AIDS IN TEACHING PHOTOGRAMMETRY

H. T. U. Smith
University of Kansas, Lawrence

THE study of photogrammetry is partly a matter of solid geometry, and clear visualization of the space relations of aerial photos is essential. The attainment of that goal is greatly facilitated by the use of various mechanical devices and three-dimensional models which represent essential relations in idealized form. The purpose of this paper is to describe certain devices which have been found particularly helpful for teaching purposes in the aerial photographic laboratory of the University of Kansas.

Models to Show Effects of Parallax

The various effects of parallax in introducing distortion on both vertical and oblique photos may be demonstrated effectively with the following equipment:

(1) A regular cone on which contours are painted at definite vertical intervals (Fig. 1 A). The cone used by the writer is made of wood, is 4 inches high, and has sides sloping 35°. It was fashioned on a wood-turning lathe, and shallow grooves were cut for the contours. The completed cone was painted dull black, with the contours in white.

(2) A wooden hemisphere of the same height as the cone, and with contours shown in the same way.

(3) Small wooden posts made of dowel pins 3 inches high and 0.5 inch in diameter, and mounted on circular discs of clear celluloid about 2 inches in diameter. These also are painted black.

(4) A large sheet of drawing paper on which grid lines are ruled at right angles with spacing at any convenient interval.

By setting the above models at various places on the grid, and viewing from different points and angles, the effects of parallactic displacement in distorting straight lines, contours, and slopes is made clear. A particularly effective method of viewing is to use a camera of fairly large size having a ground glass back. The camera is best mounted on a tripod with a tilting head, and is used with the chutter open. The effect of changing the position and inclination of the camera may then be observed on the ground glass screen. Some of the effects which may be shown in this way are pictured in Fig. 1 B–F. *B* represents a vertical photo from a point directly above the apex of the cone. The symmetrical distortion of the spacing of the contours is imperceptible, but the displacement of the upright posts toward the corners of the photo is evident, and the radial character of the displacement is made clear. *C* represents a similar photo of the hemisphere. Here the symmetrical or concentric displacement of the contours is obvious, the two lower contours being cut off from view. In *D*, the eccentric distortion of the contours is shown, together with the distortion of lines crossing the two figures. *E* and *F* represent oblique views, *F* having the larger angle of tilt. Here the contours are seen to be distorted in form as well as being displaced in position, and the convergence of the upright posts illustrates the principle that distortion is radial from the plumb point.

A Model to Show the Geometry of an Oblique Photo

To illustrate the descriptive geometry of an oblique or tilted photo, the model shown in Fig. 2 is particularly helpful. Detailed plans for constructing

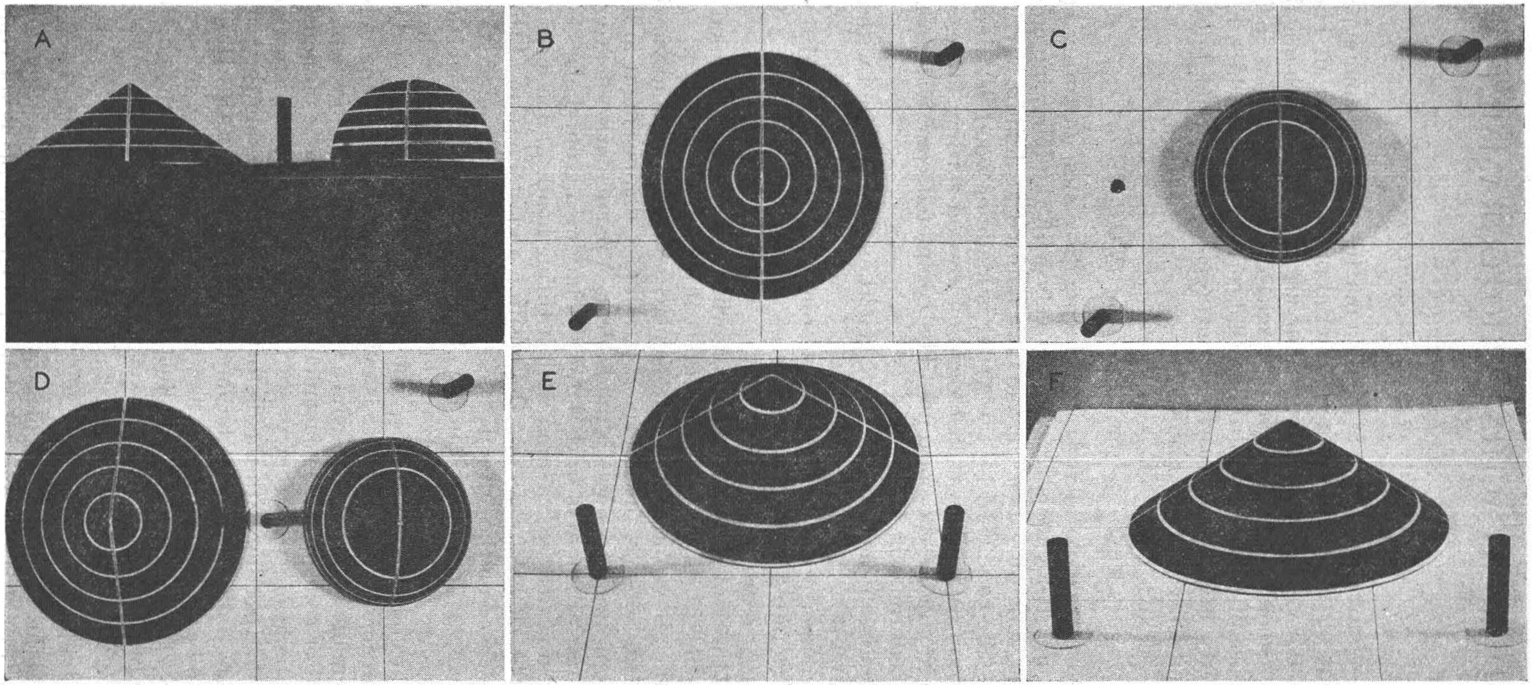

FIG. 1. Photos of models to illustrate parallactic displacement. *A* shows the models in profile; *B*, *C*, and *D* represent vertical photos, and *E* and *F* represent oblique photos.

such a model are given in Fig. 3. Clear celluloid of about 0.1 inch thickness is the material; acetate celluloid is preferred. Guide lines are drawn or cut with a scriber, and parts are then cut out with a jeweler's hand saw. The various grid lines and reference lines are similarly engraved with the scriber, and then are filled with india ink, using different colors to emphasize different sets of lines. The dimensions given in Fig. 3 are those for the original model shown in Fig. 2; for some purposes a much larger model might be desirable.

The horizontal plane is represented by *acef*, with *acml* showing the field of view of an oblique photo tilted 30°, and *jkef* indicating the field of view of a

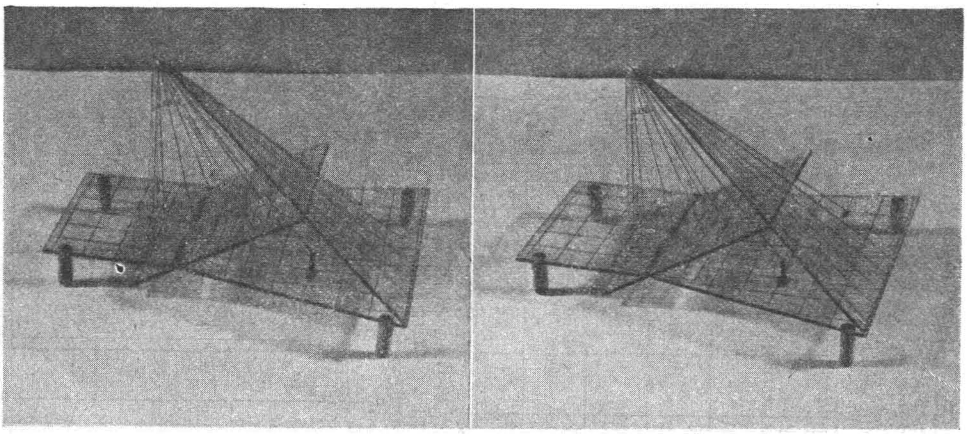

FIG. 2. Stereogram of celluloid model to illustrate the geometry of an oblique or tilted photo.

vertical photo taken from the same exposure station. A small hole is drilled at *x*, and a somewhat larger hole at *y*. At the latter point, a hollow upright post 0.45 inch high is affixed. The principal plane is represented by *pb'i'n*. The lines converging toward the perspective center at *p* have their origin along grid lines equally spaced in both directions from the isocenter, and lying in the horizontal plane parallel to the axis of tilt. The intersections of these rays with the plane of the oblique photo determine the locus of corresponding grid lines on that photo. The plane of the oblique photo is shown by *qrst*, with its perspective grid corresponding to the rectangular grid on the horizontal plane. *C* marks the center point or principal point, *I* the isocenter, and *V* the plumb point, which falls just beyond the border of the photo itself. The triangular piece *p'd'c'* shows how points for controlling the converging set of grid lines on *qrst* are determined by the intersections of rays from the grid lines on *abml* on the plane of *qrst*.

In assembling the model, *qrst* is first fitted to *acef* by engaging the slots *id* and *g'i''*. The next step consists in fitting *pb'i'n* to the two pieces already assembled, with the slot *i'o* engaging the slot *o'u*, and the triangular projection *i'nh'* fitting into the slot *ih*. All parts are now carefully aligned, and are then cemented in position, using a cement made by dissolving scraps of celluloid in acetone. Particular care is necessary at this step to check the alignment of the parts; when all is in good order, a line of sight from point *p* through any intersection of grid lines on the oblique plane should cut the corresponding intersection on the horizontal plane. When cementing is finished, a colored thread or string is passed from point *x* through point *x'* to *p*, and thence back through *y*,

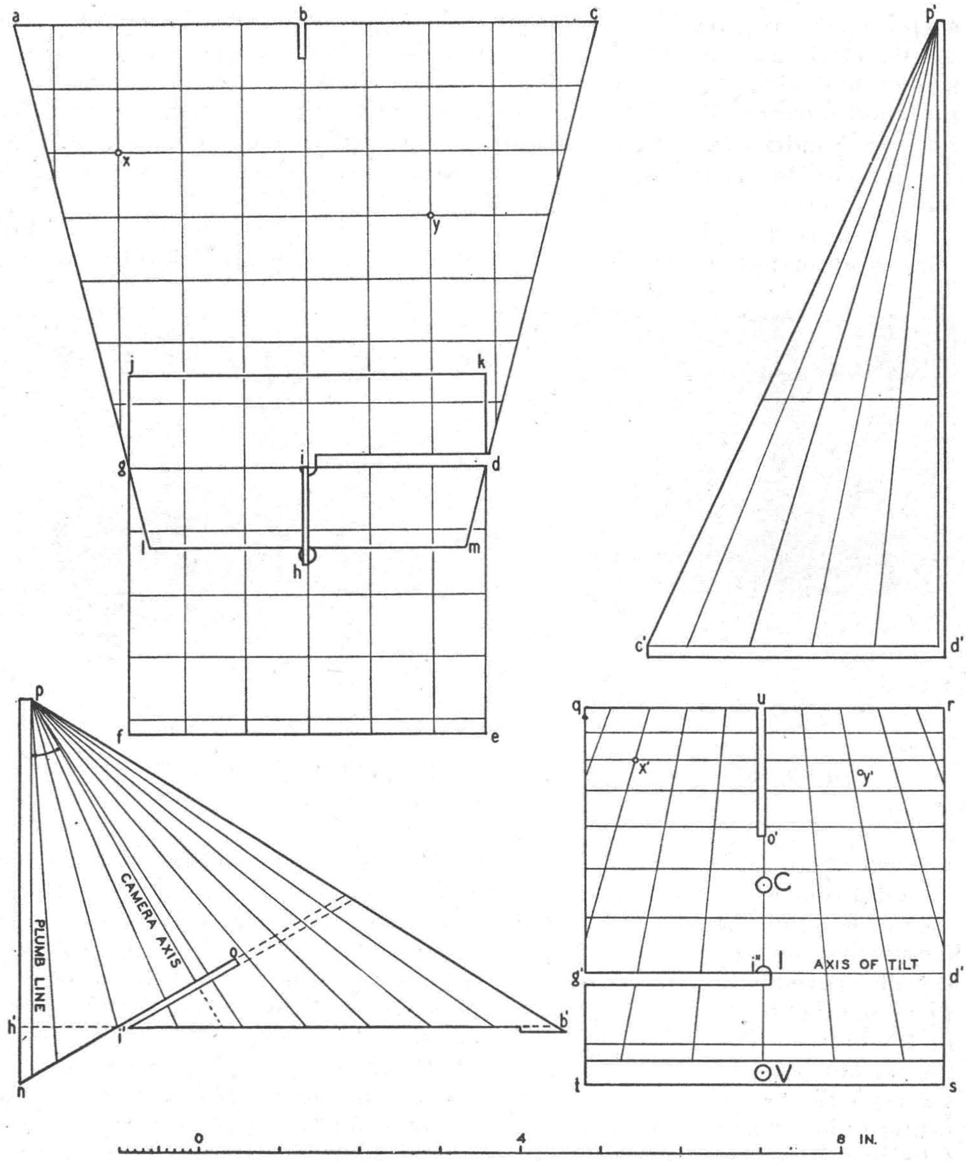

FIG. 3. Plans for the model shown in Fig. 2. Corresponding parts are indicated by the same letters.

to the top of the hollow post at y. The string from x to p illustrates the projection of a given point from the datum plane or from the plane of the vertical photo on to the plane of the oblique photo. The string from the post at y to p represents the projection of a point above the datum plane, and illustrates the combined effects of tilt and parallax.

The final step in constructing the model consists in fitting $p'd'c'$ to the part already assembled, and cementing it in position.

Parallax Grids to Aid in Contour Sketching

The parallax grids shown in Fig. 4 may be used both to illustrate the principles of stereoscopic parallax and as an aid in stereoscopic sketching of contours. This instrument is patterned after the Barr & Stroud topographical stereoscope, but is designed to be used under a separate stereoscope, which may be of either the reflection or the refraction type. The grid plates themselves are

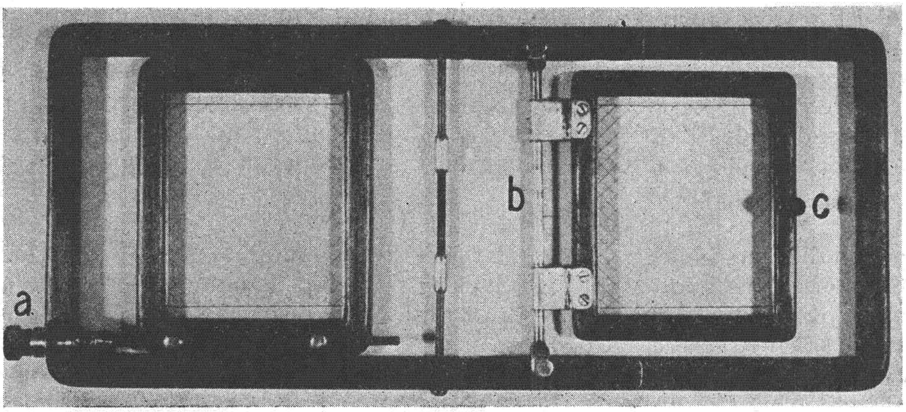

FIG. 4. Photograph of parallactic grids used for illustrating stereoscopic parallax and for contour sketching.

prepared by first drafting a set of diagonal grid lines on drawing paper, exercising particular care to space the lines evenly and make them of uniform weight; this drawing should be several times larger than the final grid plates, and the spacing of the grid lines should be such as to reduce to about 6 or 7 mm. This drawing is then photographed, and two identical positives are made on lantern slide plates (3.25×4 in.), or, if desired, on glass plates of larger size. The plates are then mounted, emulsion side down, in wooden frames, with the bottom of each plate flush with the bottom of its frame. The mounted plates are now mounted in a larger wooden frame, as shown in Fig. 4. The left-hand grid is arranged so as to be adjustable by means of the knob at *a*, which is attached to a threaded rod. The right hand grid is arranged so as to be rotated around the rod *b* as an axis. It may be brought into stereoscopic correspondence by sliding along this rod, and by loosening the screws at the ends of the rod, allowing the latter to move freely back and forth in grooves. When correct alignment is attained, the ends of the rod are clamped in position by means of the screws.

When the grids are correctly adjusted to a stereo pair of photos, the grid lines are seen in stereoscopic fusion, and provide a reference frame for ascertaining all topographic points having the same amount of stereoscopic parallax, or, if the photos are without tilt, the same elevation. By changing the setting of the grid with the knob at *a*, topographic points at a different level may be found, and, if adequate ground control is available, contour lines or form lines may be sketched directly on the right-hand photo by swinging up the grid plate on that side by the knob at *c*. An additional feature which would extend the usefullness of the instrument would be the use of a vernier scale on the left-hand grid plate, in order to measure parallax difference.