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Orthophoto Printing with the Analytical Plotter

Because of its computer system, the instrument lends itself well to the additional device.

ABSTRACT: *The Analytical Plotter, because of its design and construction, is well suited for the inclusion of a printing facility for producing orthophotos. (An orthophoto has the general appearance of a photograph but also has the positional accuracy of a map.) The addition is being incorporated in manufacture by Ottico Meccanica Italiana. The computers of the instrument already produce information relative to the map positions of points and scale data. The photograph is scanned by means of a small slit. Panoramic photographs can be processed. Ways for controlling the width of the slit and the light intensity are included.*

SINCE THE BIRTH OF aerophotogrammetry many technicians and scientists have tried to solve the problem of transforming aerial photographs into "orthophotographs," that is, photographs having the same geometric characteristics as a topographic map, and containing all the ground details of the original photograph. In particular, several ingenious solutions have recently been suggested, developed, and produced experimentally, as well as commercially.

It is evident that any aerial photograph contains the elements necessary to supply the orthophotograph, provided that its absolute orientation and the ground elevations are known. This is achieved if the photograph belongs to a stereopair already oriented. In other words, only considering the problem theoretically, any photogrammetric plotter is capable of supplying an orthophotograph of the plotted model. Naturally, in practice, the possibility of realizing the above depends on the particular characteristics of the plotter and on the greater or smaller ease with which the information necessary to the orthophotograph production can be obtained.

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This information may be divided into two separate groups: photographic information which relate to the ground details as shown on the photograph; and geometrical information which substantially relate to the modifications that the photographic coordinates must undergo to be transformed into model coordinates proportional to ground coordinates. For the first group we wish to specify that there are, fundamentally, two methods to obtain ground information from the photograph. At the present state of the art the only tested method is to scan the photograph by parallel strips. This may be performed either by using a luminous point whose variations of intensity are transmitted to the corresponding point that exposes the sensitive emulsion, or by optically reproducing the scanned image through a slit.

Apart from the geometric distortions due to the difference between the photograph and the model, the orthophotograph resolution, in the first instance depends on the dimension of the scanning point and, in the second instance, on the quality of the optical transfer system. The second group of information, as already stated, relates to the geometric transformation of the photograph and therefore presupposes the availability of a system

(analogic or digital) to supply the necessary corrections.

THIS DESCRIPTION is intended to illustrate briefly an orthophotoprinter, already at an advanced stage of construction, projected by Ottico Mecannica Italiana. The orthophotoprinter has been designed as an accessory to the Analytical Plotter system inasmuch as the basic concept of said instrument is such that it can supply all the information relevant to any photograph of any stereopair that has been oriented on the instrument; naturally, also the information required to obtain the orthophotograph, as indicated above.

The above is true for all models of the Analytical Plotter, in particular for the two models produced up to now, namely, the one used for frame photographs and the other one used for panoramic or convergent photographs. The ground reproduction may be obtained with either one of the two methods mentioned above; scanned point reproduction, and optical reproduction.

In the first instance the connection between the basic photograph and the sensitive surface (the orthophotograph) is completely electrical inasmuch as a second luminous point, having the same dimension as the scanning point, exposes an image to the sensitive surface.

In the second case an optical connection must be anticipated, that is, a true and actual reproduction of the image between the photograph and the surface to be exposed. In the orthophotoprinter described herewith, the second solution has been chosen.

For the actual rectification, i.e., the geometric transformation of the central projection photograph into a parallel projection photograph, the procedure for the two instances already considered is substantially the same. The Analytical Plotter computer supplies various types of output information including the plane coordinates both of the photograph and of the model. The orthophotoprinter utilizing this information is so constituted as to allow the transmission of the photographic coordinates to the photo carriage while the model coordinates are transmitted to the sensitive surface that is to become an orthophotograph.

Inasmuch as the model coordinates are supplied by the computer at any desired scale ratio, it is also theoretically possible to produce the orthophotograph at any desired scale. In practice it is convenient, however, to make the reproduction at approximately the scale of the photograph and then, if required, to enlarge the orthophotograph later. At this point it must be noted that the information obtained from the Analytical Plotter computer, in theory, may be utilized by any type of orthophotoprinter that may receive it, and modify it according to its own technique.

LET US NOW DESCRIBE the optical-mechanical structure schematics of the orthophotoprinter which is now under construction (Figure 1). As mentioned above, this system utilizes the photographic transfer through the optical system. A luminous slit, obtained by projecting on the photograph the rectilinear filament of an incandescent lamp, scans the photograph in parallel strips. The optical transmission system conveys these images to a film mounted in a magazine and to which at the same time are transmitted the model coordinates, as illustrated. Both the slit of the lamp and the optical transfer system are attached to the frame of the device. The plate containing the photograph slides along the two coordinates by means of servomotors (coupled in parallel to the stereoplotter servomotors) while the film magazine slides along the scanning coordinates controlled by the corresponding model coordinate servomechanism. Inside the magazine the film shifts each subsequent scan by a quantity corresponding to the length of the slit.

This is the basic concept of the instrument. To understand its functioning better it is advisable to examine some of its design characteristics. The slit that scans the plate may be rotated through a servomechanism controlled directly or indirectly by the computer so that, in case panoramic or tilted photographs are used, it is necessary to compensate the inclination of the epipolar rays resulting from the perspective effect. The same inclination is then compensated by means of a Dove prism located along the optical transfer path. The optical system that transmits images for the orthophotograph also includes a lens with variable focal length (zoom system).

WE SHALL NOW DESCRIBE how the information, relative to the slit inclination and to the magnitude variation, is obtained and utilized. In the Analytical Plotters aimed at the analysis of panoramic photographs it is necessary that the images that reach the observer's eyes be correctly oriented and be of the same dimensions so as to allow correct stereoscopic observation. In fact, if the reference grid of the panoramic photograph is observed, it is

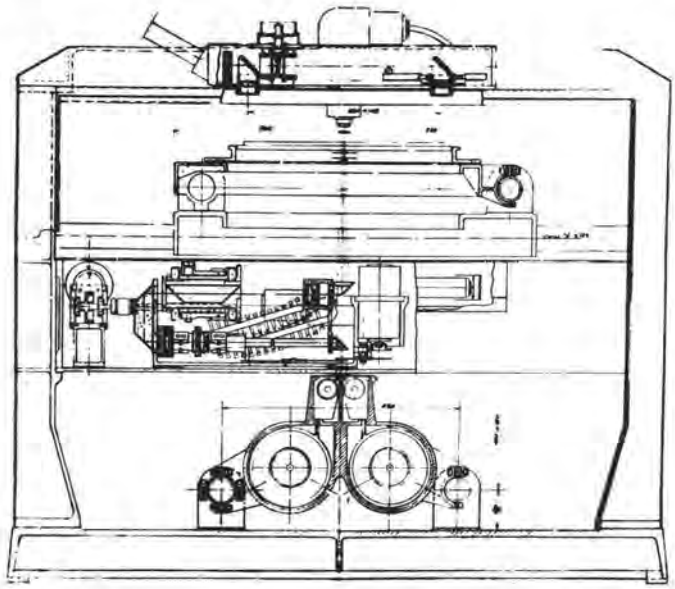

FIG. 1

possible to see that, except for the principal x-axis, the image is perspectively and dimensionally distorted in all other areas of the photograph (Figure 2).

The Analytical Plotter computer is programmed to correct these distortions. It transmits, according to each photograph plate coordinate, two types of information: an image rotation by means of the corresponding Dove prism servocontrol, and a magnification correction by means of a servocontrol of the Plotter zoom system. The same two types of information are used in the orthophotoprinter without any intermediate stage to transform the perspective image into a planimetric image.

In the Analytical Plotter model for use with almost vertical frame photographs (AP/C), the automatic corrections of the image inclinations and of the magnification variations are not anticipated because these corrections are not necessary. However, in the orthophotoprinter to be coupled to the AP/C, a correction for both the inclination and the magnification has been anticipated for use in case of photographs inclined beyond a certain limit, for which the perspective inclination of either epipolar rays or the magnification difference are not negligible and must be corrected. For these photographs it is anticipated that there will be a Dove prism rotation proportional to the ω angle (if the scanning is

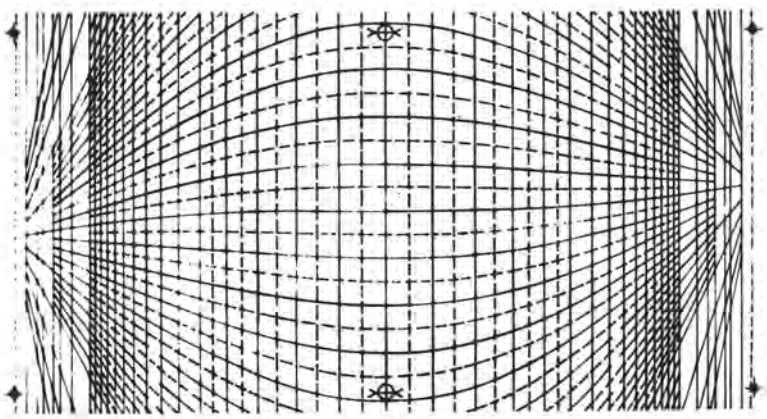

FIG. 2

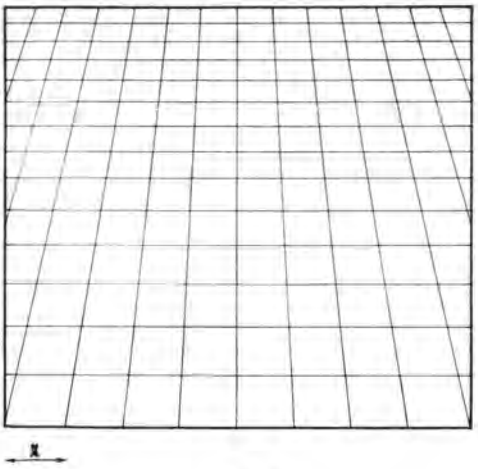

FIG. 3

performed along X-coordinate) or ϕ angle (if the scanning is performed along Y-coordinate) as well as an equal magnification correction. These corrections are supplied through very simple mechanical devices (Figure 3).

THE FOLLOWING ARE other characteristics of the orthophotoprinter. A system of variable absorption of the quantity of light utilized connected to the Analytical Plotter—more precisely to the device that controls the scanning speed. In fact, regardless of whether the scanning is directly performed under the operator's control, or whether it is automatically performed by means of an image correlator, the scanning speed varies according to the ground unevenness. Therefore it is necessary to regulate the quantity of light in a manner proportional to the scanning speed so that the orthophotograph light uniformity may be obtained.

Whenever the orthophotograph is used with the model of the Analytical Plotter used for the interpretation of panoramic photographs (AS-11A), an additional regulation of the light is needed because the light that exposes the orthophotograph is inversely proportional to the square of the magnification.

Finally there is the regulator of the slit length, a device that permits to use slits 4, 3, 2, or 1 mm. long. The choice of the length must be made by the operator in relation to the smaller or greater unevenness of the ground and also in view of the greater or smaller accuracy requirements. It is clear that the greater the length of the scanning slit the shorter will be the time necessary to completely scan the photograph. It is therefore advisable to try to reach a compromise which will take into account not only the accuracy requirements but also the possibility of sufficiently fast production.

FROM THIS BRIEF description it is possible to understand how the orthophotoprinter takes advantage of the extreme flexibility that is a peculiar characteristic of the systems based on the A.P. concept. In fact there is practically no limitation to the focal distance nor to the base components, and the exposure angles may vary within wide limits. Furthermore the correction of lens distortion, earth curvature and air refraction (being automatically supplied by the computer to the A.P. servomechanisms) are utilized by the orthophotoprinter servomechanisms that are connected to those of the Analytical Plotter. Finally, the orthophotoprinter may be used as a simple rectifier of any type of photograph, including panoramic images, through a suitable A.P. computer program.