XIV CONGRESS OF THE INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY
HAMBURG 1980

Commission V
Working Group 3

Presented Paper

Dr.eng.N.Răducanu, Bucharest, Romania

REMARKS ON PHOTOGRAMMETRIC PROCESS TRANSPOSITION ON HOLOGRAMS

ABSTRACT

Some aspects of the photogrammetric process transposition on holograms related to hologram recordings and plottings, holographic image size, hologram compilation using photogrammetric stereomodels and establishing image distorsions owing to hologram orientation errors as against reference beam are presented in this paper.

After establishing linear exterior orientation elements having a ± 8 mm accuracy and the angular ones having about 30 min, we can obtain errors of ± 12 mm in x and y directions and ± 0.17 mm in z direction.

Zeiss-stereocomparator provided with a special device to measure virtual holographic image was used, in order to study these problems.

The possibility to obtain three - dimensional images by means of holograms confronted photogrammetrists with the problem of using holography in topographic map compilations.

Attempts made in order to transpose the photogrammetric processes on holograms are in the stage of working with second - generation holograms.

First generation holograms were used to obtain three - dimensional measurements of holographic images made from stationary objects.

Second-generation hologram problems dwell upon the possibility to make holograms from photogrammetric stereomodels, to establish holographic image deformations, the optical filtering in coherent light for automatic aerial photointerpretations, as well as, one and two-dimensional optical correlation for photogram, holographic contouring necessary in orthophotorectification, the terrain model digitizing and the planimetric elements aiming at automatic topographic map.

This paper presents some aspects regarding the transposition of photogrammetric processes on holograms related to recording and reading holograms, the possibility to make holograms from photogrammetric stereomodels, the establishment of holographic image deformations due to errors in hologram orientation against the reference beam, as well as, the photograms holographic contouring, all of them on mathematical and experimental bases. In order to study these problems, we used both a Zeiss Stereoplanigraph and a Stereocomparator; we also designed and built a special device able to generate and read holograms, as well as, to make their optical correlation.

1. HOLOGRAMS OF PHOTOGRAMMETRIC STEREOMODELS

The most important problem of the photogrammetric processes transpositions on holograms consists in making the ground surface holograms. As compared to classical photography, holography implies not only special technology and conditions, but proper stability (λ /4) during recording. This is easy to do in the laboratory with small objects, but nearly impossible to do it with large objects, namely the ground surface. That is why attempts are made to obtain ground surface holograms from photogrammetric stereomodels.

The present-day efforts, as well as, a number of significant achievements are not made by photogrammetrists, but by specialists from other fields of activity such as stereoscopic television [1] , which do not give measurable stereomodels.

In order to make holograms from photogrammetric stereomodels, we built the optical arrangement and the device we present in Figure 1.

The basic optical elements of this device are the lens expanding (L_1) and collimating (L_2) light beams, (O_1, O, O_2) rectifying plane mirrors orienting beams to (H) holographic plate and making equal the optical paths.

In order to make holograms, we took a model stereoscopic pair (Figure 3) at a 1:30 and an aerial photo pair at a 1:8,500 scale. The photograms were centred using two special devices; then, they were projected and overlapped on common details;

next, holographic plates are recorded and processed photographically.

These tests have proved holograms achievements from photogrammetric stereomodels to be quite a possibility.

Some difficulties arising from image measurement are related to the floating mark and its introduction into the holographic model.

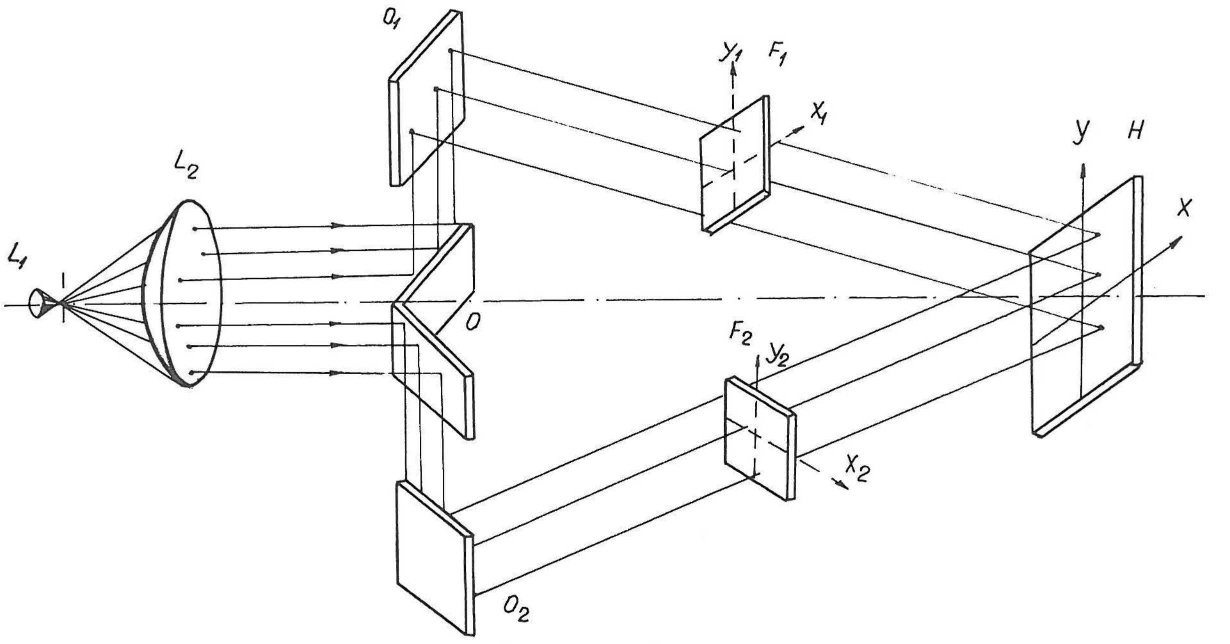

Figure 1. An optical arrangement able to make holograms from photogrammetric stereomodels.

2. EXPERIMENTAL RESULTS ON HOLOGRAPHIC IMAGE FORMATION ACCURACY

Because we are concerned with hologram measurement problems, we tried to obtain data concerning holographic image pointing and accuracy and the hologram orientation element influences on point locations on holograms, in this paper.

As test objects, we used both holograms of some small details placed at a 40 cm depth and a control grid. A Stereoplanigraph and a Stereocomparator were used to make measurements. The angle between the reference beam and the signal beam was about $29^{\circ}31'$, having the same accuracy as that used during recording. A measured point location on the hologram can be determined, depending on the ground point coordinates and the reference beam location (Figure 2).

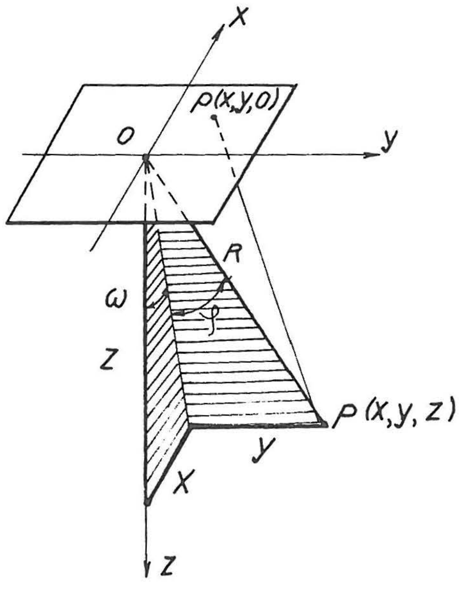

Figure 2

Coordinate system origin is set at the hologram center with the x - axis normal to the hologram plane.
A point coordinates of the holographic image, expressed in terms of φ , ω and R are:

$$
\begin{aligned}
X &= R \cos \varphi \sin \omega \\
Y &= R \sin \varphi \qquad (1) \\
Z &= R \cos \varphi \cos \omega
\end{aligned}
$$

In order to determine the pointing accuracy, as in case of the photogrammetric model pointings, a number of 150 pointings were made, obtaining the following values for accuracy estimation:

$$\Delta X = \pm 0.05 \text{ mm}; \Delta Y = \pm 0.09 \text{ mm}$$

A rectangular grid measured in a Stereocomparator was selected as test object in establishing the holographic image formation accuracy, and the following values have resulted:

$$\Delta X = \pm 0.06 \text{ mm}; \Delta Y = \pm 0.08 \text{ mm}$$

In a measuring system, a hologram can be orientated until the virtual image coincides with the object. Residual errors in plate orientation appear as interference fringe deformations which can be observed and eliminated making a new hologram orientation.
After hologram measuring in its correct position, we changed

the orientation of elements and made new measurements.
As a result of our tests, we found that an accuracy of $\pm$ 8 mm for X_o, Y_o, Z_o and of 30 minutes for φ, ω and $\varkappa$ in determining exterior orientation elements has resulted in the following point coordinate errors:

$$\Delta X = \Delta Y = \pm 0.12 \text{ mm}; \ \Delta Z = \pm 0.17 \text{ mm}$$

4.PHOTOGRAM HOLOGRAPHIC CONTOURING

As we already mentioned, the process of making terrain profiles against various directions is necessary for photograms differential rectification, as well as, for terrain model digitizing.
Papers treating optical methods for information coherent processing showed that optical correlators can be used in correspondent image selections and in optical filtering.In this paper, we present the mathematical base for one-dimensional correlation and the optical correlator used, in order to obtain altitude information as parallax profiles.In order to test one-dimensional optical correlation, a terrain configuration model was built; next, a stereoscopic photo and a hologram of this model were made (Figure 3).

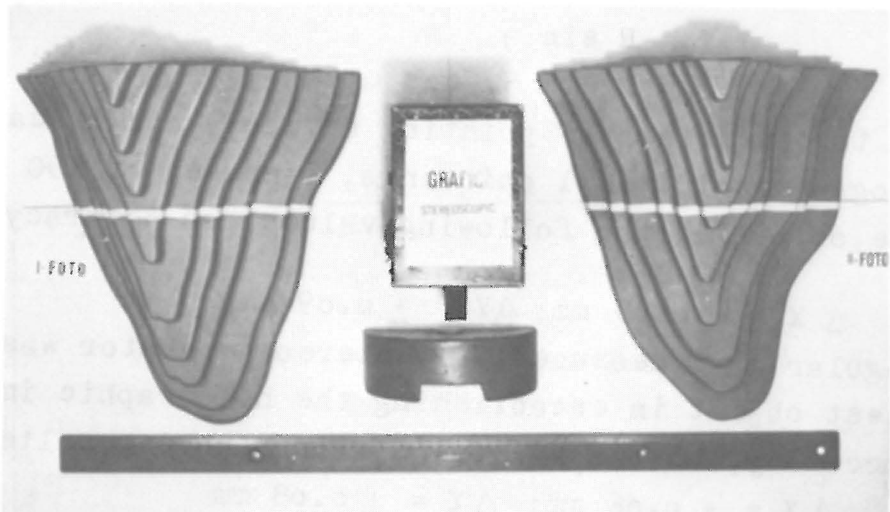

Figure 3. The Photogram - model

The terrain configurations were built step by step, in order to write contour and Fourier transform equations more easily for a certain direction (Figure 4).

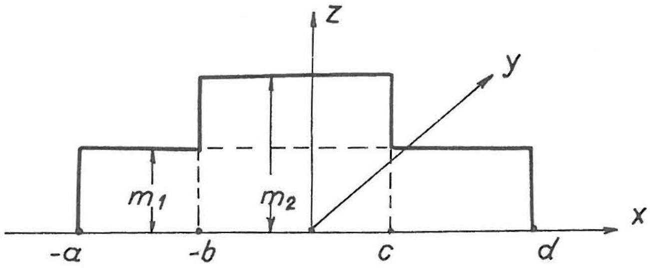

Figure 4

The solution is given for the first two steps of the profile, the equation having the form:

$$t\,(x,y) = \begin{cases} 0\;; & x < -a \\ m_1\;;\; -a & x < b \\ m_2\;;\; -b & x < c \\ m_1\;;\; c & x < d \\ 0\;; & x > d \end{cases} \tag{2}$$

The Fourier transform of the function t (x,y) is given by the expresion:

$$F(t) = \int_{-a}^{-b} m_1\, e^{ipx} dx + \int_{-b}^{c} m_2\, e^{ipx}\, dx + \int_{c}^{d} m_1\, e^{ipx}\, dx =$$

$$= \frac{m_1}{ip}\left[e^{-ipb} - e^{-ipa} + e^{ipd} - e^{ipc} \right] + \frac{m_2}{ip}\left[e^{ipc} - e^{ipd} \right] = T(p,y) \tag{3}$$

The complex conjugate has the form:

$$\bar{T} = \frac{m_1 i}{p}\left[e^{ipb} - e^{ipa} + e^{ipd} - e^{ipc} \right] + \frac{m_2 i}{p}\left[e^{-ipc} + e^{ipb} \right] \tag{4}$$

According to the argument delay rule, we have:

$$F\left[t_1(x-x_1, y) \right] = F\left[t_1(x,y) \right] \cdot e^{ix_1 p} = T_1(p,y)e^{ix_1 p} \tag{5}$$

The one - dimensional transform of the first photogram has the form:

$$T_1(p,y)e^{ix_1 p} = \frac{m_1}{ip}\left[e^{-ipb} - e^{ipa} + e^{ipd} - e^{ipc} \right] e^{ix_1 p} + \frac{m_2}{ip}\left[e^{ipc} - e^{-ipb} \right] e^{ix_1 p} \tag{6}$$

The interferometric model recorded as a hologram of the first photogram is:

$$E_f(x_f, y_f) = R_o^2 + \frac{\bar{R}}{ip}\left[m_1 \left(e^{-ipb} - e^{-ipa} + e^{ipd} - e^{ipc} + m_2 (e^{ipc} - e^{-ipb}) \right] \right.$$

$$e^{-ip(x_R-x_1)} + \frac{R_o i}{p}\Big[m_1(e^{ipb}-e^{ipa}+e^{-ipd}-e^{ipc}) + m_2 (e^{-ipc}-e^{-ipb})\Big]\, e^{ip(x_R-x_1)} \qquad (7)$$

The terrain conjugate image of the second photogram has the form:

$$t_2(x-x_2,y) = t_1\big[\, x-(x_1+p_x),\ y\big] \qquad (8)$$

The Fourier transform is given by the expression:

$$T_1(p,y)\, e^{ip(x_1+p_x)} = \Big[\, m_1(e^{-ipb}-e^{-ipa}+e^{ipd}-e^{ipc}) + m_2\, (e^{ipc}-e^{ipb})\Big]\ .\ e^{ip(x_1+p_x)} \qquad (9)$$

where $p = \dfrac{2\pi\, x_f}{\lambda\, f_1}$ is the phase pulsation.

The correlation function is given by the member - by - member product of the equations (7) and (9) :

$$r(f) \sim R^2\Big[m_1(e^{-ipb}-e^{ipa}+e^{ipd}-e^{ipc})+m_2(e^{ipc}-e^{ipb})\Big]\ \frac{i}{p}e^{ip(x_I-p_x)} +$$
$$+ \frac{R_o}{p^2}\Big[m_1(e^{-ipb}-e^{-ipa}-e^{ip})+m_2(e^{ipc}-e^{ipb})\Big]^2 e^{-ip(x_T-2x_1-p_x)} -$$
$$- \frac{R_o}{p^2}\Big[\, m_1(e^{ipb}-e^{-ipa}+e^{-ipd}-e^{-ipc}) + m_2(e^{-ipc}-e^{ipd})+m_1 (e^{-ipb}-e^{-ipa}+e^{ipd}-e^{ipc})+m_2(e^{-ipc}-e^{ipb})\Big]\ e^{ip(x_R+p_x)} \qquad (1o)$$

Taking the coordinates of the x_o, y_o output plane, the third term of the equation (1o) is the correlating signal or the filter output, and it is given by the curve presented in Figure 5.

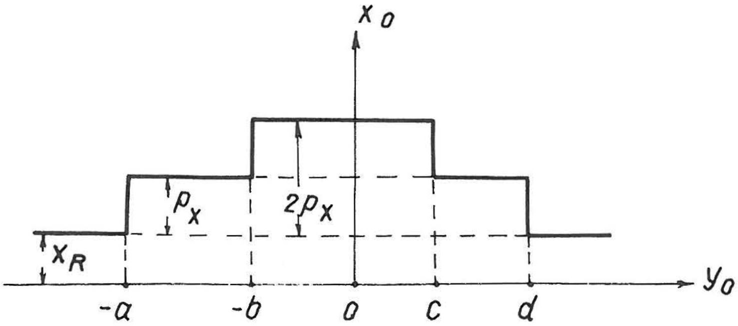

Figure 5

The point coordinates at the correlator output are given by:

$y_o = y$, with no transformation ;

$$x_o = \begin{cases} x_R & x_o < -a \\ x_R + p_x & ; -a < x_o < -b \\ x_R + 2p_x & ; -b < x_o < c \\ x_R + p_x & ; \quad c < x_o < d \\ x_R & ; \quad x_o > d \end{cases} \qquad (11)$$

where p_x is the longitudinal parallax due to the model step level differences.

For our tests, we designed and built a device for making holograms and holographic model plottings.

The optical scheme for the one-dimensional correlator is presented in Figure 6.

Generally, the main optical elements are included in the arrangement in Figure 1. In the profile making stage the processing is facilitated by use of a narrow beam for hologram scanning.

Scanning is made by a prism which, using a translation accompanied by a direction change, produces a displacement of the laser beam, making possible continuous reading of the image to be processed.

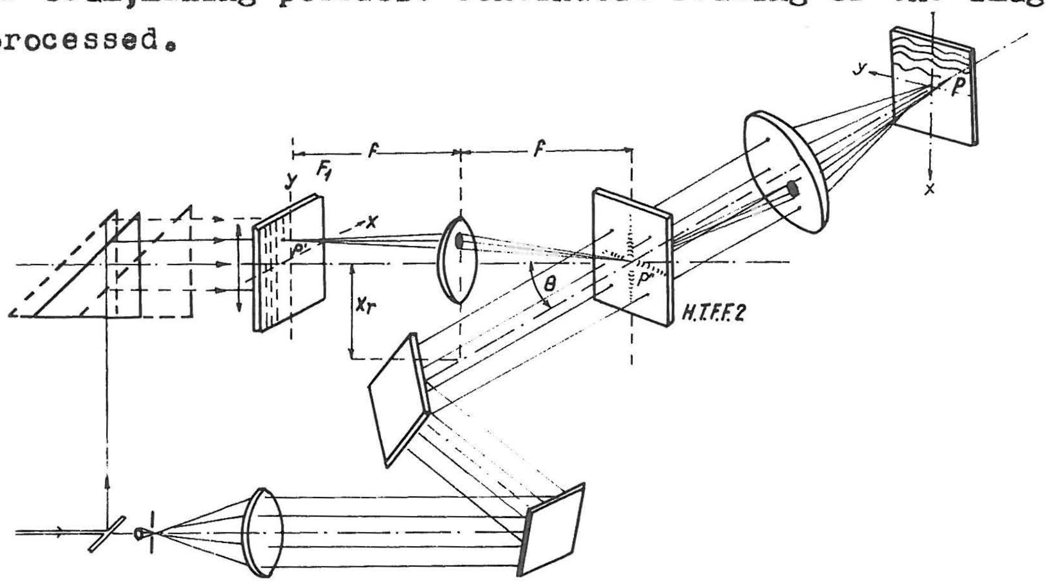

Figure 6. An optical arrangement able to make holograms and one-dimensional correlation.

After the photogram and the hologram have been aligned (Fig.7), the prism as the mobile part of the device makes the image scanning, in order to obtain profiles we need.

The holographic method used in making profiles was tested with aerial photographs. The obtained results were used for the photogram orthophotorectification at a 1:5000 scale and for making orthophotomaps at the same scale.

In order to evaluate the accuracy of the profiling holographic method, some profiles were determined by interpolation methods, using a Felix 256 computer and by direct levelling operations in the field. The maximum height errors were of ± 1.5 m, which satisfies orthophoto-rectification requirements.

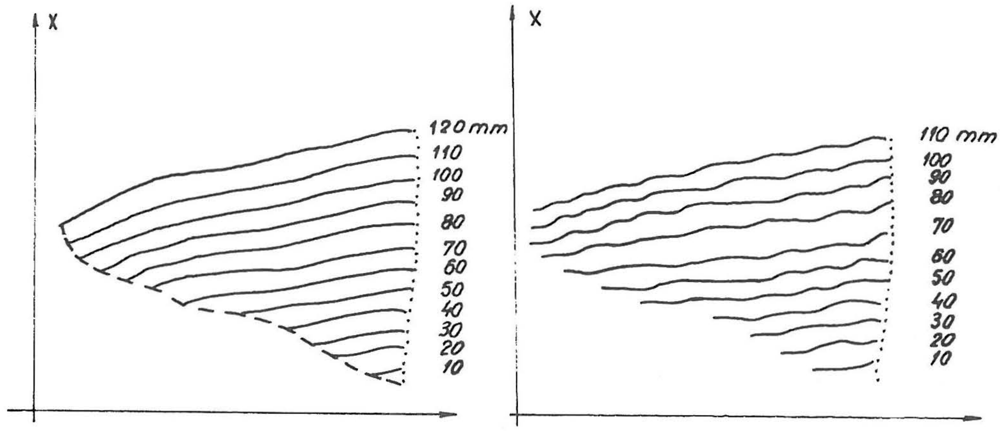

Figure 7. Profiles obtained by holographic model plotting.

Based on the problems we treated and the results we obtained, we can draw some conclusions:

- one-and two - dimensional optical correlation based on Fourier transforms holograms can be used in relative coordinate measurements and in terrain profile making necessary for orthophotorectification;
- photogrammetric stereomodel holograms made by photograms overlapping can be successfuly used in the ground surface mapping;
- use of the Fourier holograms of photogrammetric models, does not require highly precise determination of the hologram relative orientation elements;
- in the future, difficulties due to floating mark introduction into the holographic model could be eliminated using optical fibers.

If we hypothesize that the abovementioned difficulties will be overcome, in the future, we should consider the possibility to use holograms in topographic map compilations, to store data as holographic storage and to use holograms as a new data display method.

BIBLIOGRAPHY

[1] Cook, M. Invention: Télévision en relief. August 1965.

[2] Mikhail, E. Mensuration Aspects of Holograms. Photogrammetric Engineering, No. 3, 1971.

[3] Răducanu, N. Obtaining of Altitude Information Necessary to Orthophotorectifying, Using the Holograms of the Fourier Transforms of the Aerial Photographies. XII International Congress of Photogrammetry, Ottawa, 1972.

[4] Răducanu, N. Contribuţii la problema ortofotoredresării. Teză de doctorat, Bucureşti, 1975.