CLOSE-UP PHOTOGRAMMETRY WITH SIMPLE CAMERAS

P. O. Fagerholm, Royal Institute of Technology, Stockholm, Sweden

AN ESSENTIAL drawback for close-up photogrammetry is the need for special cameras. As the measuring problems vary within a very wide range for scale, photography distance and many other factors, it is almost impossible to design one or two types of cameras which will cover the entire field. Very often the measurement problem is existent for only one or a few occasions and for these it is not possible to build or buy expensive special cameras.

The main drawback when using ordinary cameras for close-up photogrammetry is the unknown and unstable inner orientation and the problem of flattening of the negative. Usually the distortion of the lens is not as rotation-symmetrical as an ordinary photogrammetric lens; this means that one cannot assume the same distortion along all diagonals.

The following includes a description of a test with simple cameras and a special technique for measuring the deformation of the stereo model. The work was accomplished and preliminary published in 1945.

The instrument was arranged for photography at a scale of 1:5 to 5:1. The cameras were (a) a 20 year old bellows-camera with negative size 9×12 cm. (about $3\frac{3}{4}\times5$ inches), and focal distance 13.5 cm. (about $5\frac{1}{2}$ inches) and (b) a Contax-camera with negative size 24×36 mm. and different lenses. The cameras were mounted vertically over a small light table. The stereobase was obtained through moving a plate with the object an appropriate distance. If the instrument set-up is now examined, it will be noticed:

1. The principal distances are unknown.
2. The principal distance as well as the principal point may change between the exposures as a consequence of the instability of the camera.
3. The distortion is unknown for the object distance in question.
4. The flatness of the negative is not satisfactory, especially if the negative is film, but also when ordinary plates are used.
5. Variations in the outer orientation of the camera, that is in position and direction of the optical camera axis due to small movements when changing negatives.

Several of these sources of error are such that they will not be compensated through a calibration made immediately before and/or after taking the photographs. If the object is placed on a flat surface with a calibration grid, the photography scale must be rather small so that the object shadows only a minor part of the entire field. To avoid this the following arrangements are made. A negative calibration grid is made photographically on glass (lines, figures and letters translucent on a completely black background). Extra lines and marks are made in the grid to avoid a false stereoscopic joining of lines when making the measurements.

On the light table a ruler is fastened securely so that the calibration grid plate can be slid along the ruler, and the base can be measured.

The position of the object and the length of the base are checked on a ground glass or with test exposures. The arrangements and procedure for the stereophotography are then—

1. Complete darkness in the room but light from the light table through the calibration grid, an edge of which is along the ruler and fixed.
2. Untouched camera. The object is carefully placed on the calibration grid in the position determined in advance. No light in the light-table; light only from above.
3. The exposed negative is replaced by an unexposed one. The calibration grid with the object thereon is carefully moved the base length along the ruler. Exposure with light only from above.
4. Untouched camera. The object is carefully taken away. Exposure only with the light-table light.

For checking and calibration purposes, a checking object with known heights is placed at the side of the object to be measured and photographed together with it (Figures 2 and 3).

If the two negatives (see Figure 1) are now observed, it is evident that the calibra-

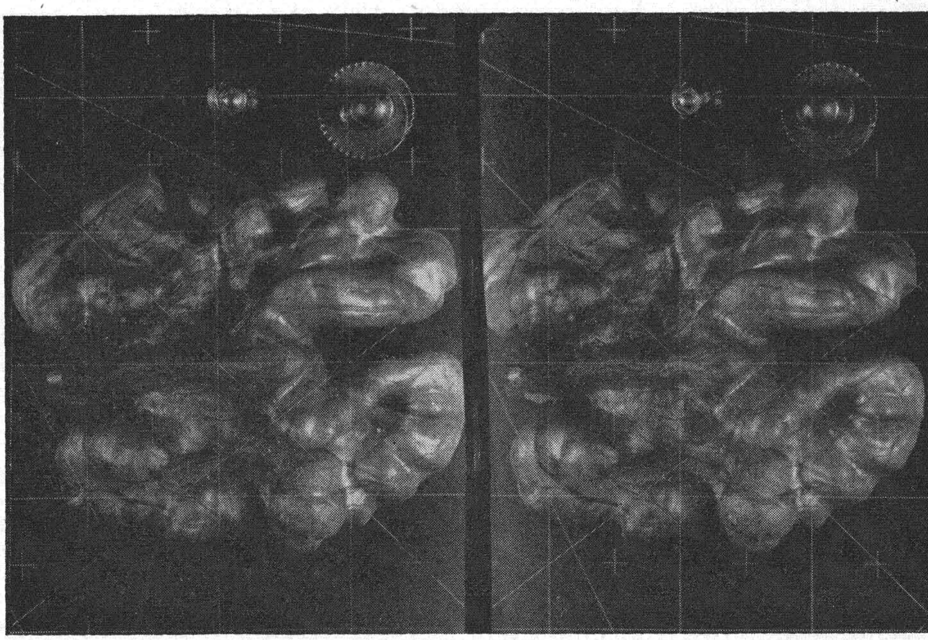

FIG. 1. Stereopair of a walnut and a translucent reference grid. The grid is also seen through the walnut.

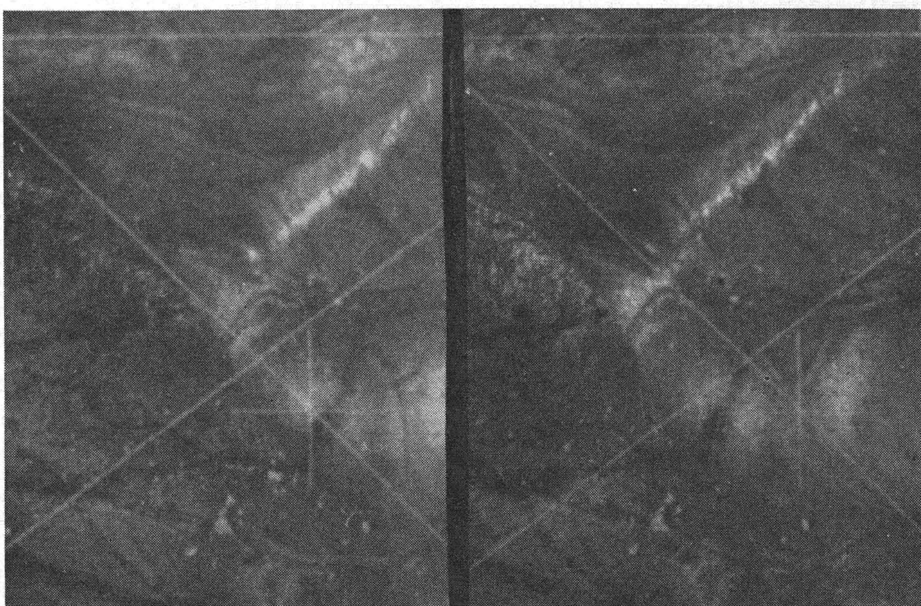

FIG. 2. Enlargement (6×) of a part of the stereopair in Fig. 1.

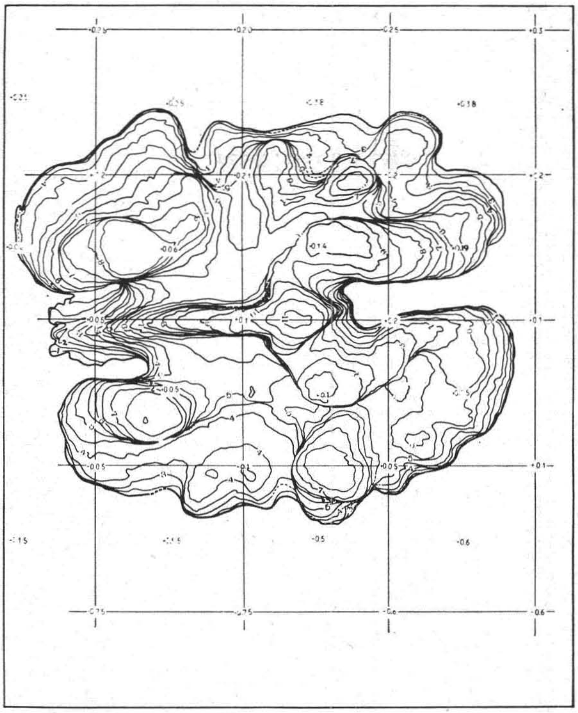

FIG. 3. A map in scale 12:1 (reduced to 2:1) with contour interval 0.5 mm. (1/50 inch) plotted in A 5 from photographs taken with an ordinary bellows-camera.

tion grid is seen through the object so that we have the reference level over the entire stereoscopic field. When viewed stereoscopically we can see the object surface *or* the grid plane or sometimes both of them simultaneously. Figure 2 shows a six times enlargement of a part of the stereomodel. The picture is 10:1. The stereopairs are mounted for ordinary lens stereoscopes.

As mentioned above the deformations of the stereomodel are easily determined through measuring the grid. At the same time the vertical scale dependent upon the principal distance, base and convergence, is checked with the distances from the vertical check-object. Horizontal planes in the object space, however, will not be parallel or parallel deformed surfaces in the stereoscopic model. Differences between the deformations of horizontal planes are quite naturally of a relatively small magnitude but must be checked when the highest accuracy is required. This was not done in the test herein described; there are several ways to do it. One possibility is to build a three-dimensional network with all the bearing parts painted in a UV-absorbing color, and only small spots with known height marked with a fluorescent paint. This space grid is placed on the grid plate between exposure 1 and 2 and between 3 and 4 and exposed only with UV-light. Such a space grid could also be a substitute for the grid plate in exposure 1 and 4.

For plotting the stereo model it is essential that there be known the principal distance, that is the distance from the inner center of perspective to the negative plane. This distance must be determined in some way, for instance through measuring the distance from the upper lens surface to the negative plane with a mechanical device and adding to this the optically determined distance from the lens surface to the inner pupil, which is varying very slowly with the focusing distance. If this latter distance is unknown an approximate principal distance is computed with the Newton formula in assuming an appropriate distance between the two pupils, roughly $\frac{2}{3}$ of the thickness of the lens. In plotting the stereo model in the plotting machine one has to use the vertical check-object to make corrections of the principal distance and the base inserted in the instrument.

With the arrangements above described there was made in 1945 some photography with a Contax at a scale of 2:1 and with the above mentioned bellows-camera at a scale of 1.8:1. Among other things the object was a walnut. In that case, a base of 28.4 mm. and an approximate principal distance of 384 mm. were used. The plotting was accomplished in the Autograph A 5 with an affine transformation of the vertical scale. The walnut was plotted at a scale of 12:1. The pointing accuracy in elevation was found to be 0.02 to 0.03 mm. in the object scale and it was possible to plot contour lines with 0.1 mm. contour interval. To avoid too many contour lines the plotting was performed with 0.5 mm. contour interval. Before the plotting the grid and the check object were measured. The measurement of the grid showed the stereoscopic deformation of the grid plate. The values are given in Figure 3 and vary between +0.38 mm. and −0.75 mm.

Summary

Through the double exposure of a negative translucent reference grid and the object, it is possible to check the height-deformations all over the model, as well as under the object. As a consequence very simple cameras can be used for taking the photographs.

PHOTOGRAMMETRIC APPLICATION IN DENTISTRY*

Percy Tham, D.Sc., Stockholm†

IN CONNECTION with certain investigations at the State Dental Institute, Stockholm, enquiries have been made about the possibilities of recording quantitatively the morphology of the jaws and the teeth by means of photogrammetric methods. The problem involved a "map plotting" of the jaws and the teeth, reproduced in gypsum casts, with a determination of the proportions in three dimensions. The measurements had to be made with an accuracy of about 0.1 mm.

A special complication was the connection of the "map plottings" of the two jaws; this must be performed very exactly in order to give the correct set of the jaws. From the mathematical viewpoint this implies that both measurements must be referred to the same system of co-ordinates.

Unfortunately, "close-up" photogram-

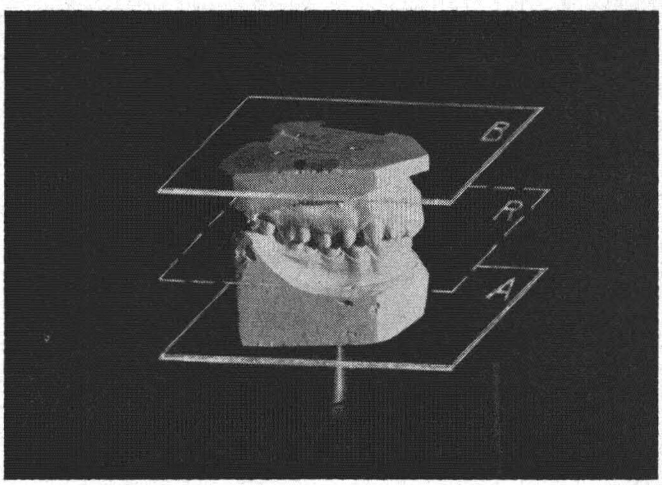

FIG. 1. The zero planes A and B of the two jaws and their reference plane *R*.

* Abstract from "Fotogrammetriska matmetoders tellampning inom odontologiem" Svensk Tandlakare-Tidskrift, Stockholm, 1946, No. 1. See also Strenger, F.: "Biting Force in Man" (dissertation), Stockholm, 1949.

† Doctor of Technology, Head of Division of Photogrammetry, Geophysical Survey Office of Sweden.