TRANSFER OF ABSOLUTE ORIENTATION FROM ONE TYPE OF STEREOSCOPIC PLOTTING INSTRUMENT TO ANOTHER

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Abstract

A method is presented for transferring the absolute orientation of a stereoscopic model from one instrument to another. A step by step procedure for application of the method for transferring the orientation from the Stereoplanigraph to the Kelsh Plotter is given with an example. Tests show that absolute orientation can be transferred from the Stereoplanigraph to Kelsh Plotter in 45 to 50 minutes with this method.

Publications Committee

At present, the Division of Photogrammetry in the U. S. Coast and Geodetic Survey has single-lens photogrammetric plotting equipment consisting of one Stereoplanigraph (manufactured in 1937), three Multiplex bars, and four Kelsh Plotters.

In the past few years it has been found that because of the close tolerance required, an excessive amount of time was used to obtain absolute orientation with the Kelsh Plotters. The time required for absolute orientation with the Multiplex was very much shorter by comparison. Experience further showed that the Stereoplanigraph far surpassed both of these instruments in the speed with which models could be oriented.

Consequently, a study was made in an attempt to devise a method whereby the time required for setting up models on the Kelsh Plotters could be materially shortened. As most of the models are bridged first on an aero-triangulating instrument such as the Stereoplanigraph before being set up in the Kelsh Plotters, the study was limited to transferring the absolute orientation already obtained on the Stereoplanigraph directly to the Kelsh Plotters without going through the usual steps of relative orientation, scaling, and leveling. This discussion concerns only the Stereoplanigraph-Kelsh arrangement but the technique is applicable to other types of stereoscopic instruments.

Six motions (*BX*, *BY*, *BZ*, Tip, Tilt, and Swing) must be adjusted to obtain absolute orientation. The method suggested here accomplishes this by use of a Right-Angle Level Bubble (two vernier level bubbles mounted perpendicularly to each other on a base—see Figure 1 and the vernier readings for the various settings on the Stereoplanigraph.

The following example will help to illustrate the procedure. The model used is one set up as part of a horizontal extension in the area of Barnstable Harbor, Massachusetts. The photography was taken with a six-inch metrogon lens camera at an altitude of 5,000 feet above sea level. The manuscript scale was 1:10,000 and the Stereoplanigraph instrument scale was 1:6,000.

After each model had been bridged in the Stereoplanigraph, the vernier readings indicating the settings of the various motions were recorded. For model 675–676 the vernier readings as recorded were:

Plate	*BX*	*BY*	*BZ*	Tip (Y-tilt)	Tilt (X-tilt)	Common X-tilt	Z_0
675	103.58	39.52	20.32	399.69	400.83		
676	262.46	34.88	20.84	400.44	401.32	400.06	548

The linear measurements are in millimeters and the tip and tilt values are in grads.

Following this, the Right-Angle Level Bubble was placed on top of the plates in the corner containing the photograph number, with the sides of the Bubble base lined up parallel to the sides of the glass diapositive. The tip and tilt as measured on the verniers on the Bubble were:

Plate	Along Line of Flight	Perpendicular to Line of Flight
675	0.42	−99.42
676	−99.79	−98.80

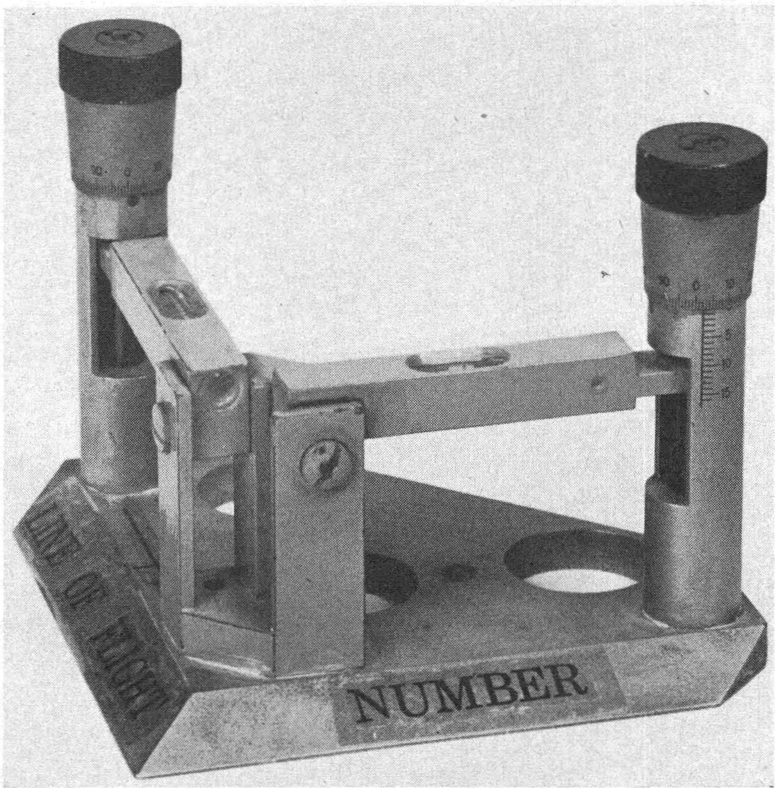

FIG. 1. Right-Angle Level Bubble.

The two plates were then removed from the Stereoplanigraph and mounted in the Kelsh Plotter at an instrument scale of 1:2,000 using a five time reduction on a pantograph to reduce it to the manuscript scale of 1:10,000. The projectors and bar were approximately leveled by eye before proceeding.

Z_o—The first step taken was to set the bar of the Kelsh Plotter at the correct height above the table so that the stereoscopic model would remain within the working range of the tracing table. This, of course, becomes more important in mountainous areas such as Alaska where elevation changes of 2,000 to 3,000 feet in a single model are not uncommon.

The Z_o vernier reading on the Stereoplanigraph is the height in millimeters of the six-inch metrogon lenses above the mirrors containing the floating mark. When the lenses are at the same elevation as the mirrors, the Z_o vernier reads 300 mm. and hence 300 must be subtracted from all the vernier readings on the Z_o column. To get the correct Z_o reading for a particular model, the floating mark is set on a point approximately in the middle of the vertical range of the model and the Z_o reading recorded. For model 675–676 the Z_o reading was 248 mm. (after subtracting 300 mm.). This figure was converted into a suitable value for use on the Kelsh Plotter by the following computation:

$$\frac{268(6,000)}{2,000} = 744 \text{ mm.}$$

where 1:6,000 is the Stereoplanigraph instrument scale and 1:2,000 is the instrument scale of the Kelsh Plotter.

In the Kelsh Plotter, the platen was set at the middle of the vertical range of the tracing table and the bar raised or lowered until the hypogon lenses were approximately 744 mm. above it.

BX—Subtraction of the two *BX* vernier readings on the Stereoplanigraph gives the air-base value at the instrument scale of the Stereoplanigraph. The air-base value for model 675–676 was mathematically converted for use on the Kelsh Plotter:

$$262.46 - 103.58 = 158.88 \text{ mm.}$$

$$\frac{158.88(6,000)}{2,000} = 476.64 \text{ mm.}$$

The two projectors in the Kelsh Plotter were moved until the distance separating the centers of the hypogon lenses was 476.64 mm.

BY—There is no *BY* motion of consequence on the Kelsh Plotters. Because the flight line of the photography is always parallel to the *X* axis of the Kelsh Plotter, the need for this motion in relative orientation is eliminated. The model 675–676 was cleared along the line of flight by swing-swing of the projectors as usual.

BZ—Elevations (two will usually suffice) were read on model 675–676 in the Stereoplanigraph at points approximately along the line of flight near the photo centers. These elevations were recovered stereoscopically on the model in the Kelsh Plotter, by means of the leveling screws. It is here that care must be taken to prevent an inversion of results. On the Kelsh Plotter used in this instance, the projector illuminated by the red beam was on the side of the bar containing the one leveling screw. The tracing table was indexed on the elevation under the blue projector. On reading the elevation at the point under the red projector, the model was found to read 5 feet lower than the correct elevation as determined by the Stereoplanigraph. It would appear, therefore, that the one leveling screw should be turned so as to raise that side of the model and thus also raise the red projector more, relative to the blue projector. However, on quickly checking around the model it was found that the images from the red projector were too "large" relative to the blue images, and that therefore the red projector should be lowered. Accordingly, the red projector was lowered until the elevation on that side, instead of being 5 feet low, was 10 feet low. In other words, the *error was doubled.*

Tip and Tilt—The tip and tilt values as determined in the Stereoplanigraph were recovered for the plates in the Kelsh Plotter with the Right-Angle Bubble, by use of the proper tip and tilt motions. As before, the Right-Angle Level Bubble was set on the plates in the Kelsh Plotter in the corner containing the photograph number with the sides of the Bubble base placed parallel to the sides of the glass diapositive. It should perhaps be noted that the tip and tilt vernier readings on the Stereoplanigraph cannot be recovered readily in the Kelsh Plotter. This is due to the fact that the tip and tilt angles on the Stereoplanigraph are measured parallel and perpendicular to the *X* axis of the instrument without regard for the swing present in the plates. In many instances it has been found preferable to recover the Tip and Tilt first, before clearing the *BZ*.

After this step the *Y* parallax was removed from along the line of flight by swing-swing, and the elevations for recovering the *BZ* were re-read. The elevation error was doubled as previously explained, and the tip and tilt angles reset once again with the Right-Angle Bubble. It was found that the swing-swing needed to clear parallax along the line of flight was almost negligible. Likewise the elevations for recovering the *BZ* checked out very close to the values established with the Stereoplanigraph. On examining the model for *Y* parallax, only a trace could be noted.

After the tip and tilt angles have been entered twice, the amount of *Y* parallax remaining is usually less than a dot. Occasionally, it has been necessary to use the Right-Angle Bubble three times. Often some of the corners of the model exhibit no parallax whatsoever, while the remaining corners show a ½ dot. At times the models have been entirely cleared of parallax. It has been found further that the models are level within 0.50 mm. on the tracing table of the elevations established throughout the model by the Stereoplanigraph.

From this point, it should be possible to refine the model within 20 minutes or less for detailing and contouring. For the Barnstable Harbor, Massachusetts, project this meant completely removing *Y* parallax, leveling within one foot of field determined elevations (0.15 mm. on the tracing table) and scaling to within 0.25 mm. of horizontal control.

A test run of the procedure was made on this project. To completely remove *Y* parallax, level and scale within requirements the time required was:

Model 692–693	Time 40 minutes
Model 695–696	Time 50 minutes
Model 696–697	Time 50 minutes
Model 697–698	Time 45 minutes
Model 674–675	Time 45 minutes

Model 675–676	Time 45 minutes
Model 676–677	Time 45 minutes
Model 677–678	Time 50 minutes

The average time thus required was between 45 and 50 minutes. It should be noted that the tips and tilts in these pictures were in the neighborhood of 2 to 3 degrees. Furthermore, crab was present to a large extent.

During a bridging operation on the Stereoplanigraph, the models in a long bridge generally "drop off" giving rise to what is known as a *BZ* curve. After the elevations read during this vertical extension are corrected by the *BZ* curve, the corrected elevations along the line of flight can be used in the Kelsh Plotter for the *BZ* solution.

This method of transferring absolute orientation will make possible the setting up of models in the Kelsh Plotters that could not heretofore be cleared due to extensive water areas. They can now be set up in the Stereoplanigraph and quickly transferred to the Kelsh Plotters.

The method is comparatively simple and straight-forward and is not demanding of any particular great skill or dexterity to be fully utilized. It seems, therefore, that no difficulty should be experienced in training operators to follow this procedure.

PHOTOGRAMMETRIC ENGINEERING WITH A WILD PHOTOTHEODOLITE

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Abstract

In using a Wild Phototheodolite for mapping construction sites of a Hydro-Electric Scheme in the Australian Alps, it was found that the amount of field and office time will be reduced through using several tabulations. Time is always scarce when working on construction schemes. So the tables in the paper may be helpful. A new method for increasing the plotting range of the Wild A5 for terrestrial photogrammetry is also given.

TERRESTRIAL photogrammetry will make possible preparing large-scale maps of high accuracy in mountainous areas at comparatively low cost. Therefore this oldest branch of photogrammetry is still alive. As at the Boulder Dam in USA and at most of the hydro-electric schemes in the European Alps, the Snowy Mountains Hydro-Electric Authority uses terrestrial photogrammetry for large-scale mapping of various construction sites in the Australian Alps. The equipment consists of a Wild phototheodolite (plate size 10×15 cm.), 24 plateholders in two boxes, three tripods, a 2-meter subtense bar, a Wild Rangefinder (from 110 ft.–1,600 ft.) and an Abney Level. (A second phototheodolite has just arrived.) A Wild Autograph is used in the plotting.

Among the objects photographed are dam and shaft sites; excavations for dams and power stations and road; and construction camp sites. The phototheodolite is especially helfpul in checking and recording the progress in excavation and construction. This work during photographing is not interrupted or only briefly. The entire survey is completed in one or two days, thus giving an exactly timed record. The scale of the stereogram (Autograph plot) ranges from 1:120 to 1:2,400, with contour intervals of from 1 foot to 10 feet. At this scale the engineer will get all details for investigation and construction.

For this large-scale survey of important construction sites no gaps should occur. Accordingly the length of the base and the various swings and tilts must be determined exactly. The distances N and F to the nearest and farthest point of the area to be photographed are measured with the Wild rangefinder. The base length is then found according to the well known formula

$$\frac{F}{15} < b < \frac{N}{4}.$$

In planning for and in the construction of important construction projects, it is