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3-D Information from Orthophotos

The orthophotograph technique is a distinctly new procedure with specific characteristics, possibilities and limitations.

INTRODUCTION

THE NUMBER OF ARTICLES recently published on the subject of orthophoto technique is proof of the rapidly growing interest in this technique. It also reflects the extensive research and development taking place in this field. This is understandable if one considers the uniqueness of the orthophoto technique, its exceptionally wide range of application and the multiplicity and magnitude of associated problems. For the *photo-interpreter* active in earth sciences, the photogrammetrist and the cartographer, the orthophoto technique provides a new tool and a new means of expression which requires a new set of rules and criteria.

ABSTRACT: *An orthophotograph is defined as a differentially rectified photograph; consequently, a tendency is to consider orthophotos for presenting planimetric information only. The orthophoto technique, however, provides three-dimensional information which should be used in mapping operations such as contouring, relief shading and terrain digitization. In addition, the creation of stereo-orthophotos offers the possibility of three-demensional interpretation and measurement of orthophotographs. Thus, it opens new vistas for surveyors, cartographers and photo-interpreters. The discussion is complemented with an analysis of the accuracy of three-dimensional information derived from the orthophoto process.*

In the conventional sense, the orthophoto technique is restricted to the production of differentially rectified photographs. The importance of this approach lies in the ease with which aerial photographs of variable scale are transformed into photographic images of uniform scale, independent of the topography. Orthophotographs can then be used to determine the relative horizontal position of terrain points, natural or artificial. Basically, the orthophoto technique offers three-dimensional information which should be extracted and recorded for further use. This is particularly obvious since the third dimension, the vertical, can usually be extracted or directly used in an automatic fashion without an additional outlay of work or time.

There are two very important considerations supporting our attitude:

- Terrain is a three-dimensional phenomenon and consequently its two-dimensional representation is insufficient. In many projects, precise knowledge of the vertical configuration of the terrain is as important as its horizontal configuration.
- The interpretability of single photographic images (such as orthophotos) is much inferior to that of stereo images. Since in the orthophoto technique the identification of various details is left to the user, everything in our power should be done to provide him with the best means to interpret the orthophoto pictures. The obvious answer is to offer the user the possibility of stereo-viewing which has proven advantageous in photogrammetric and photo-interpretive operations.

The purpose of the present paper is to review various means of extracting three-dimensional information when using the orthophoto technique and to indicate the ramifications of the solutions proposed.

Extracting Three-Dimensional Information at the Scanning Stage

DIGITIZATION OF TERRAIN (RECORDING OF x, y AND z COORDINATES OF POINTS DISTRIBUTED ACCORDING TO A CERTAIN PATTERN)

Obviously, we are assuming production of orthophotos as a primary operation. In all the presently used processes, manual or automatic, the virtual model of the terrain is scanned along parallel lines. The spacing of the profiles equals the selected length of the slit which in turn depends upon the topography of the terrain. By using one of the available techniques, the three coordinates of profile points can be recorded *on line* at preselected, even intervals without disturbing the scanning and the local *lowest* and *highest* points of the profile can be added. If one uses more powerful equipment, such as the Analytical Plotter, or more sophisticated recording facilities, characteristic points of the profiles could also be recorded.

The recorded points then represent the terrain in a form suitable for computational processing. If used as discreet points defined by their three coordinates, it is correct to consider the x- and y-coordinates as error-free and to attach the error to the z-coordinate alone. This error will consist of all the errors inherent in the stereomodel being viewed in the orthophoto plotter, and in the profiling process. Profiling errors can be assumed to be up to

$$(4 \text{ to } 6) \times e_p$$

where e_p is the standard vertical pointing accuracy characteristic of the instrument and the operator.

A direct-viewing type of plotter and an average constant profiling speed are assumed. As in contouring, the operator has a tendency to follow the profile at a systematically erroneous height; consequently, elevation differences derived from the profiles are better than the absolute elevations.

Digitizing terrain is quite popular but it has, at least for the present, much less practical value than some enthusiasts would like to believe. Manipulation of tremendously large data requires computational facilities that are not usually available. For this reason, it seems to us that the next two modes of extracting three-dimensional information when using the orthophoto technique are of much greater immediate interest.

MARKING THE CONTOUR LINES

In this known method of operation, the horizontal position of contour lines is marked simultaneously with the production of the orthophoto without the operator's participation. For various reasons, in the instrumental solution adopted by the National Research Council of Canada, the contours are marked by dots, each contour in a different color. By joining the marks of the same color, a contour line is produced. If the positions of the marks are recorded numerically, a computer can derive the contour lines and have them plotted automatically. The same can be done manually. Both ways are acceptable in many mapping operations but neither can provide the same detailed presentation of each minor terrain feature afforded by direct contour plotting on a stereoplotter. To obtain comparable results, a stereo-orthophoto approach is necessary and is discussed later.

AUTOMATIC RELIEF SHADING

The orthophoto technique lends itself to providing three-dimensional information on terrain in another, purely visual form. We are referring here to relief shading.

Several unsuccessful attempts at automatic relief shading have been made. The profiling mode of operation underlying the orthophoto technique is ideal for the purpose; instrumental solutions are fully automatic and can be very simple and inexpensive if a simple approach is taken.

Even though the shading procedure is totally based on the orthophoto technique, this does not restrict the use of shading results in maps of any form. The photographic record of the shade pattern, obtained automatically as a by-product of the scanning process, can simply be used in the final map printing procedure.

The addition of relief shading to topographic maps of mountainous areas is an important cartographic enhancement which permits immediate three-dimensional perception of the terrain presented. It is seldom used, however, on account of the expense and the time required for conventional, manual shading. An automated process for producing relief shading, based on the profiling method of scanning a stereomodel (as in the orthophoto technique) would solve this long-standing and difficult problem.

The Effect of Profiling Errors

The profiling process is subject to certain errors in height which, in an average type of terrain, are in the order of 0.03 mm.—a probable figure for direct-viewing type, manually operated instruments. These errors directly affect the recorded contours by a similar amount. In addition, they affect the planimetry of the orthophoto image so that the contours recorded do not coincide with the corresponding terrain details in the orthophoto. These shifts of the orthophoto image are of particular interest as they do not only affect the vertical accuracy but also the planimetric accuracy of orthophotos. They depend on the profiling error, the terrain slope and the angle between the vertical and the projecting light ray.

We shall study the affect of a profiling error Δz according to Figure 1. A small area of the surface of the stereomodel is considered for this error analysis and is represented by a tilted plane. Assuming that the profiling error is constant during the rectification of the above small area, the center of the slit will move on a surface, referred to as *film plane* in Figure 1, which is parallel to the considered section of the stereomodel, and is defined by consecutive profiles within this area. It is in fact an idealization of the position of the film within a small area when a scanning slit of infinite small width is used.

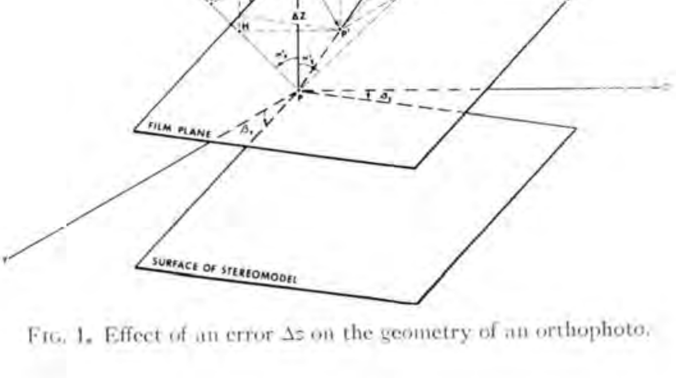

Fig. 1. Effect of an error Δz on the geometry of an orthophoto.

A point P on the model surface is projected on the film plane when the slit is in position P'. This results in a planimetric error in the orthophoto image, which is represented by the distance CF. The X and Y components of this error can be determined as follows:

$$\begin{aligned} \Delta x' &= AC - AB = \Delta z \tan \alpha_x' - FP' \tan \alpha_x' \\ \Delta y' &= CE - DE = \Delta z \tan \alpha_y' - FP' \tan \alpha_y'. \end{aligned} \tag{1}$$

From Figure 1, we derive further:

$$FP' = (\Delta z \tan \alpha_x' - FP' \tan \alpha_x') \tan \beta_x + (\Delta z \tan \alpha_y' - FP' \tan \alpha_y') \tan \beta_y$$

from which follows:

$$FP' = \Delta z \frac{\tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y}{1 + \tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y}. \tag{2}$$

By substitution of Equation 2 into 1, the following equations for the $X-$ and Y-components of the planimetric error are obtained:

$$\left.\begin{aligned} \Delta x' &= \frac{\Delta z \tan \alpha_x'}{1 + \tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y} \\ \Delta y' &= \frac{\Delta z \tan \alpha_y'}{1 + \tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y} \end{aligned}\right\} \tag{3}$$

where

Δz is the profiling error

α_x', α_y' are the components in the X-Z and Y-Z planes, respectively, of the angle between the projecting light ray and the vertical

β_x, β_y are the components of the terrain slope in the X-Z and Y-Z planes, respectively.

The displacements $\Delta x'$ and $\Delta y'$ that can be expected in an orthophotograph, produced at four times the scale of the original photographs are given in Table I.

The maximum value of 32° for the components α_x' and α_y' in Table I refers to the case of wide-angle photographs (format 230 mm$\times$230 mm, $f=150$ mm) with 60 percent longitudinal overlap and 20 percent side overlap. In less extreme conditions (for example if slope components β_x and β_y do not exceed 20°, which corresponds to a maximum slope angle of 27°) the planimetric errors do not exceed 0.14 mm, which is within the generally accepted accuracy of graphical representation. Consequently, as long as the profiling accuracy remains within acceptable limits, the contour marks will be quite accurate, even considering the location error of the contours due to a slightly displaced orthophoto image along the contour line.

TABLE I. PLANIMETRIC ERRORS IN ORTHOPHOTOGRAPHS RESULTING FROM PROFILING ERRORS OF 0.12 mm

α_x', α_y' \ β_x, β_y	−0°	−10°	−20°	−30°	−32°
0	0 mm.	0 mm.	0 mm.	0 mm.	0 mm.
10°	0.02	0.02	0.02	0.03	0.03
20°	0.04	0.05	0.06	0.08	0.08
30°	0.07	0.09	0.12	0.21	0.25
32°	0.08	0.10	0.14	0.27	0.34

TABLE II. VALUES FOR $(\tan\alpha \tan\beta)/(1+2\tan\alpha\tan\beta)$ AS A FUNCTION OF THE COMPONENTS α AND β OF THE PROJECTION ANGLE AND THE TERRAIN SLOPE, RESPECTIVELY

α \ β	0°	−10°	−20°	−30°	−32°
0°	0	0	0	0	0
10°	0	−0.033	−0.074	−0.128	−0.141
20°	0	−0.074	−0.180	−0.362	−0.417
30°	0	−0.128	−0.362	−1.000	−1.296
32°	0	−0.141	−0.417	−1.296	−1.782

THE EFFECT OF THE SIZE OF THE SCANNING SLIT

Much more serious errors occur in the planimetry due to the size of the slit. Ideally, the slit should be reduced to a point. As this is not possible, and the economy of the orthophoto process requires long slits, a compromise must be accepted. The same is true for the width of the slit. A certain slit width has to be maintained to satisfy the exposure requirements of the film. On the other hand, the slit width should be as small as possible to keep image movements during the time of exposure (caused by vertical movements of the film plane) within reasonable limits. The planimetric errors that are caused by the *width* of the slit are very small in relation to those caused by the *length* of the slit and will be neglected in the following discussion; a slit of infinitesimal *width* is therefore assumed in the formulation.

Assuming that the center of the slit coincides with the surface of the stereoscopic terrain model and the ends of the slit are a distance Δz above or below the model surface, the expression for the error components $\Delta x'$ and $\Delta y'$, derived from Figure 1, can be used for computing the maximum errors that are caused by the length of the scanning slit:

$$\Delta z = \tfrac{1}{2} l \tan \beta_y.$$

Assuming that the projecting light rays are parallel for the entire length of the slit, by substituting the above expression in Equation 3, we obtain:

$$\begin{aligned} \Delta x' &= \frac{1}{2} l \frac{\tan \alpha_x' \tan \beta_y}{1 + \tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y} \\ \Delta y' &= \frac{1}{2} l \frac{\tan \alpha_y' \tan \beta_y}{1 + \tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y} . \end{aligned} \quad (4)$$

For a simplified case in which $\alpha_x' = \alpha_y'$ and $\beta_x = \beta_y$, and substituting α for $\alpha_x' = \alpha_y'$ and β for $\beta_x = \beta_y$, the resulting planimetric displacement amounts to

$$\Delta x' = \Delta y' = \frac{l}{2} \cdot \frac{\tan \alpha \tan \beta}{1 + 2 \tan \alpha \tan \beta} .$$

In Table II, values for the expression

$$\frac{\tan \alpha \tan \beta}{1 + 2 \tan \alpha \tan \beta}$$

tabulated for different angles α and β are given. By multiplying these values by the proposed half-length of the slit, the planimetric errors to be expected for the ends of the scanning slit can be found. Negative values of the terrain slope component β are considered and result in a maximum displacement of the orthophoto details.

As can be seen, the planimetric error caused by the length of the scanning slit can be quite serious. To keep them within tolerable limits, the following precautions should be taken:

- The size of the slit must be carefully selected according to the accuracy requirements.
- Narrow-angle cameras, or only the central portions of wide-angle photographs, should be used.
- Caution should always be exercised where points are located on steep slopes.

Obviously, the second and third rules are the same as those observed in usual rectification. However, if the orthophoto technique is used, the errors are significantly smaller than in ordinary rectification. The accuracy requirements should not be exaggerated. Most areas are relatively flat and, for example, a 20° slope is rarely encountered in built-up areas. Finally, no technique should be used beyond its natural limitations. Accuracy, speed and cost of mapping are conflicting factors in any production process and they can be simultaneously satisfied only within certain limits.

Stereo-viewing of Orthophotos

So far, we have discussed various ways of extracting three-dimensional information from conventional orthophotos and the accuracy of the information so derived. However, even using the best orthophoto—i.e., of superior definition and metric quality—only a limited amount of information can be extracted because this involves only a single photographic image. It is well-known that the interpretability of single photographs is inferior to that offered by stereo-viewing. In addition, a large number of pertinent terrain details are often obscured on one photograph of a stereopair whereas they are quite visible on another.

Possible solutions to this problem consist of viewing the orthophoto stereoscopically with either an aerial photograph enlarged to the approximate scale of the orthophoto, or with the contact copy of an aerial photograph. The first method leads to a simple viewing system—a stereoscope of a convenient size—but necessitates enlarged photographs, and thus an additional product requiring instrumentation and laboratory facilities. The second method—stereo-viewing of the orthophoto with an ordinary photo print—is also possible but the viewing instrument needed is more complex[2] because it requires a pantographic arrangement and an optical magnification adjustment in the viewing system.

Other drawbacks of both solutions are the variable vertical parallaxes that must be continuously corrected during the viewing process, and the difficulty of extracting precise vertical information. Nevertheless, in many operations based on the use of orthophotos, this is the only approach that can be taken if conventional orthophoto techniques are used to extract the maximum information. This applies particularly to all the operations concerned with interpretation and plotting of planimetric and topographic details on the orthophotos, including detailed representation of the contour lines drawn from the drop-pencil marks mentioned earlier.

Retaining the Three-dimensional Information in the Orthophoto Products

In an effort to find a satisfactory solution along the lines indicated in the preceding paragraph, still another solution was formulated at the National Research Council by Collins[4] which combines the possibility of stereo-viewing with the particularly simple geometry of a new product. We are referring here to the *stereo-orthophotos* in which the conventional orthophotograph forms a stereopair with a pseudoorthophoto produced from an adjacent photograph. The pseudoorthophoto, called stereomate, is distorted by artificial horizontal parallaxes that are proportional to the height differences in the terrain. Because the vertical parallaxes between the orthophoto and the stereomate are practically anihilated in the differential rectification process, the

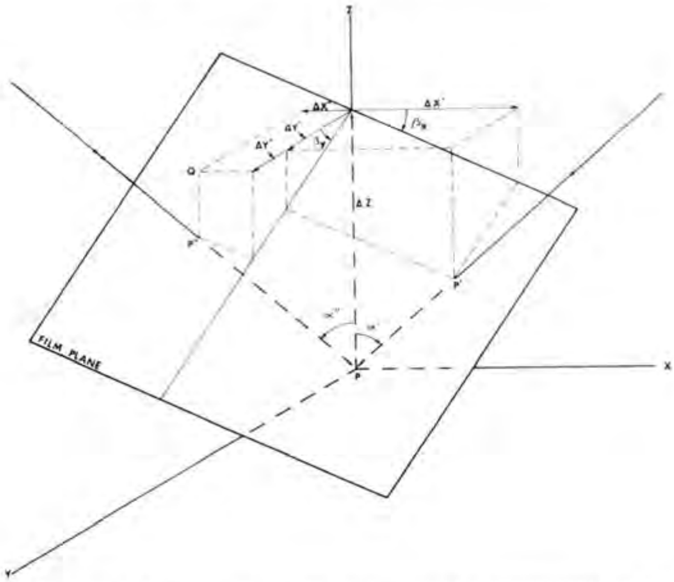

FIG. 2. Effect of an error Δz on the geometry of a stereoscopic orthophoto.

stereo-viewing of the stereo-orthophotos is made particularly simple by using an ordinary stereoscope. On the other hand, the metric characteristic of the stereo-orthophoto permits the simple and rapid execution of graphical or numerical processing of the *stereomodel* defined by the stereo-orthophotos. As can be seen, the stereo-orthophots satisfy two basic requirements that are not met by the conventional orthophoto products:

- They offer superior readability.
- They permit a convenient derivation of the three-dimensional information.

It is obvious that all the planimetry and topography (contour lines) can be plotted from the stereo-orthophotos. Consequently, stereo-orthophotos constitute an ideal means for identifying and symbolizing all the details that require special attention and they are also eminently suitable for drawing contours, particularly if they have already been marked during the orthophoto scanning process.

Assuming a pin-hole scanning slit, the three-dimensional ground information obtained from stereo-orthophotos would be as precise as the information produced by conventional, stereophotogrammetric procedures. However, the economic considerations force us to use a slit size which has an effect on the accuracy of stereo-orthophotos. Therefore, we propose to discuss the accuracy of stereo-orthophotos in the following paragraph.

ACCURACY OF STEREO-CRTHOPHOTOGRAPHS

For various practical reasons, the scanning of the stereoscopic model is performed parallel to the camera base. Parallaxes are introduced by a shift of the film, on which the stereomate is produced, parallel to the scanning direction. In the following, we shall consider the amount of film shift to be proportional to the height of the film plane above the elevation reference plane.

If the stereomate is produced from the left-hand photograph (see Figure 2), we can derive the following values for the shifts $\Delta x''$ and $\Delta y''$ using a formulation similar to the one used for Equation 3:

$$\Delta x'' = -\frac{1}{2} l \frac{\tan \alpha_x'' \tan \beta_y}{1 - \tan \alpha_x'' \tan \beta_x + \tan \alpha_y'' \tan \beta_y}$$
$$\Delta y'' = \frac{1}{2} l \frac{\tan \alpha_y'' \tan \beta_y}{1 - \tan \alpha_x'' \tan \beta_x + \tan \alpha_y'' \tan \beta_y} . \qquad (5)$$

The film shift amounts to

$$s = d(z + \Delta z - QP'')$$

where

d is the ratio between horizontal and vertical film movement,
z is the height of model point P above the elevation reference plane, and
$\Delta z - QP''$ is the vertical distance between P and P''.

Consequently, the parallax error for point P in the stereoscopic orthophoto is:

$$\Delta p_x = \Delta x' - \Delta x'' - d(\Delta z - QP'')$$

with

$$QP'' = \Delta y'' \tan \beta_y - \Delta x'' \tan \beta_x.$$

Substituting Equation 4 and 5 we obtain:

$$\Delta p_x = \frac{1}{2} l \tan \beta_y \left\{ \frac{\tan \alpha_x'}{1 + \tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y} + \frac{\tan \alpha_x'' - d}{1 - \tan \alpha_x'' \tan \beta_x + \tan \alpha_y'' \tan \beta_y} \right\} . \qquad (6)$$

The y-parallax for point P can be expressed by:

$$p_y = \Delta y' - \Delta y''.$$

Consequently,

$$p_y = \frac{1}{2} l \tan \beta_y \left\{ \frac{\tan \alpha_y'}{1 + \tan \alpha_x' \tan \beta_x + \tan \alpha_y' \tan \beta_y} - \frac{\tan \alpha_y''}{1 - \tan \alpha_x'' \tan \beta_x + \tan \alpha_y'' \tan \beta_y} \right\} . \qquad (7)$$

From Equation 6 it can be seen that the parallax error Δp_x is small when d is equal to the base-height ratio ($d = \tan \alpha_x' + \tan \alpha_x''$). Both terms, and consequently Δp_x, become zero if in addition $\tan \alpha_x' = 0$. Parallaxes p_y are equal to zero if $\tan \alpha_x' = \tan \alpha_y'' = 0$, that is, for points located on the line through both nadir points if the normal case of vertical camera axes is considered. The errors reach their maximum values in the corners of the stereo overlap. In Table III, the errors Δx, Δy, Δp_x and p_y computed from Equations 4, 6 and 7 are presented for a stereo model consisting of 60 percent overlap, wide-angle photographs ($f = 150$ mm). Nine points evenly distributed over the model to within 29 mm from the edges (corresponding to a 75 percent side overlap) were considered. A slit length of 4 mm and terrain slope components $\beta_x = \beta_y = -10°$ were assumed. The ratio between horizontal and vertical film movement was accepted to be $d = 0.613$, which corresponds to the base-height ratio for the average projection distance of 600 mm.

Because the planimetric errors and the x- and y-parallaxes in stereoscopic ortho-

TABLE III. PLANIMETRIC AND PARALLAX ERRORS IN THE STEREO ORTHOPHOTOS FOR A SLIT LENGTH OF 4 mm. AND TERRAIN SLOPE COMPONENTS $\beta_x = \beta_y = -10°$

Point	x	y	$\Delta x'$ proj. dist. 600 mm.	$\Delta y'$ proj. dist. 600 mm.	Δp_x			p_y		
					Proj. dist. 570 mm.	Proj. dist. 600 mm.	Proj. dist. 630 mm.	Proj. dist. 570 mm.	Proj. dist. 600 mm.	Proj. dist. 630 mm.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1	0	0	0	0	−0.010	0	+0.009	0	0	0
2	+184	0	−0.114	0	−0.024	−0.011	0	0	0	0
3	+368	0	−0.243	0	−0.041	−0.027	−0.014	0	0	0
4	0	+345	0	−0.226	−0.011	0	+0.010	−0.027	−0.025	−0.022
5	+184	+345	−0.128	−0.240	−0.028	−0.014	−0.002	−0.030	−0.027	−0.025
6	+368	+345	−0.274	−0.257	−0.050	−0.033	−0.018	−0.035	−0.032	−0.027
7	0	−345	0	+0.184	−0.009	0	+0.009	+0.018	+0.016	+0.015
8	+184	−345	−0.103	+0.194	−0.020	−0.009	0	+0.020	+0.019	+0.017
9	+368	−345	−0.218	+0.204	−0.034	−0.022	−0.010	+0.022	+0.020	+0.018

photos depend on the projection distance the computations were performed for horizontal planes at the three following levels:

1. The average model height, corresponding to a projection distance of 600 mm.
2. A distance if 30 mm above the average model height.
3. A distance of 30 mm below the average model height.

The planimetric errors $\Delta x'$ and $\Delta y'$, computed for the additional projection distances did not vary more than 7 percent from the values of the corresponding errors for the 600 mm projection distance. They are therefore not listed in Table III.

As can be expected, the parallax errors Δp_x are considerably smaller than the planimetric errors Δx. This is partly explained by the fact that errors in the x-parallax caused by the difference in height between a point in the stereomodel and the film plane, are to a certain degree compensated by the horizontal displacement of the stereomate film. This error compensation is most effective when the ratio d is equal to the base-height ratio. This is demonstrated in Table IV where the root-mean-square value of the x-parallaxes in the nine points is given for three different values of the ratio d. The values m_{px} are given for small slope components only. For the larger slopes, the influence of the value tan β on the root-mean-square value m_{px} dominates the effect of the value d. The computations were carried out for the same positions in the orthophoto as referred to in Table III and for a slit length of 4 mm.

The influence of the terrain slope on the geometry of stereoscopic orthophotographs is demonstrated in Figure 3 which presents the root-mean-square values of errors Δx, Δy, Δp_x and p_y for different terrain slopes. The differences between the root-mean-square values for Δp_x and p_y were very small in our example. These values are therefore presented in a single curve. An enlargement factor of four times between the scale of the original (wide angle) photographs and the orthophoto-stereomate combination was considered. The computations were performed for the same nine positions in the stereo overlap that were referred to in Table III and for a slit length of 4 mm. The errors are considerably reduced if a smaller portion of the stereo overlap is used for rectification.

TABLE IV. ROOT MEAN SQUARE VALUES m_{p_x} FOR DIFFERENT RATIOS d

d	m_{p_x}	
	$\beta_x = \beta_y = -5°$	$\beta_x = \beta_y = -10°$
0.5133	0.020 mm.	0.049 mm.
0.6133	0.004	0.017
0.7133	0.014	0.023

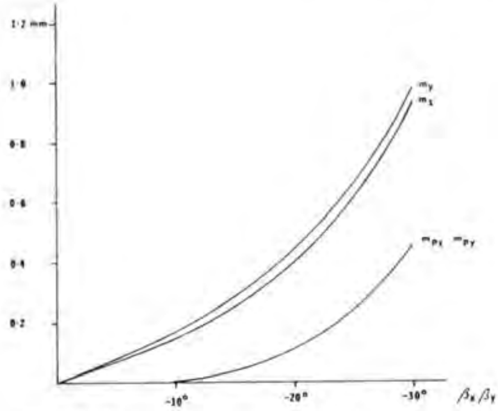

FIG. 3. Errors in stereoscopic orthophotographs produced from wide-angle photographs. The length of the scanning slit is 4 mm.

Errors in profiling and the vertical discrepancies Δz between the end of the scanning slit and the surface of the stereoscopic model have a similar effect on the geometry of stereoscopic orthophotos if the scanning of the orthophoto and the stereomate are performed simultaneously. The scanning errors are then identical for both the orthophoto and the stereomate, and a similar formulation can be used to compute the resulting errors Δx, Δy, Δp_x and p_y. However, as the profiling errors are generally much smaller than the vertical distances between the ends of the slit and the stereomodel, their effect on the geometrical quality of stereoscopic orthophotos is not very significant.

The error analysis presented here is based on the assumption that the artificial parallaxes introduced in the stereoscopic orthophotos are linearly related to the height differences in the stereoscopic model. The effect fo parallax errors can be considerably reduced by introducing artificial parallaxes according to the parallax equation, taking into account the variations in the base-height ratio. The plotting equipment, in which stereoscopic orthophotos are processed, would then have to be equipped with a corresponding vertical readout.

REMARKS

Restricting the orthophoto technique to planimetric presentation of the earth's surface in a fashion similar to conventional photoplans is technically and economically unjustifiable and wrong. The orthophoto technique is a distinctly new procedure with specific characteristics, possibilities and limitations. It is unique because the basic operation, the scanning of the stereomodel (or the equivalent operation) in a profiling mode, provides three-dimensional information on the terrain, and should be fully exploited. The horizontal information is presented in the form of a photographic image of the earth's surface containing a wealth of natural and artificial details.

However, any meaningful metric operation can be performed on such an image only after details are correctly identified. This can be done efficiently only if stereoviewing is introduced. Various possibilities are open in this regard but stereo-orthophotos are of particular interest because they offer an extremely simple, efficient and complete solution to many mapping and surveying problems in which precise definition of specific points and knowledge of their three coordinates is essential.

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