PANORAMIC PHOTOGRAPHS IN CLOSE RANGE PHOTOGRAMMETRY

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At present terrestrial stereophotogrammetry is widely used in various branches of national economy and, in particular, for solution of many problems concerned with the geometric check of building structures during their erection, mensuration of their deformations,testing the production equipment installation etc.

The accuracy of the point coordinate determination with the object-distance from 10 to 200m ranges from 1 to 2mm.

To provide greater precision of the method one should either increase the focal length of the cameras or decrease the photography range. The conditions at the terrain in industrial photogrammetry, however, impose constraints of their own on the location of photostations with respect to the object and on the camera optical axes orientation. This results in increasing the number of photographs and control points that leads to the reduction of economical efficiency as a whole. This disadvantage may be eliminated by applying panoramic photography.

Panoramic photocameras have been lately employed mainly in aerial survey for the purpose of special photointerpretation. However, the possibility of their application for topographic purposes for map and plan compilation is being considered now. Image distortion caused by greater exposure time of the whole photograph and by camera and its carrier movements during the exposure is the main obstacle which is to be overcome. Both drawbacks are eliminated when panoramic photographs are taken from the fixed photostation. In addition, one can utilize the main panoramic photography property- the all-around field of vision. Due to this very property the panoramic photography was employed to study the relief of the Moon's surface by means of the Soviet automatic stations Luna-9 and Luna-13, Venera-13 and Venera-14.

The conventional panoramic photograph processing involves convertion of cylindrical photographs into equivalent flat ones with the subsequent use of coordinates and paralaxes. This approach is not efficient in case of circle-of-sight photography. The simalteneous linear and angular measurements of a panorama and the subsequent processing of the data obtained seem to be more efficient.

Figure 1 shows a pair of panoramic photographs with S_1 and S_2 as the projection centres. Point a_1 on the left-hand photograph represents point A of the object. Its position is uniquely defined by a dihedral angle α_1 contained by the planes passing though the photographic base and the object point and the coordinate z= $a_1 a_i'$.

If a pair of oblique cylindrical photographs was taken with a camera having known elements of internal orientation f_k, z^o, it enables us to restore the bundles of the projecting rays. The position of the bundles with respect to the external geodetic system of coordinates is defined by five elements for each photograph: $\varkappa_1, \varkappa_2$ - angles of tilt of photographs in a vertical plane going through the photographic base;
ω_1, ω_2 - angles of tilt of photographs in a vertical plane perpendicular to the photographic base;
X_S, Y_S, Z_S - coordinates of the projection centres of the left and right-hand photographs.

The rectified photo coordinates X', Y', Z' are connected with their cylindrical coordinates of an image point by the following equations

$$\left.\begin{aligned} X' &= a_1 f\cos\alpha + a_2 f\sin\alpha + a_3 z \\ Y' &= b_1 f\cos\alpha + b_2 f\sin\alpha + b_3 z \\ Z' &= c_1 f\cos\alpha + c_2 f\sin\alpha + c_3 z \end{aligned}\right\}, \qquad (1)$$

where a_i, b_i, c_i - the elements of a rotation matrix.

For cylindrical photographs there is no rotation angle in a horizontal plane, hence the nine elements of a rotation matrix are

$$\left.\begin{aligned} a_1 &= \cos\varkappa & b_1 &= \sin\omega\,\sin\varkappa & c_1 &= \cos\omega\,\sin\varkappa \\ a_2 &= 0 & b_2 &= \cos\omega & c_2 &= \sin\omega \\ a_3 &= \sin\varkappa & b_3 &= \sin\varkappa\,\cos\omega & c_3 &= \cos\omega\,\cos\varkappa \end{aligned}\right\}. \quad (2)$$

The ground coordinates of object points in a photogrammetric coordinate system are defined in a general form by the known equations

$$X_\varphi = NX', \quad Y_\varphi = NY', \quad Z_\varphi = NZ',$$

where

$$N = \frac{B_Y Z_2' - B_Z Y_2'}{Y_1' Z_2' - Z_1' Y_2'} = \frac{B_Z X_2' - B_X Z_2'}{Z_1' X_2' - X_1' Z_2'} = \frac{B_X Y_2' - B_Y X_2'}{X_1' Y_2' - Y_1' X_2'}, \qquad (3)$$

and B_X, B_Y, B_Z - base components.

If $\varkappa_1 = \varkappa_2 = 0$ and $\omega_1 = \omega_2 = 0$, the base coincides with the direction of axis X and the formulae (3) are simplified to:

$$X_\varphi = B\,\frac{\sin\alpha_2 \cdot \cos\alpha_1}{\sin(\alpha_2 - \alpha_1)}, \quad Y_\varphi = B\,\frac{\sin\alpha_2 \cdot \sin\alpha_1}{\sin(\alpha_2 - \alpha_1)},$$

$$Z_\varphi = B\,\frac{z\,\sin\alpha_2}{f\,\sin(\alpha_2 - \alpha_1)}. \qquad (4)$$

One can note that horizontal parallax being a compulsory argument in flat photograph processing is not apparently present in (4).

The error of the point position defined is obtained by the formula

$$M = B\,\frac{m_\alpha \sqrt{\sin^2\alpha_1 + \sin^2\alpha_2}}{\rho\,\sin^2\gamma},$$

where γ - is the angle of convergence of the camera optical axes.

According to the structural features two types of panoramic cameras are distinguished:

1. Camera, using a fixed film forming half of the cylinder on the fixed base and a lens rotating about the cylinder axis.

2. Camera, rotating about its vertical axis and having a lens rigidly mounted to the camera body. The image motion in the plane of the supporting back is compensated by the film movement.

The first type cameras are simpler in design but have a number of disadvantages:

- field of view from horizon to horizon is not more than 180°,
- camera size cannot be less than $2f_k$,
- it is hard to provide film flattening with respect to the cylindrical surface.

The second type camera is preferable from photogrammetric point and for this reason it was taken as a basis for developing panoramic phototheolite PTF-1 (fig2) at the Research Institute of Applied Geodesy (Novosibirsk,USSR). The instrument consists of fixed and rotating parts. The fixed one contains a glass limb which graduations are recorded on a photograph during the exposure. The moving part contains a lens, filmmoving mechanism, optical system projecting limb graduations on the photograph, and camera electric motor drive or spring drive.

The phototheodolite features:

camera focal length 150mm
field of view from horizon to horizon .... 360°
vertical field of view .... 28°
panoramic photograph dimensions 942x88mm
film roll capacity 20m
horizontal circle division .... 1°
electric power source voltage .... 12 v

The photograph taken by this instrument may be considered as a developed horizontal limb of an angle measuring instrument with the terrain represented on it. That is why it is more efficient using limb graduations to measure horizontal angles of intersection from a base line, instead of measuring planimetric coordinate X of the unrolled photograph, and to measure coordinate Z as in a case of a flat image.

The peculiarity of photographs is in their two focal lengths. One of them provides photograph scanning in the vertical plane and is equal to the focal length of the objective, the second is defined by the speed of the film movement with the image motion compensation.

The resulting small anamorphosis of photographs is fairly well eliminated during the analytical processing.

The movement of the vertical field of view in a panoramic camera is performed by changing the direction of the bundle of rays by means of a two- or three-mirror attachment, mounted in front of the objective. The mirror system is mounted in a single frame fixed to the phototheodolite body. Mirrors are made in the form of narrow strips enabling the exposure of the part of the photograph bounded by the slit. When using the attachment the panoramic photograph is obtained in the form of a truncated cone. One should just consider the angle of inclination of the ~~main optical~~ axis of the objective when processing the photo.

To coordinate the points under restricted conditions, that is, in the shops of industrial enterprices, at the construction sites,the panoramic photography of a short and rigid base line is efficient. For this purpose the set of panoramic theodolites contains a special stereo-attachment consisting of two parallel mirrors sloping at an angle of 45° to the main optical axis of the objective. The separation between the mirror centres is equal to one half of the base line 0.5B.

To obtain a stereocopic pair of photographs it is advisable to take them with two positions (left and right) of the attachment with respect to the objective. When processing the images the positions of points defined with respect to the horisontal circle are measured on two photographs. The difference in readingsis a parallactic angle of intersection from both ends of a base line.

For the purpose of increasing the accuracy of panoramic photography a panoramic phototheodolite with the objective focal length of 400mm was developed. Its peculiar feature consists in the fact that the main axis of the objective is vertical and coincides with the instrument axis of rotation. The rotating mirror sending the projecting beam forth the objective is mounted in front of it. Inclining the mirror by different angles of tilt one can move the sector of the vertical angle of sight of the objective upwards and downwards, that is, take both cylindrical and conic photographs. The instrument is equipped with the limb having a scale division of 20'. Its graduations are recorded on the photographs enabling to measure horizontal ahgles with an error not exceeding 7". The full length of an unrolled phptograph is equal to 2510mm. The instrument also contains a unit providing the film movement only during the scanning of a sector corresponding to the required part of a photographed object. The length of the exposed area of the photo should not be less than 7mm since it should contain at least one numbered graduation of the limb. Individual areas are combined by a unified numbering of the limb. Therefore the photograph involving several zones has the properties of a single photograph.

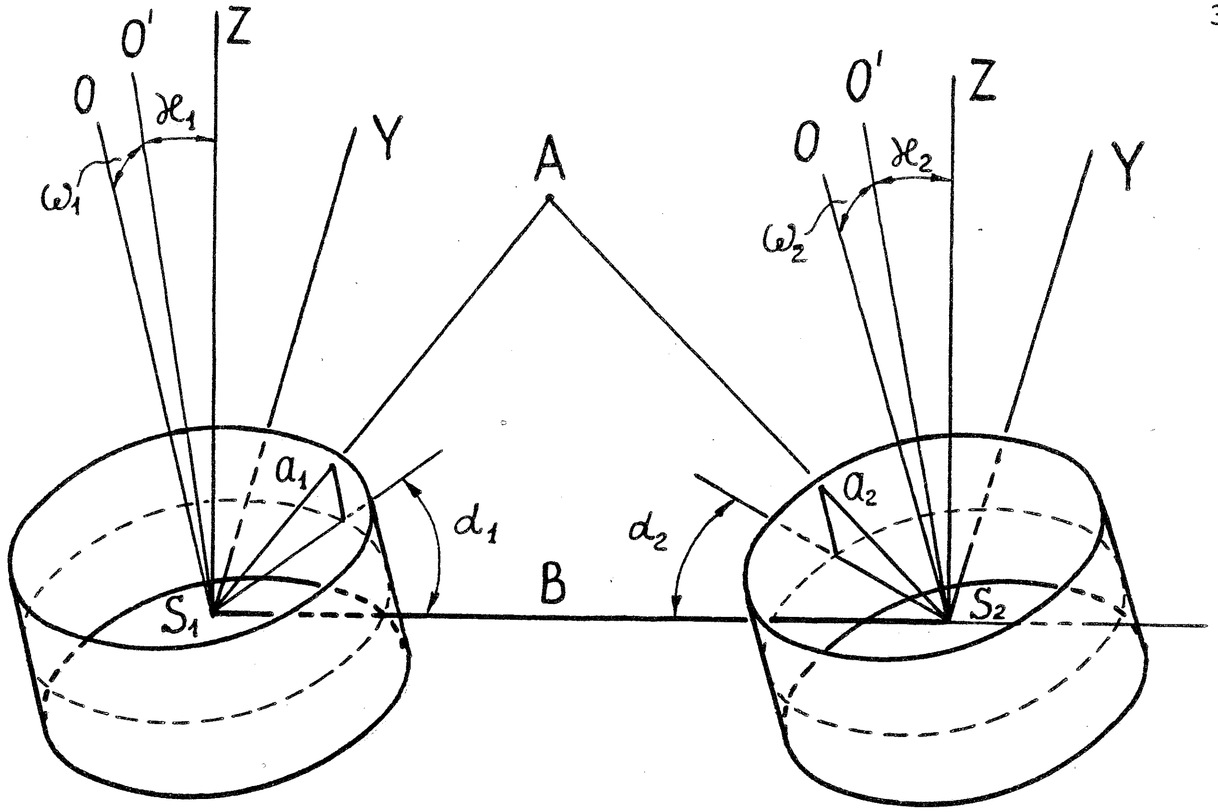
Stereoscopic measurements of panoramas are not always possible with the help of the available photogrammetric instruments due to the difference of panorama scales.

For this purpose a special stereocomparator has been developed. The instrument enables to measure coordinates z and intersection angles at the points defined on the photos from the ends of the base line. The data measured are automatically read and recorded in a microprocessor and the geodetic coordinates of the points defined are obtained at the output.

In conclusion, it should be emphasized that the application of the terrestrial panoramic photography is preferable for the solution of some engineering and photogrammetric problems. These advantages are:

- panoramic photographs cover greater part of the terrain as compared with flat ones having the same focal length. The accuracy is not affected;
- the amount of field work is drastically reduced;
- the location of control points in a photographed area of an object is not required. The control points may be located at any elevation in the opposite direction of the object;
- the amount of control points does not depend on the number of photographs taken from one photostation since all the photographs can be tied to one and the same set of points;
- the application of high quality superwide-angle objectives is not necessarily required;
- the camera focal length increase for the purpose of greater accuracy does not reduce an angle of coverage in a horizontal plane; the objective field of view in a vertical plane can be increased by ordinary means.

The above described instruments have been employed at the industrial enterprices in Novosibirsk. The results obtained meet the quality and accuracy requirements.



O
O'
Z
Y
A
ω_1
$\varkappa_1$
a_1
α_1
S_1
B
α_2
a_2
S_2
X
ω_2
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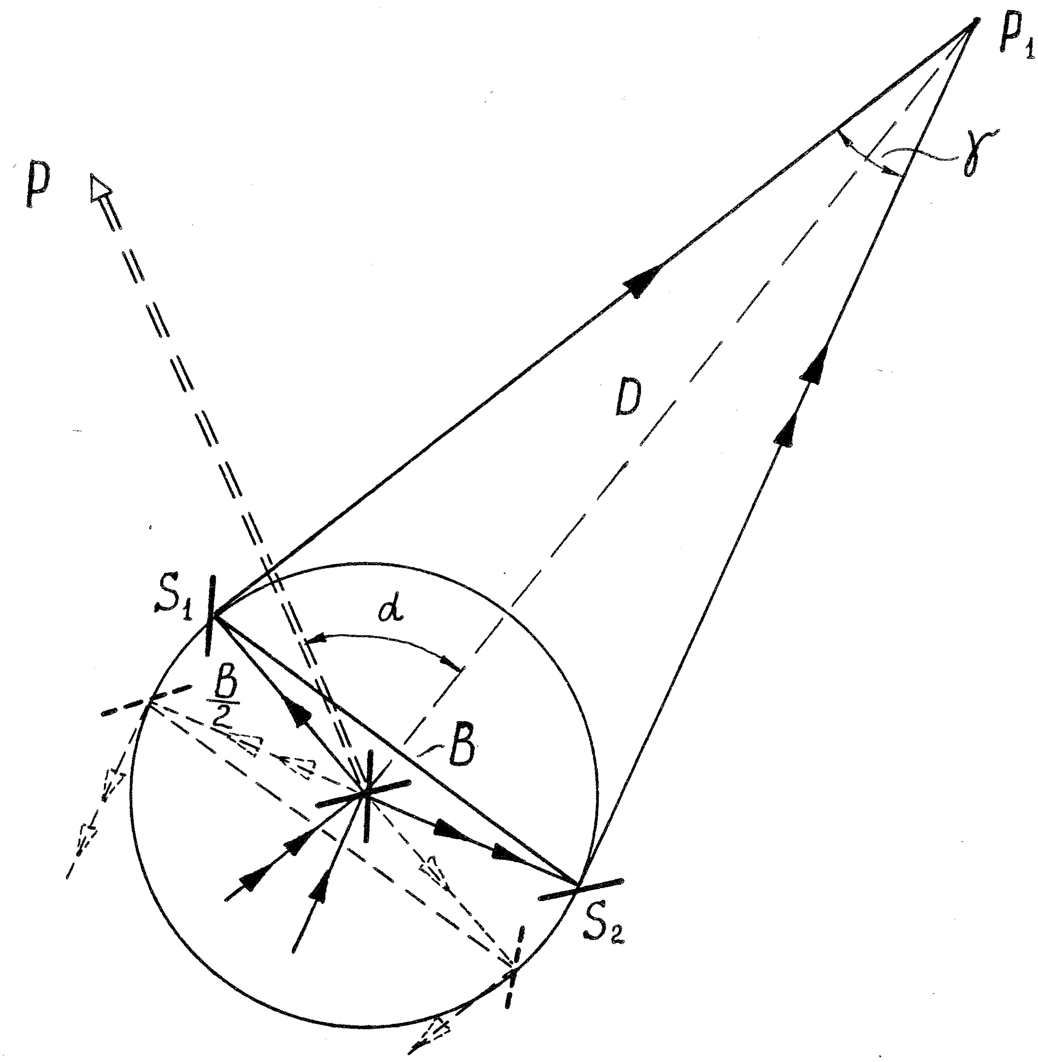
Fig. 1



P_1
γ
P
D
S_1
α
$\frac{B}{2}$
B
S_2

Fig.3

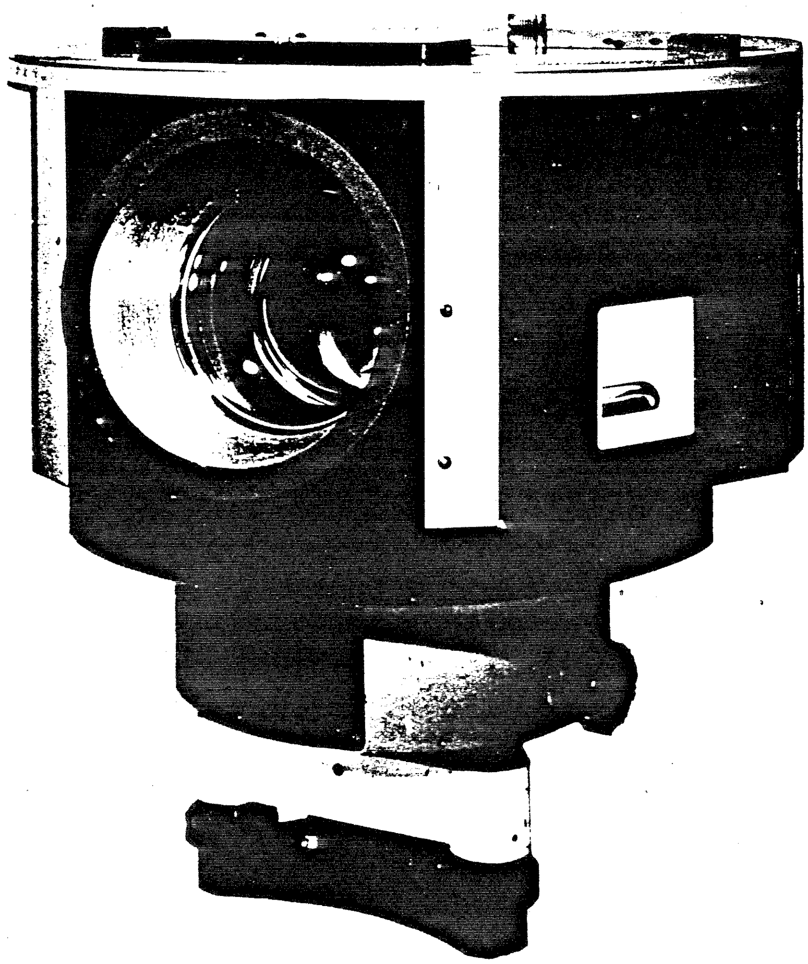


fig.2