Air Survey

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IN England, where accurate maps are available for almost any purpose, we are apt to take their existence for granted and to forget the foresight, time and labour necessary for their preparation and constant revision. For engineering and administration there are the sheets at scales of 6 in. and 25 in. to one mile; the soldier, and in particular the gunner, prefers a map on a scale of about 2½ in. to one mile; walkers and cyclists, the 1 in. to the mile series; the motorist uses a ¼-in. map, of which series a special edition is produced for the airman; and finally the map of England at 10 miles to the in. is available for those who do their long-distance journeys by air. All these benefits are the result of the wisdom of those who initiated the Ordnance Survey of Great Britain.

The increasing importance of air communications in the British Empire, leads to a consideration of the type of map best suited to purposes of navigation and identification of places. A map on a scale of 1/1,000,000 (or about 16 miles to the inch) would satisfy the demands of the navigator, while for identification purposes a scale of 1/250,000 (or ¼ in. to the mile) is a suitable compromise with other normal requirements. A series of sheets on these two scales would adequately and reasonably fulfil all demands that are likely to be made, and should be the aim and object of any scheme of mapping for flying purposes.

Now, by far the greater part of the Empire is virtually unsurveyed, and the existing maps are rapidly becoming out of date. The methods exist whereby our vital survey needs can be met and on which an efficient organisation can be evolved. We shall examine below the broad basis of such a technique.

Photography as an Aid to Survey

Suppose that from some station commanding a good field of view a photograph is taken with the axis of the camera horizontal. Then from a knowledge of the calibration data of the camera we may construct on the photograph a graticule system depicting angles subtended at the perspective centre, in the same way that parallels of latitude and meridians of longitude on the surface of the earth depict angles subtended at its centre.

In this case azimuths will be represented by vertical straight lines, and elevations by hyperbolic curves convex to the horizontal. With a knowledge therefore, of the orientation of the camera axis at exposure, we have a pictorial record of angles in space to all objects in the field of view, such as might have been obtained by an observer with a theodolite. Suppose, now, that the exact position of the camera station is known and that another photograph is taken from a second known station covering much the same field of view from a different aspect. From the data provided by the two photographs the positions in space of all points in the common field of view can be determined by means of two-ray intersections. Various methods of applying this principle have been evolved, ranging from actual determination of angles, followed by computation, to completely automatic plotting.

The photography of an area from two different points of view opens up the possibility of stereoscopy. In ordinary life, by having two eyes separated by a short eye-base (about 2½ in.) we obtain two slightly different plane views of the same object space, from which our brains interpret a picture in the solid. This faculty is seldom consciously called into play, since there are usually other factors enabling us to estimate relative distances, but it is interesting to note that in the animal world it is possessed only by beasts of prey, the eyes of herbivorous animals being so situated that they view the world as a flat panorama. Where the base separating the two viewpoints is large, then by observing the two photographs in a stereoscope we may obtain the same view of the landscape as would be obtained by a giant possessing the large eye-base. The country is seen in relief as a small-scale plastic model. This property is made use of in automatic plotting machines.

The application of this method is restricted by the limitation of the field of view. Though of great value in hilly country, it is of little value in flat or gently undulating regions. The advent of flying offered freedom from this restriction, by virtue of the almost unlimited field of view available. Since then, the application of air photography to every variety of survey has been closely studied, and methods are now available to suit every kind of need.

When two overlapping photographs are taken from known ground stations and at measured orientations, it is a simple matter to place them in a plotting machine so that they are in the same angular relationship one with the other as they were at exposure. By using an occular system equivalent to placing the eyes in the two positions originally occupied by the lens, so that the left eye observes the left-hand photograph and *vice versa*, all angular relationships between the camera stations and the object space are preserved. The plastic model is, therefore, true in shape, but at a different scale. In the case of air photographs, however, the exact positions of the air stations are not known, neither are the orientations of the photographs. Some other procedure must, therefore, be devised.

Now it can be proved that if two photographs taken from air stations S_1 and S_2, and covering, in part, a common area of ground, can be adjusted so that any five pairs of corresponding points lie in the same basal planes, then all other pairs will lie similarly in their basal planes, and the photographs are correctly oriented. (Fourcade. "Transactions of Royal Society of South Africa." Vol. XIV. Part I (1926).)

Plotting Machines

A plotting machine is an instrument for reconstructing from a pair of overlapping photographs, a spacial model on which the detail and contours may be traced out and plotted on a drawing board automatically. In order to define the point in space observed, a floating mark is used; that is to say, a conventional mark whose apparent position in space may be altered by means of certain mechanisms connected with the drawing pencil. By adjusting the mark to lie coincident with the ground at any point, the position and height of that point are automatically recorded.

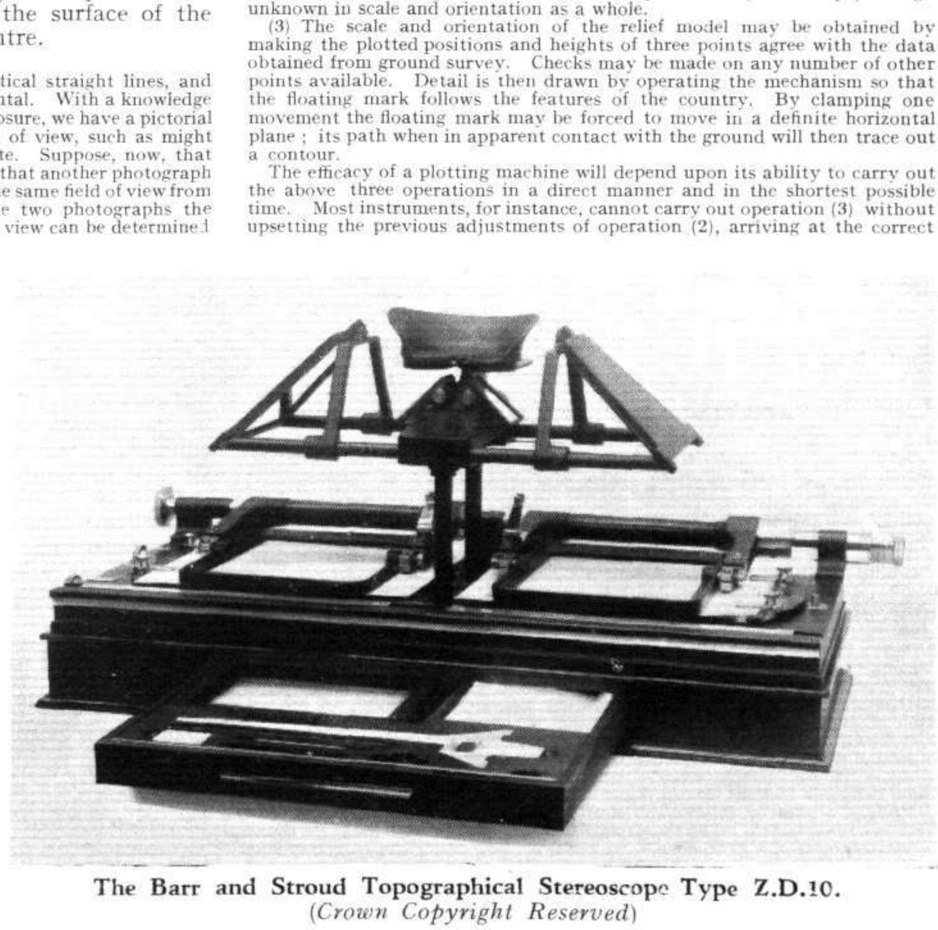
There are many types of plotting machine, differing widely in their optics and mechanisms, but the general principles of their operation remain the same and entail three stages:—(1) Internal orientation; (2) external orientation; (3) setting of scale and orientation of relief model.

(1) Every plotting machine consists essentially of two goniometers, which are dimensional replicas of the camera with which the photographs were taken, and are fitted with similar lenses. Internal orientation consists of the setting of the pair of photographs in their goniometers so that they occupy the same relationship to the rear nodal point of the lens as they did at exposure, and will depend upon the calibration of the particular camera used. Angular relationships between points on the plates and their perspective centres are now true.

(2) External orientation, or the relative orientation of the pair of goniometers one with the other, consists of the adjustment into their respective basal planes of five pairs of corresponding points. Want of correspondence can be observed by means of the floating mark, and eliminated by means of setting movements. Internal orientation is not changed, and the reconstruction of the steroscopic model is now complete as regards shape, though unknown in scale and orientation as a whole.

(3) The scale and orientation of the relief model may be obtained by making the plotted positions and heights of three points agree with the data obtained from ground survey. Checks may be made on any number of other points available. Detail is then drawn by operating the mechanism so that the floating mark follows the features of the country. By clamping one movement the floating mark may be forced to move in a definite horizontal plane; its path when in apparent contact with the ground will then trace out a contour.

The efficacy of a plotting machine will depend upon its ability to carry out the above three operations in a direct manner and in the shortest possible time. Most instruments, for instance, cannot carry out operation (3) without upsetting the previous adjustments of operation (2), arriving at the correct



The Barr and Stroud Topographical Stereoscope Type Z.D.10.
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