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Compilation Base Orientation by Graticule

Analytical plotter stereo models may be oriented directly to compilation base grid intersections rather than to plotted ground control.

Abstract: *Compilation base to stereomodel orientation classically requires locating control points with respect to a graticule and stereoplotter operator judgment in aligning the compilation base with the stereomodels. Methods may be developed for analytical plotters such that a compilation base may be oriented to a stereomodel by model coordinates of graticule intersections. Such methods eliminate the requirement and expense of plotted control and reduce human error in compilation base orientation and other facets of compilation.*

Introduction

Compilation base to stereomodel orientation classically requires plotting control points with respect to a graticule or grid. Such plotting may be accomplished simultaneously with plotting of the graticule or grid, or the control may be plotted manually on reproductions of master graticules or grids. Subsequently, plotter operator interpretation is required to orient the compilation base control plot to the stereomodel. If the control plot does not fit perfectly, the operator must attempt to mentally perceive and physically apply a least squares solution to the problem.

With analytical stereoplotters, such as the Bendix AS-11 series, this problem area may be avoided by developing stereomodel coordinates of graticule intersections. The compilation base, without control plot, may then be oriented to the stereomodel by model coordinates. The application of this process eliminates the requirement for and expense of plotted control, tests the calibration of the plotter coordinatograph each time the compilation base is oriented, reduces human error in compilation base orientation and in model absolute orientation, and compensates composite model error.

The development of this orientation system is contingent on the method used to develop compilation control. These are typically:

- Control which is derived by independent model triangulation with the compilation photographs,
- Control from sources other than the compilation photographs, and
- Control which is derived by analytical triangulation with the compilation photographs.

Application with Independent Model Triangulation

First, consider application when compilation control is derived by independent model triangulation with the compilation photographs. To support independent model triangulation, each model is initially established by interior and relative orientation. A preliminary absolute orientation may be accomplished to scale and approximately level the model. This setup should be translated to maintain horizontal model coordinates centered with respect to the neat model. The

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parameters defining this initial model setup are recorded for future reference. Model-to-model pass point positions, strip-to-strip tie point positions, and ground control point positions are observed in model coordinates X_m, Y_m, and E_m: An arbitrary model origin is defined as XMBAR = Ø, YMBAR = Ø, and EMBAR = mean observed E_m. Model sets of initial observations, including the arbitrarily defined model origin, and other constraints are processed through an independent model triangulation/adjustment scheme. A ground position for each observed point and for the arbitrary model origin is derived.

Then, on an individual model basis, data must be processed with respect to a map projection system. First the array of map graticule intersections that are in the model proximity are identified. These are the positions for which absolute model coordinates will subsequently be developed. These graticule intersection positions and triangulation derived point and arbitrary model origin positions are transformed to scaled Cartesian coordinates of the desired map projection, such as Lambert or Mercator, by conventional projection mathematics. Scale, for this process, is determined by map drawing scale, plotter-coordinatograph ratio limitations, and other plotter considerations.

Then, the absolute coordinate system for each model must be developed. This coordinate system is absolute in the conventional vertical sense. Horizontally, the absolute coordinate system is the projection scaled Cartesian coordinate system, translated and rotated horizontally such that it horizontally approximates the initial model coordinate system. If the initial model was set up reasonably centered with respect to instrument limits, this definition of the absolute coordinate system should not present a problem. The horizontal translation from the scaled Cartesian system to the absolute system can be computed from the arbitrary model origin coordinates expressed in the scaled Cartesian and initial model coordinate systems. The horizontal rotation from the scaled Cartesian system to the absolute system can be computed from the horizontal direction bias between scaled Cartesian and initial model coordinate systems, where horizontal direction is defined as horizontal direction from the respective arbitrary model origin coordinates expressed in the scaled Cartesian and initial model coordinate systems. The horizontal rotation from the scaled Cartesian system to the absolute system can be computed from the horizontal direction bias between scaled Cartesian and initial model coordinate systems, where horizontal direction is defined as horizontal direction from the respective arbitrary model origin. This translation and rotation are then applied to derive absolute coordinates X_g and Y_g (E_g is undefined) of the models' graticule intersections and absolute coordinates X_g, Y_g, and E_g for the points observed in the initial model.

Each initial model can then be absolutely oriented by means of Schut's Transformation[1]. The arbitrary model origin XMBAR, YMBAR, EMBAR is substituted for Schut's common perspective center of both the control and data systems. Absolute coordinates X_g, X_g, and E_g of points initially observed are used as control and initial model coordinates X_m, Y_m, and E_m are used as data. Application of the parameters of this transformation to the previously recorded initial model setup parameters will establish the absolute orientation model setup parameters. This transformation should also be applied to the initial model observations.

The absolutely oriented model will contain the same deformation characteristic, if any, of the initial model. Such deformation may be caused by interior and/or relative orientation errors of the initial model setup. Interior error in this context includes photo carriage calibration error. Also, the triangulation/adjustment scheme may have altered shape with respect to initial model shape, particularly along tie edges, and if compilation is small scale, a graticule error may be encountered. Therefore, a Model Deformation Coefficient (MDC) displacement[2] may be required to accommodate composite deformation, in which

$$\Delta X_{mdc} = a_1 X_g + a_2 Y_g + a_3 X_g^2 + a_4 X_g Y_g + a_5 Y_g^2 + a_6 X_g^3 + a_7 X_g^2 Y_g + a_8 X_g Y_g^2 + a_9 Y_g^3$$

$$\Delta Y_{mdc} = b_1 X_g + b_2 X_g + b_3 X_g^2 + b_4 X_g Y_g + b_5 Y_g^2 + b_6 X_g^3 + b_7 X_g^2 Y_g + b_8 X_g Y_g^2 + b_9 Y_g^3$$

$$\Delta Z_{mdc} = c_1 X_g + c_2 Y_g + c_3 X_g^2 + c_4 X_g Y_g + c_5 Y_g^2 + c_6 X_g^3 + c_7 X_g^2 Y_g + c_8 X_g Y_g^2 + c_9 Y_g^3$$

where X_g, Y_g, and E_g are absolute coordinates and ΔX_{mdc}, ΔY_{mdc}, and ΔZ_{mdc} are internal plotter corrections which model composite deformation.

The degree of the MDC polynomials must be carefully considered in order to reliably model composite deformation. In many cases composite deformation is minimal and can be ignored.

The stereo model may then be set up for compilation with the absolute orientation model setup parameters and MDC coefficients. The setup may be tested for error, and operator index may be established, by occupying absolute coordinates for the points initially observed and comparing these positions with their respective visual model positions. The compilation base is then oriented by the absolute coordinates of graticule intersections.

Application without Triangulation

Consider applications when compilation control is independent of the compilation photographs, such as control triangulated with another set of photographs or field surveyed control. This system would differ from the first system in that pass and tie points need not be observed in the initial model setups; in that any given set of initial model observations, with respective model origin, would be derived in scaled Cartesian coordinates of the desired map projection by direct polynomial adjustment to control expressed in that system; and in that the array of map graticule intersections that are in the model proximity would have to be identified in scaled Cartesian coordinates. This system may be adequate only when there is a sufficient quantity of control per model to assure reliable modeling of composite deformation and to assure model-to-model and strip-to-strip continuity.

Application with Analytical Triangulation

A similar concept can be developed when compilation control is derived by analytical triangulation with the compilation photographs. Such a system might employ the analytical plotter as a stereocomparator to support triangulation or might employ a data base of camera calibration and triangulation data supported by monoscopic analytical plotter observations of photo data. In either case camera imposed images such as fiducials and/or *reseau* images would be observed to establish the relationships between the coordinate systems of observation and the calibrated camera coordinate system.

The development of this concept would be more lengthy than the two systems previously described since it would have to include

- Analytical triangulation or data base access;
- Definition of each models' absolute coordinate system based on triangulated exposure station data;
- Transformation of triangulated data to the models' absolute coordinate system;
- Identification and transformation of model proximity graticule data to the models' absolute coordinate system; and
- Supported mathematics to derive analytical plotter adjustment data such as systematic photo coordinate adjustment, film shrinkage adjustment, and radial distortion adjustment.

Summary

The reliability of these methods is critically dependent on two factors: the analytical plotter operators' ability to repeat an interior orientation and the reliability of the polynomial adjustments involved. The feasibility of these methods depends largely on the degree of access to a large scale computer. Finally, application of these methods eliminates the requirement and expense of plotted control, tests the plotter coordinatograph calibration each time a compilation base is oriented, reduces human errors in compilation base orientation and model absolute orientation, and compensates for composite model deformation.

References

1. Schut, G. H., "Formation of Strips from Independent Models," *Photogrammetric Engineering*, Vol. 34, No. 7, July 1968, pp. 690-695.
2. *AS-11B-1 Automated Analytical Stereoplotter*, Vol. I, December 1969.