SPACE PHOTOGRAPH STEREOSCOPIC PLOTTING, USING ANALOGICAL METHODS

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Zusammenfassung

Es werden, die an die Raumbilder gestellten Anforderungen, vom Standpunkt ihrer stereoskopischen Auswertung, dargestellt: es wird der Einfluss der inneren Refraktion und der Erdoberflächenkrümmung auf die Orientierung des Raumbildmodells und auf die darauf durchgeführten Messungen, behandelt.
Es wird das Flussdiagramm des technologischen Prozesses für die analogische stereoskopische Auswertung der Raumbilder dargestellt und dessen Hauptetappen beschrieben.
Es werden die Verfahren der Orientierung der Raumbildmodelle, der Kartierung der Grundriss- und Reliefelemente, beschrieben. Nach Darstellung der Ergebnisse, werden Endbemerkungen über den mit "Saliut" - Raumbildern durchgeführten Versuch und die künftige Auswertung der "SPOT" - Raumbildern, gemacht.

Space photogrammetry has been developed theoretically and practically, based especially on space photographs taken by Apollo 15, 16 and 17 spacecrafts, Skylab and Saliut - Soyuz orbital system [1].
Based on results obtained in Remote Sensing, we can find the following remarks "...many specialists foresee a large leap within terrestrial surface mapping, which can be compared to that related to replacement of the classical methods by the aerial photogrammetric ones, when horizontal measurements are made", in the above mentioned work.

1. Requirements related to map precision, which is compiled using photographs

Photographic systems taking space photographs, mathematical basis for pointing out distortions seen on space photographs and theoretical considerations regarding their stereoscopic plotting are given in the following works [1], [5], [6], [11], [13]. After [1]:

- ground resolution of a space photograph R_f is established, using the relation:

$$R_f = 5 \cdot 10^{-5} M_h \qquad (1)$$

where M_h = map scale denominator

- ground map resolution (R_h) is calculated using the expression:

$$R_h = M_h/1000 \qquad (2)$$

- standard error σ of the relative horizontal position of a ground control point, established on a stereoscopic model, is given by :

$$\sigma_p = M_f \sigma_t \qquad (3)$$

where M_f = photograph scale denominator and σ_f = map measurement precision of a point on photograph; standard error σ_h to establish point height on a photograph is given by :

$$\sigma_h = M_f \cdot H/B \cdot \sigma_m \sqrt{2} \qquad (4)$$

where H = height for taking photographs;

B = ground distance among stations taking photographs, which constitute the stereomodel;

σ_m = standard error of height measurement of a point on a stereomodel;

H/B = inverse of base/height for taking photograph ratio.

Requirements concerning map precision compiled at various small scales using photograph plotting and those mentioned in [1], that is σ_h = 0.3 of contour interval, special for various scales and based on expressions (1) - (4) are given in Table 1.

2. Factors influencing space photograph geometry

Considering that photographic systems (sensors) taking photographs gives a ground resolution shown in column 3 of Table 1, values computed and written in columns 4-6 can be attained only if space photographs, that is stereoscopic model, are plotted using not only factors special for classical stereo-photogrammetry but other ones, such as: various distortions of space photographs (interior refraction, window unflatness through which photographs are taken, a.s.o.), ground surface curvature.

Table 1

Requirements concerning map precision at various scales

Map scale (M_h) 1:	Ground map resolution (R_h) [m]	Ground sensor resolution (R_f) [m]	Position standard error		Contour interval [m]
			horizontal [m]	vertical [m]	
1000000	100	50.0	300.0	75.0	250
500000	50	25.5	150.0	30.0	100
200000	20	10.0	60.0	15.0	50
100000	10	5.0	30.0	8.0	25

Some theoretical considerations on these influences are given below.

2.1. Interior refraction influence

Correction of x -, y - point coordinates of a space photograph, due to interior refraction influence [5], is made using expressions:

$$x_c = x + x\left[1 + (z^2 + y^2)/f^2\right] k$$
$$y_c = y + y\left[1 + (x^2 + y^2)/f^2\right] k \qquad (5)$$

where: x_c, y_c = corrected point coordinates;

x, y = considered point coordinates measured on a Stecometer;

f = focal length of the photographic system;

k = a coefficient equal to the angular value of the radius direction change, and which makes a 45° angle with the optical photographing axis.

2.2. Terrestrial surface curvature influence

Terrestrial surface curvature can be pointed out, that is considered, using the drawing in Figure 1, where a vertical section of a photograph triplet, oriented to one of the analogical plotting instruments is shown. The instrument projection plane E is considered to be superposed over O_2XY plane of O_2XYZ rectangular coordinate system in this drawing.

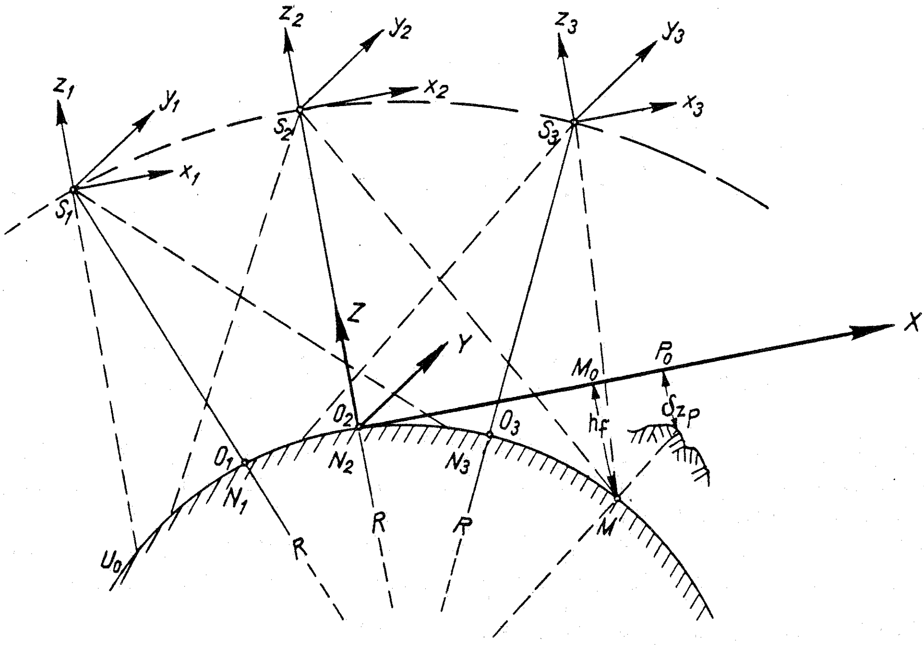

Figure 1. Vertical section of a space photograph triplet

Considering point N_2 to be the origin of the model coordinate system, the stereoscopic model point coordinates are established within OXYZ rectangular coordinate system, when geodetic heights of the considered points within the stereoscopic model are measured on a line starting from the respective points and being perpendicular on U_0 plane.

$\overline{PP_0} = \delta_z = -z$ and it is the height error of P point caused by terrestrial surface curvature (Figure 1) [13]. In [8] work, it is shown that δ_z can be computed using expression:

$$\delta_z = \frac{L^2}{2R} \tag{6}$$

where: R = the Earth mean radius; L = distance between N nadir point and P point.

Considering (6), we can compute Z geodetic height value of any point within the stereoscopic model, made on a space photograph, using the following formula :

$$Z = h - \frac{L^2}{2R} \tag{7}$$

where: h = geodetic height of the considered point.

3. Experiment related to a technological process concerning a stereoscopic space photograph plotting.

Based on the special - subject literature [10], [9], [12], [8] we have investigated, and on the items already mentioned, a technological process concerning a stereoscopic space photograph plotting was made, using a Carl Zeiss Jena Stereoplanigraph . The flow chart of the developed technological process is shown in Figure 2.

3.1. Characteristics of the used basic materials

The stereogram, we have selected for our experiment, is contained in a photograph strip taken from the space in July, 1979 by Soyuz - Saliut orbital system and covers our country territory.

The focal length of the camera f = 200.355 mm; photograph format 18 x 18 cm and their scale $m_f \approx 1 : 1,000,000$. A grid having a 1 cm contour interval is made on the photograph. Studying stereogram and terrain it represents, the following elements have been established: $h_{min} = 25$ m; $h_{max} = 350$ m; $h_{N2} = 80$ m (Figure 1); $H_{min} = 215.1$ km; $H_{max} = 215.425$ km; $H_{N1} = 215.770$ km.

Just a mention , because we have not the original negatives or some of their duplicates, the negatives we have used were performed in our Institute, using photographical film and 1/1 copies.

To identify the conjugate control points (photograph-map), a copy using a negative for projection and a 10 x magnifying coefficient was made.

Topographic maps at a 1:50,000 scale were used to identifiy control points required by absolute stereomodel orientation.

3.2. Cartographic projection selection

Analyzing [5] and [15] works, we come to the conclusion that cartographic projections suitable to small scale mapping, using space photograph, are: Mercator cartographic projection (UTM) followed by Kavaraiski and Gauss ones. After thorough analyses, the authors of this paper considered that the most advantageous projection is 1970 plane scant stereographic projection for our country, which features are presented in 4 .

4. Experimental technological process stages

4.1. Preparatory works

A large work volume is covered by preparatory works within this experiment. Some of them are given below.

Thus, 24 topographic details existing on the space photographs and on 1:50,000 scale topographic maps, fulfilling condition required by control points have been chosen.

The angular geodetic coordinates B, L and h height have been measured for each control point. It is worth saying that B, L values have been measured with about a ± 1 s precision, and h heights have a ± 5 m evaluation.

Geodetic coordinates B, L have been changed into X, Y rectangular coordinates, using a computer based on algorithms and formulae given in [3] and CORSTE programme presented in [14] .

The plane rectangular coordinate x", y" have been measured on a Stecometer in order to validate control points, which were chosen and marked on a negative, using B transmark device These values and the calibrated grid values ($d_x = d_y = 170$ mm) printed on the photograph into the input data of COREXRIG programme [14], x", y" coordinate corrections have been performed, using an electronic computer, thus eliminating influences of the emulsion support (photographic paper) distortion and interior refraction, as well.

The introduction of these corrected coordinates into the input data of OREXRIG programme package, based on criterion $\sigma \leq \Delta S$ (where: $\Delta S = \sqrt{x^2 + y^2}$; $\Delta x = x_c - x_f$; $\Delta y = y_c - j_f$; x_f, y_f are known values, and x_c, y_c are computed coordinates for the same points in an iterative cycle) entails the elimination of 7 wrong control points (identification, measuring, marking, a.s.o.) out of the chosen 24 point set.

The following problems related to possibilities of the analogical stereoplotters in space photograph plotting, having the parameters mentioned in 3.1, are also solved within the preparatory stage.

Thus, in [13] it is mentioned a first condition according to which a space photograph can be plotted on an analogical stereoplotter requiring a convergence angle (Figure 1) not exceeding 26°.

Computation of θ values for stereograms taken by Saliut-Soyuz orbital system, also considering analogical stereoplotters existing in our country is presented in Table 2; they were computed using the following formula :

$$\sin \frac{\theta}{2} = M_s \frac{bx}{2R} \tag{9}$$

where M_s = stereoscopic model scale denominator;

b_x = computed stereoscopic model base ($bx = b \frac{M_f}{M_s}$, where b = base for taking photographs measured on one of the original photographs; M_f = original photograph scale; M_s = stereoscopic model scale; R = the Earth mean radius.

Table 2

Values θ computed for various M_s scales considering: m_f = = 1:1,010,000; b measured = 75 mm; 2R = 12,724,000 m.

Device	b x limit [mm]	Stereoscopic model base 1 :	b x computed [mm]	θ
Zeiss Jena Stereoplanigraph	300	750 000	101,0	00°17'03"
		500 000	151,5	00°17'03"
		400 000	189,4	00°17'03"
Stereometrograph	280	750 000	101,0	00°17'03"
		500 000	151,5	00°17'03"
		400 000	189,4	00°17'03"
Wild A 8 Autograph	220	750 000	101,0	00°17'03"
		500 000	151,5	00°17'03"
		400 000	189,4	00°17'03"

Values computed and given in column 5 of Table 2 show that, considering convergence angle θ condition, the above mentioned space photographs can be plotted stereoscopically, using the analogical stereoplotters existing in our country.

Another problem we have approached was related to our stereoplotter possibilities to establish relations among space photograph scales, their stereoscopic model scales and scale of the map to be compiled. It was solved based on some parameters special to analogical stereoplotters (Table 3), data special to

544 - 545 stereogram discussed in 3.1. and formulae in [10], as well.

Table 3

Some parameters special to stereoplotters we have at our disposal

Device	Parameters			
	f	m_s/m_h	Z [mm]	
	[mm]	max	min	max
Zeiss Jena Stereoplanigraph	206± 5 152± 4 100± 2,5	5^x	150	640
Stereometrograph	98-215	5^x	140	340
Wild A 8 Autograph	98-215	4^x		

4.2. Peculiarities of stereoscopic space photograph plotting

Space photograph interior and exterior orientations, excepting stereoscopic model levelling and relief plotting, using analogical stereoplotters are similar to those employed in classical photogrammetry.

Peculiarities of the relief levelling and plotting are caused by the need to consider terrestrial surface curvature, thus, revealing a disagreement among values measured on Z scale (of the device) and geodetic heights on the considered reference plane.

In order to consider terrestrial surface curvature, the method presented in [2] was used, according to which the stereoplotting centre can be established in one of N_i, N_{i+1} nadiral points or among them. The control point heights to be measured on Z scale have been computed using formula (7), when the plotting centre was established in N_2 point (Figure 1).

Table 4

Levelling elements of 544-545 space photograph

Point no.	h [m]	L [mm]	Δz [m]	h_f [m]	h_f cor. [m]	Readings on a drum [m]	Differences [m] (Col.5-6)
1.	170	507,8	810	-640	-642	-660	-18
2.	175	500,1	785	-610	-612	-640	-28
3.	115	417,8	548	-433	-434	-410	24
7.	190	483,1	732	-542	-543	-520	23
8.	90	273,5	235	-245	-246	-262	-26
9.	145	357,0	336	-193	-193	-210	-19
11.	175	183,5	106	69	69	53	16
N.	80	0,0	0	80	80	70	-10

Because a 200.355 mm focal length cannot be measured on Zeiss Jena Stereoplanigraph (table 3), the converted bundle method given in [7] has been employed.

Although the stereoscopic model can be levelled within about 20 m precision, contourings cannot be traced because of the terrestrial surface curvature influence.

In our country, a 1:200,000 scale topographic map is compiled, having a 50 m contour interval. After [1], the value of δ_z (6) must not exceed 16 m. In such a case, to eliminate the terrestrial surface curvature influence, the considered surface must not be larger than those shown in (6), when contourings take

place, namely $L = (2\,R\,\Delta z)^{1/2} = (12740\ \text{km} \times 16\ \text{m}) = 14\ \text{km}$.
Stereogram used has been devided into 44 sections and contourings were made only over mountainous zones. In submountainous zones, contour levels are not significant, thus certifying the theory described in [1] according to which relief representation can be made only if stereomodels are developed, using F_1 and F_{1+5} photograms.
Good results have been obtained in horizontal element development, some additional measures should be provided.
We can draw the conclusion that, although we have not primary original materials at our disposal, our experiment points out the possibility to stereoscopically plot space photographs,using analogical stereoplotters more and more in the future,especially now when SPOT satellite is to be launched on a cir - cumterrestrial orbit.

BIBLIOGRAPHY

1. Brown D., Colvocoresses A.P. ş.a., 198o - Manual of Photogrammetry, Chapter XVII "Satellite Photogrammetry",American Society of Photogrammetry, Falls Church, SUA.
2. $x^x x$ 1979 - Seminarul internaţional de teledetecţie organizat de Institutul de Cercetări Stiinţifice şi de Producţie "Priroda", Moscova - Duşanbe.
3. Cantemir D., 1974 - Metode de calcul pentru valorificarea proiecţiei cartografice 197o. Temă de cercetare I.G.F.C.O.T.
4. Drăghici M., Tudor C., 1973 - Cu privire la proiecţia stereografică 197o, adaptată pentru teritoriul RSR. Referat prezentat la sesiunea ştiinţifică jubiliară "15 ani de activitate I.G.F.C.O.T." Bucureşti.
5. Gonin G.B., Strelnikov S.I., 1975 - Kosmiceskaia siomka , Izd. Nedra, Leningrad, SSSR.
6. Kienko V.P., 1979 - Osnovi Kosmiceskogo prirodovedenia , GUGiK pri Soveta Ministrov SSSR.
7. Lobanov A.N., 1957. - Fototopografiia, Izd. VI, Leningrad, SSSR.
8. Lobanov A.N., 1971 - Aerofototopografiia, Izd. Nedra,Moskva, SSSR.
9. Marton G., Zagharu N., 1971 - Fotogrammetrie, Ed. Ceres, Bucureşti.
1o. Oprescu N., 1953 - Curs de fotogrametrie, vol.I,partea a II-a, Lito, MAS-Atalierele de material didactic,Bucureşti.
11. Oprescu N., 198o - Curs de teledetecţie, Laboratorul CNST-CRAS, Bucureşti.
12. Oprescu N., Calistru V., Turdeanu L., 1982 - Fotogrammetrie, I.C.B.
13. Preobrajenskii I.A., 1974 - Necotorîie voprosî fotogrammetriceskoi obrabotki snimcov planet,polucennîh s bolşîh vîsot fotografirovaniia. Izvestia VuZ "Gheodeziia i aerofotosiomka", Moskva, SSSR.

14. Salariu I., 1983 - Proces tehnologic optimizat-integrat de teledetecţie pentru întocmirea fotohărţilor. Analele I.G.F.C.O.T., vol.V, Centrul de material didactic şi propagandă agricolă. Redacţia de propagandă tehnică agricolă, Bucureşti.

15. Ziman I.L. ş.a., 1978 - Koordinatnaia priviazka i gheodeziceskie trebovaniia snimcov MKF-6. "Intercosmos, Tezisâ docladov ". Budapeşt.