*Instrumentation for Stereotemplets**

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ABSTRACT: *Supplemental horizontal control has been of continuing interest to photogrammetric research personnel. Stereotemplet triangulation, only a few years old yet a standard mapping tool in the Geological Survey, probably needs a re-evaluation from the point-of-view of instrumentation. Research has been initiated to determine the most suitable templet materials and methods of preparing templets. One proposal is for a variable-ratio slot cutter and this is considered worthy of practical tests. The theory involved in stereotemplets and the requirements for reducing the scale, model-to-publication, seem to be conducive to the development of such an instrument.*

IN MANY photogrammetric mapping organizations, the problem of improving the reliability of supplemental control is of particular interest to research personnel. For those who are not in frequent contact with the term, supplemental control is defined simply as knowledge of the position, both vertical and horizontal, of points in each stereoscopic model, with sufficient accuracy and density that topographic mapping by photogrammetric methods may proceed. Photogrammetrists sometimes refer to such control points as "picture-point elevations" or "pass-points." This paper will be limited to a consideration of supplemental horizontal control.

THE BREAKTHROUGH OF STEREOTEMPLET TRIANGULATION

In the supplemental-horizontal-control field, one of the more recent innovations of practical importance is the stereotemplet triangulation technique suggested by Marvin B. Scher of the U. S. Geological Survey.[1] Since 1955, this system of obtaining horizontal-scale solutions for photogrammetric mapping has been implemented in every topographic mapping office of the Geological Survey from Washington, D. C. to Sacramento, California. Research projects and production experience have borne witness to the value of the technique as a mapping tool.

NEW TEMPLET MATERIAL AND STUDS

Modification of existing equipment designed for other techniques is often necessary to obtain the maximum benefits that may be derived from a new process. In a paper[2] given before this Society in 1957, Mr. Harold J. McMillen of the Atlantic Region of U.S.G.S. touched upon the desirability of eliminating some of the equipment and materials inherited from the radial-line slotted-templet days. The templet material, studs, slot cutters, and the procedures were to receive the attention due them.

Still undergoing operational tests are several templet materials that are believed better than the pattern boards used heretofore. Dimensionally stable white vinyl-acetate sheeting from 0.015 to 0.020-inch thick, with matte surfaces, promises to be quite suitable as templet material. It readily accepts holes and slots whose edges freely permit the automatic scale-adjustment feature to take place. Vinyl-acetate effectively resists indentation from the horizontal force exerted by the metal studs; and it is sufficiently rigid to function well in an assembly of templets. Moreover, the price of vinyl-acetate is reasonable.

Because of some objectionable features found in the older types of studs, the design of the studs for stereotemplets has been changed to take on a modern look, As shown

[1] Scher, M. B., "Stereotemplet Triangulation," PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, December 1955.

[2] McMillen, H. J., "An Operational Report on Stereotemplets," PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 4, September 1957.

* Presented at the 24th Annual Meeting of the American Society of Photogrammetry, Washington, D. C., March 26–29, 1958. Publication approved by the Director, U. S. Geological Survey.

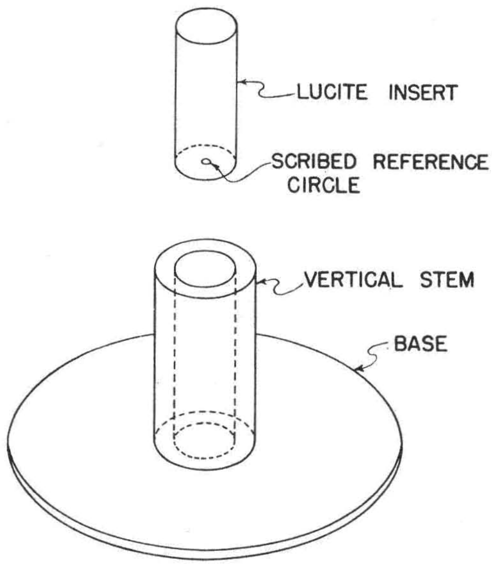

FIG. 1. Improved stereotemplet control and pass-point stud.

in Figure 1, the base of the new stud has been made larger in diameter to prevent tipping of the vertical stem. A thinner base is used to permit each templet to remain as nearly as possible in a horizontal plane, in the vicinity of the stud. The vertical stem has greater inside and outside diameters. More accurate machining is permitted by increasing the inside diameter; to maintain strong walls in the stem, it follows that a larger outside diameter is desirable. The result provides a reduction of eccentricity between the longitudinal axes of the inner and outer surfaces of the stem. The greater inside diameter also makes possible the use of a clear lucite insert bearing a circular mark as a viewing device, self-contained in each control-point stud. Thus, the position of the control stud with respect to plotted control may be observed even after an assembly of templets is complete.

In earlier experience with the less accurate radial templets, each control stud was pinned or nailed in place on the assembly board. Even if a nail were started at the correct position, there was no assurance that its final, driven position would be correct, nor was an observation check possible. The newly designed stud, without the insert, is used as a pass-point stud.

Let us consider the manner of preparing stereotemplets, including the stereoplotting of selected pass-points and the cutting of circular holes and slots. These parts of the process probably deserve at least as much study as has been given to materials and studs. Mapping offices that prepare stereotemplets with slot cutters originally designed and manufactured for conventional radial-line templet operations, are fortunate if these instruments serve their purpose. With the thought that some improvements can be made over past designs, a modification or new design of a slot cutter will be considered further on in this paper.

DEVELOPMENTS THAT PARALLELED STEREOTEMPLETS

At the time stereotemplets first came into use, other remarkable developments were taking place in the Geological Survey. ER-55 projectors were replacing the workhorse of photogrammetry, the multiplex. The use of pantographs in stereocompilation was approaching the 100% stage. Compilation scribing at the publication scale of maps was rendering obsolete the pens and inks and the large-scale manuscripts since referred to as "wallpaper." All of this took place with the objective of increased production for a given expenditure. The pantograph became the means for obtaining the necessary reduction from model-scale to the smaller compilation-scale, required for scribing.

Today in stereotemplet triangulation, pass-points selected in each model are reproduced by pantograph at the reduced scale on duplicate templets. When the matching templets, properly punched with holes and slots are assembled over control plotted on a scribing color-separate, the resulting scale of the assembly is that of map compilation, usually 1:24,000. In this way, the horizontal supplemental control or pass-points derived from the assembly may be transferred directly and easily to a working manuscript. Savings are realized through elimination of the need for a large model-scale control-base and subsequent reduction to compilation scale by copy-camera.

Thus, a scale-reducing instrument, the pantograph, which was designed and manufactured for a compilation task and which is suitable for that use, has been adapted to a control phase. True, both supplemental control and compilation are nominally required to be of fourth-order accuracy. But should not control techniques be more accurate than compilation techniques? Let us look carefully into the use of the pantograph in stereotemplet preparation. We should acknowledge that the pantograph has served us well in these last few years in which many developments have appeared on the scene; at the same time, we should seek better solutions to our scale problems by continued improvement of the techniques in use.

Here, let us consider one of the basic concepts of stereotemplet triangulation: it is primarily a system of triangulation. Its ability to extend control successfully depends on the accurate mechanical construction of a network of triangles. The horizontal accuracy of points established depends on a number of factors, of which we shall name a few: (1) accuracy of ground control, (2) accuracy of plotted control, (3) fidelity of horizontal positions in the stereoscopic model, and (4) accuracy of azimuths of the sides of triangles in the stereotemplet network. The first three factors may be considered static in the comparisons that will be made. The fourth factor is one of the major concerns of this paper.

THE CURRENT STEREOTEMPLET PROCESS

The basic information from which a stereotemplet is derived is in the form of image-points located in a stereoscopic model in correct planimetric position. Examples of such points are shown schematically at the top of Figure 2. The model is formed as a

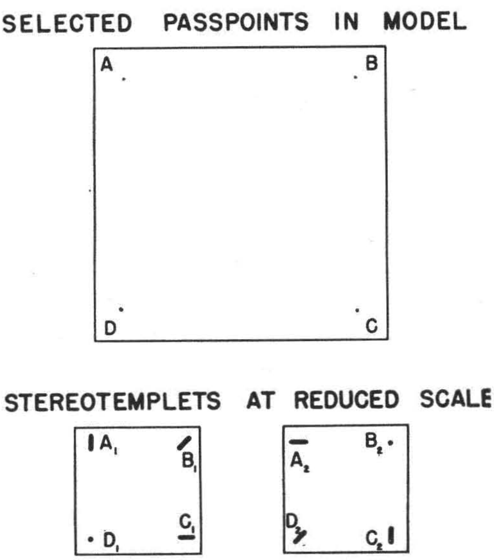

FIG. 2. Current stereotemplet technique.

result of careful interior and relative orientation and approximate absolute orientation of the corresponding perspective bundles of rays. Then, to illustrate the very general case, four well-defined image-points, A, B, C and D are selected as pass-points. In the current technique, the pass-points are plotted on duplicate templets by means of pantograph, at approximately the reduced compilation scale. Referring to the reduced-scale matching templets at the bottom of Figure 2, points D_1 and B_2 are chosen as radial centers for their respective templets and are punched with circular holes. All other pass-points on each templet of the pair are slotted radially from their respective radial centers. The matching templets, when superimposed and studded together, become part of a templet assembly and perform as two triangles, DAB and BCD, adjustable in scale as a pair, in the triangulation net.

Two obstacles are found along the path to a successful stereotemplet solution. First, if control bases are prepared at a smaller-than-model scale, added position-accuracy burdens are imposed on the personnel engaged in aerotriangulation and their equipment. Second, if a pantograph is used to duplicate azimuths of the radial lines which form the network of triangles, additional errors may creep in unnoticed.

For the sake of economy and over-all convenience in a mapping system, it is important to retain the smaller-than-model scale aspects of compilation procedures. Then, if a technique can be devised which more accurately preserves the directions of the very radial lines that are used as stereotemplet construction lines, the accuracy of the product must be improved. An answer seems to lie in a technique involving an instrument that may be called the "variable-ratio stereotemplet slot cutter." The technique and instrument are in the proposal stage only; however, we hope to commence the construction of an experimental model in the near future. For the present, we will have to rely on the schematic representation of Figure 3 for assistance in the description of the proposed clot cutter.

THE VARIABLE-RATIO STEREOTEMPLET SLOT CUTTER

Figure 3 represents, at the upper right, a table top with a built-in track (1) flush with the table top, about 48 inches long and rigidly straight within 1 or 2 thousandths of

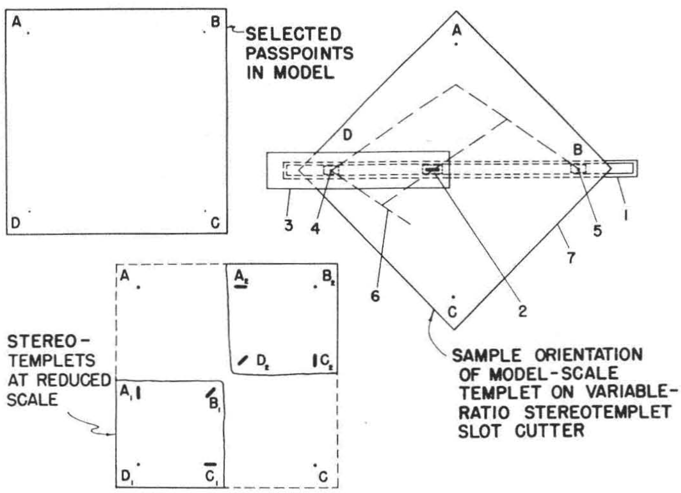

FIG. 3. Proposed stereotemplet technique and instrumentation.

an inch. A slot punch-and-die assembly represented by the slot (2) is at a fixed position about 12 inches from the left end of the track, the punch-assembly being cantilevered from the left side of the table by means of a sturdy casting (3). Each of the two stud carriages (4 and 5) move longitudinally along the track in a precisely straight line, and contain round studs projecting vertically above the table top about a quarter of an inch. A straight line connecting the centers of studs (4 and 5) should bisect the slot (2) produced by this instrument. The movement of the studs is controlled by means of an inexpensive variable-ratio pantograph (6) which need not be a precision instrument. The arm-connection normally called the king-post is attached to the stud (4) and the tracing-point is attached to the other stud (5). By means of a bracket and a vertical pin (not shown), the "drawing point" of the pantograph is pin-connected to the bracket so that the pantograph arm can rotate about a vertical axis through the center of the punch-and-die assembly at (2). Thus, whatever reduction ratio is set in the pantograph, the same ratio exists between the distances from the left stud to the right stud, and the left stud to the center of the slot, regardless of the over-all distance between the studs. Obviously, other features relating to dimensions, convenience of use and other details must be considered in the final design of such an instrument. The technique of making stereotemplets with such a slot cutter as described below should further clarify the reasons for its proposal.

THE PROPOSED TECHNIQUE

Again referring to Figure 3, the upper left diagram represents a stereoscopic model with four pass-points selected, as in Figure 2. The pass-points *A*, *B*, *C*, and *D* are carefully stereoplotted on a model-size templet, and circular holes, as shown in the lower left diagram, are punched for these four points. The templet is removed from the plotting table and placed on the slot-cutter table with hole *D* placed over stud (4) and hole *B* over stud (5). In the example shown, the pantograph is set for about 2.5:1 reduction ratio.

With the templet lying flat on the table top in the sample orientation shown by the edge (7), a slot B_1 is cut. By leaving *D* in place at (4), holes *A* and *C* may in turn be placed over stud (5) and slots A_1 and C_1, respectively, may be cut. To cut slots A_2, D_2 and C_2, hole *B* is placed at (4), and the slots are cut with three successive orientations of the templet material as previously described. The lower-left and upper-right portions of the model-size templet are the reduced-scale matching templets desired. They are easily separated from the large templet by cutting along the irregular lines shown.

ADVANTAGES

The advantages claimed for the proposed technique and instrumentation are the following:

1. The instrument would be especially designed for stereotemplets with greater over-all accuracy engineered into it.
2. Pass-points would be plotted by direct orthographic projection from the model to the templet material, eliminating a scale change at this point in the procedure and the use of a compilation-type pantograph with the horizontal errors it may have.
3. Orientation of the templet material on the slot cutter is automatic after the four (or more) pass-points are punched with circular holes. There is no need for aligning a needle in the slot-punch with a needle-hole on the templet to orient the templet. The personal error involved in this operation when existing slot cutters are used would be eliminated completely.
4. The azimuth of each radial line is established by two points plotted at model scale, rather than at a reduced scale. The potential azimuth error decreases with an increase in the distance between points used to establish the azimuth.
5. The track of the slot cutter would be sturdier than a compilation-type pantograph and therefore not as susceptible to damage as the pantograph. The purpose of the pantograph in the proposed slot cutter is to provide a ratio of radial distances; it performs no azimuth-reproduction function whatsoever. The ratio of radial distances need not be precise because of the latitude given by the length of the slots.
6. An accuracy check for a slot cutter of the proposed type should be easier to perform than for a compilation-type pantograph.

DISADVANTAGES

It is only fair to mention disadvantages too. One might wonder, for example, what use is proposed for the material in the model-scale templet that contains points *A* and *C* (lower left, Figure 3). It may be more efficient to discard it than to attempt to use it for two more matching templets for another model. With a bit of planning and luck, however, just such use might be made by plotting the selected pass-points for a new model on the same large templet in such a way that the two hitherto unused portions may also produce usable stereotemplets.

If the reduction ratio from model scale to templet scale were less than 2:1, the technique could not be applied without some modification of the proposal because the two parts of the stereotemplet would overlap. However, in practice, this ratio usually is greater than 2:1.

It is also reasonable to expect "bugs" to appear during the initial operational tests of such a proposal.

CONCLUSION

Stereotemplet triangulation has been accepted as one of the standard operations in our mapping program. It is hoped that the proposals in this paper will facilitate stereotemplet triangulation wherever it is used.