A NEW CONCEPT FOR QUANTITATIVE INTERPRETATION OF STEREO PHOTOGRAPHS BY NON-PHOTOGRAMMETRIC SPECIALISTS.

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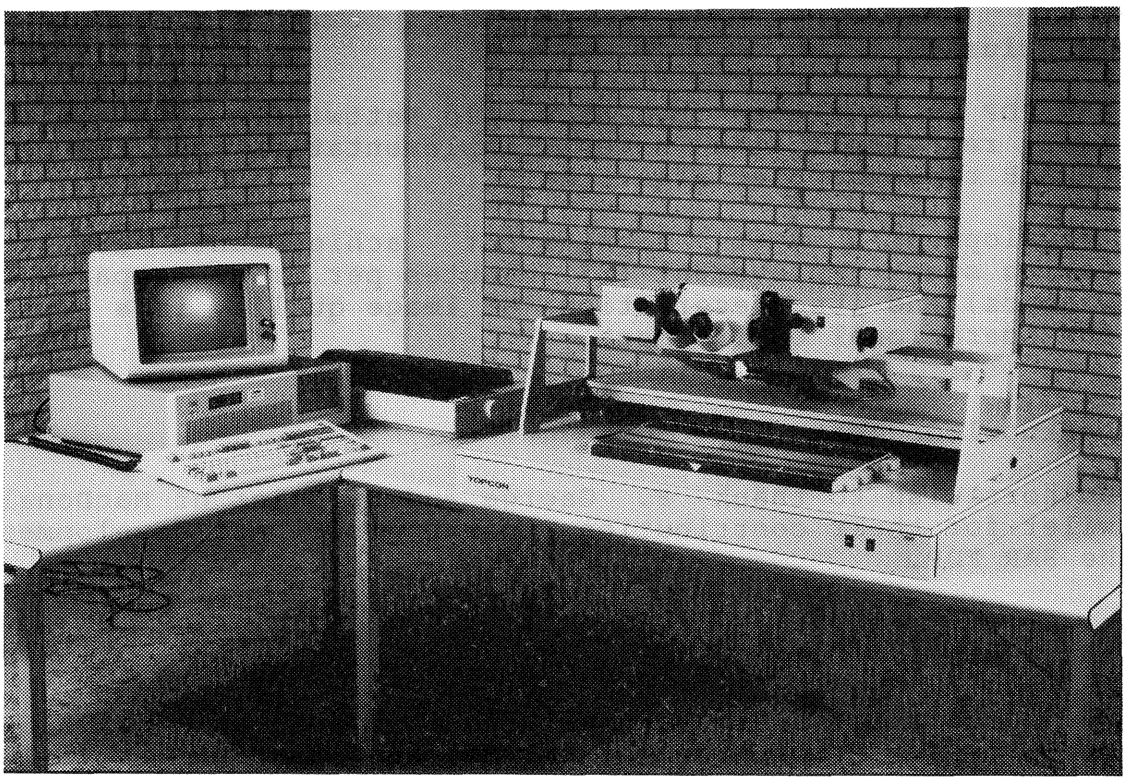
Abstract:

- The basic objective of the development is to provide equipment for digitizing stereomodels, which are instantly available to specialist in any field using stereophotography
- The stereograms are provided with parameters predetermined by a photogrammetrist and stored on a diskette.
- The basic design principle of the equipment aims at a high degree of repeatability in restitution of analytical stereomodels.



1. Introduction

The objective of this paper is to explain the background of a new production system for digitising stereomodels. The principle was developed by ITC and worldwide patent application have been made for the equipment and the methods involved. Tokyo Optical Co. Ltd. (Topcon) has obtained the exclusieve licence for production and marketing of the system. The system called PA-1000 is shown in the exhibition during the Congress. The equipment can be used in 2 modes, as stereocomparator for digitizing image coordinates and as restitution equipment for digitising terrain model coordinates.

2. The need

Specialists from different disciplines use aerial and space photographs to acquire specific information about the surface of the Earth. To locate the recognised characteristics from different sources, some geographic link is required with the actual terrain. The conventional method for this is to mark the information on the photographs first and then tranfer the marked data to a base map, usually with somewhat primitive means.

In modern digital data handling, the required link is formed by the corresponding terrain coordinates. Direct recording and registration of new data and on-line interactions with previously stored information should be extremely convenient if digitized terrain coordinates are available to the interpreter automatically at any time during stereo observation without the need of laborious orientation procedures that require considerable photogrammetric skill and high accuracy in measurement of y-parallax.

3. The basic principle

The new system presented here uses a specially equipped scanning stereoscope, which automatically digitizes an instantly available "analytical terrain model". This terrain model is unequivocally defined by a set of predetermined photogrammetric parameters that are provided to the interpreter together with the photographs.
The measuring system has been designed to give a high degree consistency, so that analytical terrain models, once determined, will be directly available on any PA-1000 equipment anywhere without an orientation procedure.
The logical providers of the parameter values are the aerial survey companies that also arrange for the photography.

4. The measuring system

To assure exact and identical positioning of the photographs in any PA-1000, each photo has a perforation that matches the corresponding studs on the plate carriers of all PA-1000 instruments. For an unambiguous reset of the measuring system, a check point is clearly marked on the lefthand photographs. During scanning, the plate carrier (with the photographs in fixed position) is moved freehand under the fixed stereoscope. The observation system contains two measuring marks, one fixed and the other (right hand) adjustable for horizontal parallax (p) only. The plate carrier has a parallel guidance system, from which the horizontal orientation can be adjusted for control of vertical parallax (α).
During scanning the horizontal position of the plate carrier is continuously detected by two linear encoders. The measuring lines of the encoders, one for x and one for y, have a fixed position in the digitising platform on

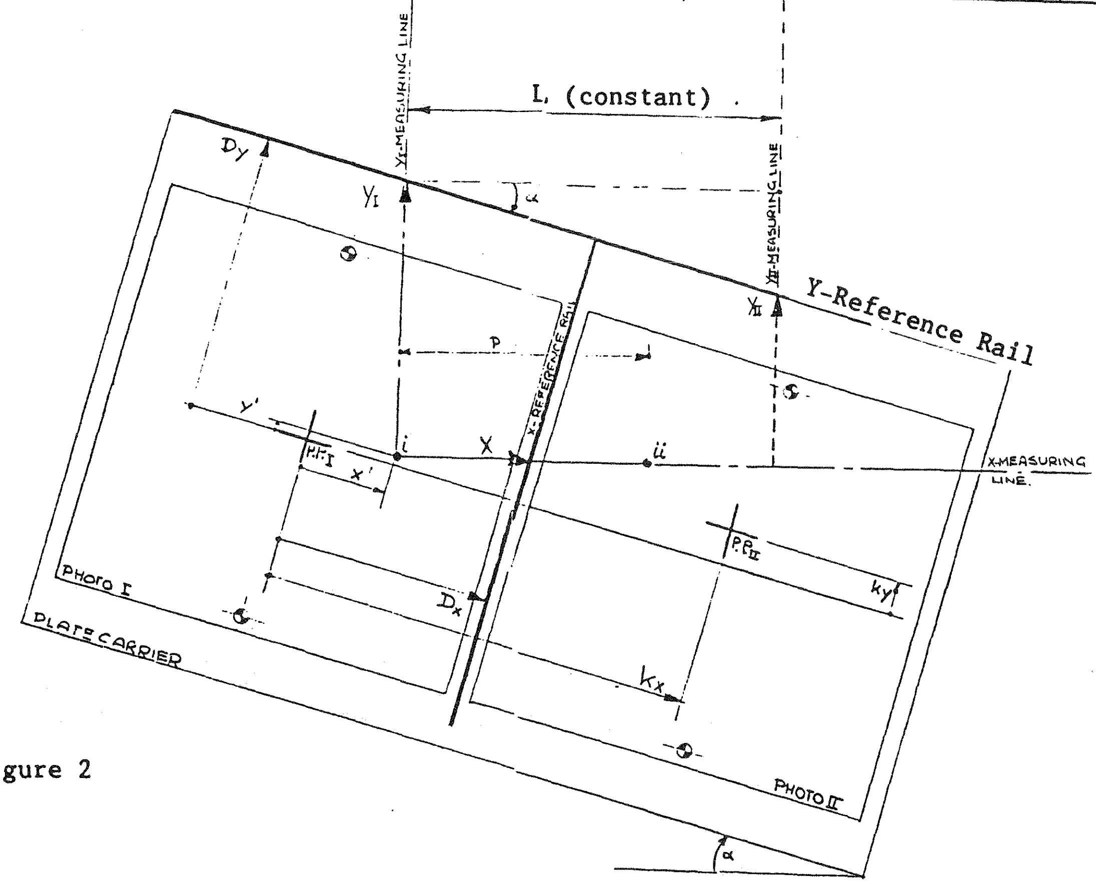


Figure 2

STEREOVIEWER WITH FL.MARK

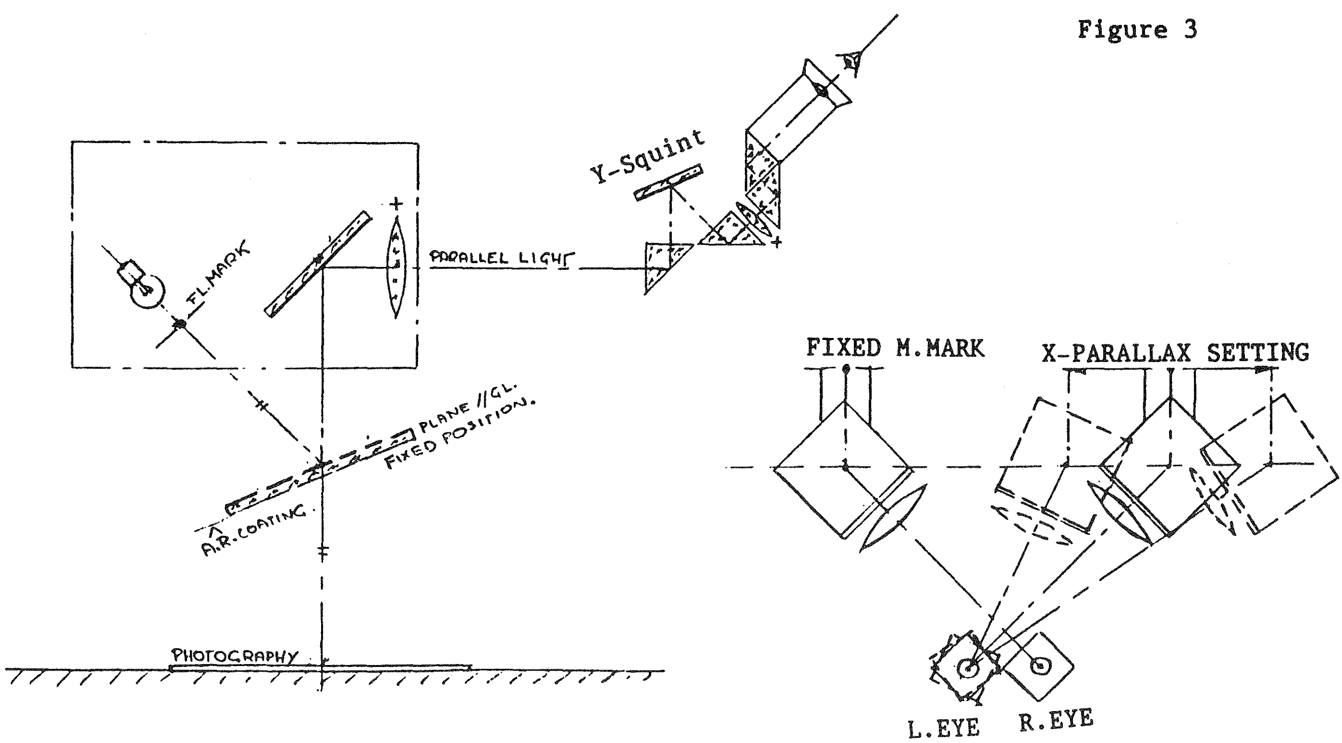


Figure 3

which the plate carrier is moved. The motion of the linear encoders along their measuring lines is controlled by a mechanical linkage with a rectangular x-y reference, consisting of two fixed rails, rigidly connected with the plate carrier. The encoders register the position of the photo point appearing coincident with the fixed left hand measuring mark. To avoid "comparators errors", the intersection of the x and y measuring lines of the encoders coincides with the fixed line of sight of the left hand observation system (Abbé principle).
To use the instrument in comparator mode, for example to determine parameter values and aerial triangulation, the PA-1000 measuring system should be equipped with a third linear encoder y_{II} parallel to the original y_I at a fixed distance L. This arrangement is required for precise measurements of α, independent of the accuracy in parallel guidance. The parallax screw in the stereoscope has been provided with an encoder for feedback of the actual value p.
To avoid the random influence of image motion on parallax measurement the apparent floating mark is reflected into the optical system via a fixed mirror (see fig. 3).
For the derivation of the terrain coordinates, reference is taken to image coordinates x'y' for the left hand and x"y" for the right hand exposure. As usual, the respective principal points are taken as origin, the directions of the coordinate axes however, are defined by the studs on the plate carrier and are taken for both exposures parallel to the xy reference.

As can be seen from fig.2 the image coordinates x'y' can be derived from the actual values x, y_I and α according to:

$$x' = D_x - x.\cos\alpha \qquad \text{------------------(1)}$$

$$y' = D_y - y_I.\cos\alpha$$

Dx and Dy are assumed to be given predetermined parameters of inner orientation for the left hand exposure.
The variable parallax p in the sytem is defined as the distance between two corresponding points on the stereogram when mounted on the plate carrier.

The image coordinates x"y" of the right hand exposure are defined by the following relations:

$$x'' = x' + p.\cos\alpha - K_x \qquad \text{------------------(2)}$$

$$y'' = y' + p.\sin\alpha - K_y$$

Kx and Ky represent the given predetermined parameters of inner orientation for the right hand exposure.

5. The analytical terrain model

The analytical terrain model is expressed in a coordinate system (UVW) with the left hand exposure station (I) as origin. The W-axis is taken vertical in the terrain. U is an assumed horizontal flight direction, defined by the azimuth ξ.
The model coordinates relate to the terrestrial coordinates (ENH) according to:

$$\underline{E} = A_\xi.\underline{U} + \underline{E}_I \qquad \text{----------------- (3)}$$

For the left hand exposure, auxilliary photo coordinates $(\overset{\circ}{x}\overset{\circ}{y}\overset{\circ}{z})$ expressed in the (UVW) system are assumed as:

$$\underline{\overset{\circ}{x}} = A_I \cdot \underline{x}' \qquad \text{------------------ (4)}$$

A_ξ, A_I and $\underline{E}_I$ represent the predetermined parameters of absolute orientation for the left hand exposure.
The terrain model coordinates are expressed by:

$$\underline{U} = \lambda' . \underline{\overset{\circ}{x}} \qquad \text{------------------ (5)}$$

in which λ' is the scale factor varying from point to point. Taking the known elevation of the check point C as reference, W_i depends on the variable ΔH_i, which is controlled by the operator by means of a pulse generator and given as primary input to the computer. The function for this is:

$$W_i = \Delta H_i + (H_c - H_I) \qquad \text{------------------ (6)}$$

From this the scale factor is determined as:

$$\lambda'_i = \frac{W_i}{\overset{\circ}{Z}i} \qquad \text{------------------ (7)}$$

Using the above equations, the required terrain coordinates are determined directly from x', y' and ΔH as variable input controlled by the operator. For immediate verification of the set ΔH, realtime control of the corresponding parallax p is required.

6. Automatic parallax control

Absolute orientation of the right hand exposure is expressed by the predetermined rotation matrix A_{II} and the base components Bu, Bv, and Bw during exposure. Assuming an auxilliary model coordinate system $(\hat{U}, \hat{V}, \hat{W})$ with the origin taken in the exposure station II and parallel to the photo coordinate system (x", y"), we derive for the right hand projection:

$$\underline{\hat{U}} = A_{II}^T \cdot (\underline{U} - \underline{Bu}) \qquad \text{------------------ (8)}$$

The scale factor λ'' for the right hand projection is then determined by:

$$\lambda''_i = \frac{\hat{W}_i}{-C} \qquad \text{------------------ (9)}$$

(C being the given principal distance)

and consequently:

$$x'' = \frac{\hat{U}}{\lambda''} \text{ and } y'' = \frac{\hat{V}}{\lambda''} \qquad \text{------------------ (10)}$$

Finally α and p are derived from (2) as:

$$\alpha = \arctan \frac{y''-y'+Ky}{x''-x'+Kx} \qquad \text{------------------ (11)}$$

and $$p = \frac{x''-x'+Kx}{\cos\alpha} \qquad \text{------------------ (12)}$$

For all-round model restitution, automatic parallax control is provided for convenient line digitising and contouring. As in the determination of E, N, H and p, the α occurs only as cosine function, high accuracies should not be required for α. When used in compatator mode p and α are controlled manually by the operator.

7. Preparation of the photographs.

As noted above, the photographs should be perforated. A special perforator unit punches two holes that correspond to the studs on the plate carrier. The perforator unit contains an orientation line for rough orientation of the photographs according to the base. Because each exposure is involved in two overlaps, the individual photograph should be punched twice, once for each overlap.

If several copies are required with identical perforation, it is best to provide a duplicate negative with the initial perforation. Any number of positive copies can then be produced, using pre-perforated photographic material. Loose studs are then used to obtain a perfect match during contact printing. Although the PA-1000 instruments are equipped to handle separate photographs, it is better to print corresponding overlaps simultaneously on one sheet of pre-perforated material. Apart from being convenient, this procedure also adds considerably to the stability of the orientation of the photographs on the plate carrier. This is particularly important if paper prints are used, the holes of which may wear out after multiple use!

For each overlap, a good quality check point must be selected, which can be conveniently measured stereoscopically. The position is not critical, but a central position in the model is prefered. To avoid identification errors, the check point should be clearly marked on the left hand photograph as it appears on the plate carrier.

8. Determination of the parameter values

The required photogrammetric parameter values are classified for:
- inner orientation: Dx, Dy, Kx, Ky and C (principal distance),

- relative orientation: R (3x3), (relative rotation matrix RH proj.)
  Bu, Bv, Bw (base components during exposure),

- absolute orientation: Q (3x3), (absolute rotation matrix LH proj.)
  E_I, N_I, H_I,

- check point pre-set: x'_c, y'_c, p_c, α_c and H_c

The matrices used in the description relate to Q and R as:

$A_{II}=A_I.R$ and $Q=A_\xi.A_I$.

For the determination of the parameter values the PA-1000 should be used in the stereocomparator mode. The "Commod" programme produces the image coordinates x′, y′, x" and y" of all points measured. It also registers the parameter values of inner orientation and the pre-set parameters for the check point. The derivation of relative and absolute orientation parameters on the basis of stereocomparator measurement is standard practice in any photogrammetric organization.

The parameters (stored on diskette) are delivered to the interpreters together with the prepared photographs. The software package "Plotmod", for restitution of the analytical terrain model reads the parameters from the diskette and immediately produces after the reset on the marked check point, the terrain coordinates E,N,H, for further handling.