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Perspective Center Determination

The physical locations of the exterior and interior centers can be marked on the sides of the camera

(Abstract on next page)

FIG. 1. Terrestrial survey camera (Zeiss TMK) placed on a table for the location of the perspective centers. The camera can be translated with the screws *T1* and *T2* and rotated with the screw *R*. The table can be levelled with three foot-screws

INTRODUCTION

IN THE PRACTICAL use of photo-theodolites and stereocameras, in particular for close-up photography as well as for the calibration of such cameras, it is of great importance to know and to indicate the location of the exterior and also the interior perspective centers of the lens. From the exterior perspective center, for instance, the distances to control points should be measured. If the cameras are to be calibrated with the aid of plane test fields, the camera constant can easily be determined if the distance from the exterior perspective center to the test field can be measured with high quality. If, furthermore, the plane of the negative can be located parallel to the plane of the test field and the outer perspective center can be located on the perpendicular to the test field through the center of the field, the interior orientation can be completely determined from plane test fields only.

So far, manufacturers seldom if ever indicate marks on the outside of the cameras for the location of the perspective centers. Therefore some experiments have been made in order to locate and mark these points, in particular the exterior perspective center, in cameras to be used for measurements of various kinds. The procedures used are briefly summarized here. The center points of the entrance and exit pupils of the lens are regarded as the physical definitions of the actual centers, as is well known from optics.

TRANSLATIONS AND ROTATION OF THE CAMERA AND OBSERVATION THROUGH ONE THEODOLITE.

The camera is placed on a horizontal table which can be translated in two orthogonal directions with the screws *T1* and *T2* (Figure 1). The table can further be rotated around a vertical axis with the screw *R*.

If the shutter is open and the diaphragm is

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illuminated from the back side of the camera, the image of the diaphragm, seen from the front side, is the physical exterior perspective center through which all rays from the object must enter the camera. Therefore, if the lens is observed through a theodolite on the same level as the lens, the observer can point at the center of the image of the diaphragm (Figure 2). If the camera is rotated around the vertical axis, the image of the diaphragm will move if it does not coincide with the vertical axis of rotation. Through the use of the two translations the camera can be moved until the image of the diaphragm remains fixed on the cross of the theodolite. Due to the aberrations of the lens, some minor movements may occur which have to be averaged. After the best coincidence between the exterior perspective center and the vertical axis of rotation has been determined in the way indicated, the projection of the perspective center can be intersected on the top of the camera from at least three or more different rotations of the camera. Performed experiments have proved that this operation can be made with high quality as judged from the error figures that can be drawn graphically. Similarly the projection of the perspective center can be marked on the camera below and to both sides of the lens. It is advisable to determine the projections of the perspective center for different *f*-stops. Ordinarily there are small differences for evident reasons.

Similarly the interior perspective center can be treated and the projections of this point can be marked on the camera. It should be noted, however, that the distance from the interior perspective center of the lens to the negative plane does not necessarily agree with the camera constant (focal length). The latter is a factor for converting the image coordinates into angles which shall become congruent with the angles between the rays on the object side of the lens in the moment of exposure (see Reference 1). Systematic errors of the image coordinates (as, for instance, radial distortion, tangential distorition, affine deformations, asymmetries etc.) have to be taken into account at the calibration of the camera, as is well known from literature.

In the manner indicated above a great number of ordinary cameras, phototheodolites, etc., have been treated with good results. (Not only is the location of the exterior perspective center of great value) to facilitate the calibration procedure, but also for the practical performance of terrestrial photography for measuring purposes under different conditions (convergent, normal convergent cases etc.) the known position of the projections of the projection center is of importance. Manufacturers should always mark these points on the outside of the cameras.

ABSTRACT: *These techniques apply especially to phototheodolites and close-up photogrammetric cameras. Using a relatively simple procedure, the perspective centers can be located and marked on the outside of the camera, as manufacturers seldom indicate these points. The location of the exterior perspective center is particularly important because it is the point to which object distances should be measured and/or a plumb bob should be hung for positioning a camera over a station on the ground. The interior perspective center is of importance for completing the calibration of a camera.*

FIXED CAMERA AND THREE THEODOLITES

In those instances where the cameras are large and heavy, or if ordinary stereocameras with bases 40 cm. or more are to be treated, another method for the determination of the projections of the exterior and interior perspective centers on the cameras has been applied.

In front of the camera are placed three or more theodolites which can be directed to-

FIG. 2. The camera and the theodolite for the observation and intersection of the projections of the outer perspective center.

FIG. 3. The outer perspective center to be observed and projected on the outside of the camera with three or more theodolites. *F*-stop 1:70.

wards the lens and in which the image of the diaphragm can be observed. The camera axis should preferably be horizontal, and the theodolites placed on the same level as the center of the lens. With the theodolites the projection of the center of the diaphragm image can be intersected on the top of the camera and below the lens and marked.

In the Figures 3 through 6 some examples of the application of the method mentioned are shown. In Figure 3 the exterior perspective center is clearly seen for a small *f*-stop (1:70) and in Figure 4 for the *f*-stop 1:6.3. In the latter instance it is suitable to determine

FIG. 4. The image of the diaphragm for the *F*-stop 1:6.3.

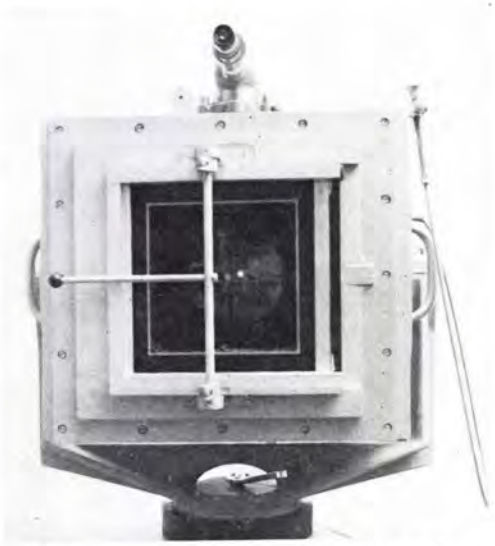

FIG. 5. The inner perspective center of the same camera as shown in Figures 3 and 4.

the center of the image of the diaphragm from bisections horizontally and vertically. In Figure 5 the interior perspective center is shown for a small *f*-stop. In Figure 6 the projections of the exterior and the interior perspective centers are shown on the top of the camera. Under the lens in the cover of the camera a hole is drilled indicating the projection of the exterior perspective center. The hole is threaded and a plumb string can be fastened for adjusting the camera above a signal on the ground. Finally the horizontal projections of the exterior perspective center are marked on the sides of the camera.

The camera is a rebuilt aerial camera $c = 75$ cm. to be used for deformation measure-

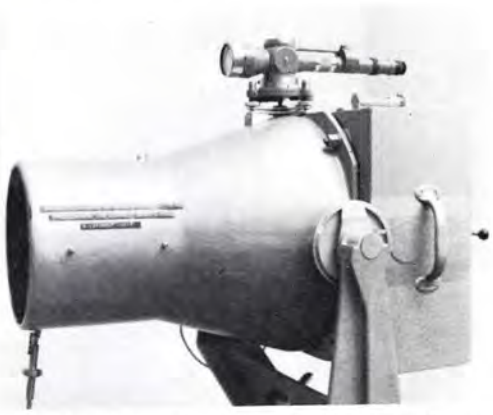

FIG. 6. The marks outside the camera indicating the projections of the perspective centers.

ments and as a phototheodolite. In this particular camera the distance from the interior perspective center to the negative plane is about 40 cm. only but the camera constant is about 75 cm. This clearly illustrates the meaning of the camera constant.

Summary

The simple methods described above for the location and marking of the perspective centers of cameras in general has proved to be very suitable for many evident purposes and can be recommended to manufacturers and to all users of cameras for measurement purposes. As indicated above, the calibration under operational conditions is greatly facilitated, and plane test fields, as described in Reference 2, can be used for complete calibrations. The problem of adjusting the negative plane parallel to the test field can evidently be solved with autocollimation, provided that the exterior perspective center and the collimator are located on the perpendicular to the test field through the center of the field. In this way every camera user should be able to perform a complete calibration of his camera equipment at a minimum of cost and work.

References

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