantages are:

1) facility in application to close-range photogrammetry, which concerns objects in closed and slightly or badly illuminated environments so that they require, in any case, to be illuminated before the taking;

2) possibility of making one single take;

3) automation by a completely digital approach with the help of only the typical instruments for digital processing of images, without using sophisticated and/or dedicated instruments.

For future applications, we envisage:

1) possibility to study high-speed phenomena and, at least theoretically, to design a cinephotogrammetry system;

2) application to remote sensing (theoretically not excludable).

The method proposed has been tested with satisfactory results for terrestrial takes of objects in slight relief. However, the authors hope that this method may, in the near future, be extended to the general case of objects of any form and in presence of shades, and above all, that a complete automation of restitution procedure may be implemented, with particular attention to relative and absolute orientations.

REFERENCES

(1) "Manual of Photogrammetry" Fourth Edition, American Society, of Photogrammetry, 1980.

(2) F. Ackermann: "High-Precision Digital Image Correlation", Photogrammetry week, Stuttgard, 1983.

(3) "Handbook of non-topographic photogrammetry", American Society of Photogrammetry, 1979.

(4) E. Baj, "Riprese fotogrammetriche con l'ausilio di un proiettore metrico", Bollettino della Società italiana di Topografia e Fotogrammetria n. 3/4, 1980, pagg. 95-98.

(5) E. Baj, P.L. Casalini, S. Lombardi, A. Tonazzini, in "Due metodi per la lettura automatica dei punti nodali di un reticolo luminoso proiettato su un oggetto", Bollettino della Società Italiana di Topografia e Fotogrammetria N. 3/4, 1983, pagg. 73-83.

(6) W.K. Pratt, "Digital Image Processing", J. Wiley & Sons, 1978.

(7) A Rosefeld, A.C. Kak: "Digital Picture Processing", Academic Press, 1976.

(8) L. Azzarelli, M. Chimenti, O. Salvetti: "Un sistema di elaborazione automatica di Immagini del Territorio", Annual Conference A.I.C.A. 1981, Pavia pagg. 337-345.

(9) L. Azzarelli, M. Chimenti; "Progetto e descrizione del microfotometro automatico modello MFA/250/LS", Progetto Finalizzato Informatica, P2, Territorio, 1983.

(10) L. Azzarelli, B. Baj, M. Chimenti, "Preprocessing of Procedures for Automatica Plotting in Photogrammetry", W.G. II/2, XVth ISPRS Congress, Rio de Janeiro, 1984.