The Bausch & Lomb Photogrammetric Award

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Numerically Assisted Relative Orientation of the Kern PG2

Graduate Award

ABSTRACT: *Previous research has demonstrated that the Kern PG2 can be used as an accurate monocomparator. A program has been developed and tested for performing numerically assisted relative orientation of this instrument which utilizes its comparator capability. The program employs a two-dimensional conformal coordinate transformation and the collinearity equations, and is solved on a personal computer. This paper outlines the procedures followed, and gives an example of the typical results obtained.*

INTRODUCTION

THE PG2 is a useful and versatile stereoplotter; however, orientation of this instrument, especially by inexperienced operators, often requires large amounts of time and results in considerable eye strain. As demonstrated by Pearsall and Wolf (1976), the Kern PG2 stereoplotter can accurately perform the function of a comparator. This capability can be exploited as an aid in performing relative orientation of the instrument. The procedure consists of first measuring x and y photo coordinates of fiducial marks and pass points. These points are then transformed into the calibrated fiducial coordinate system by a two-dimensional conformal coordinate transformation. Using the transformed coordinates, an analytical computation is performed to obtain the parameters necessary for relative orientation. Having calculated these parameters, they are placed on the dials of the instrument and then manually refined to their final values to complete the orientation.

By performing relative orientation as described above, eye strain can be eliminated and the time requirements greatly reduced. More importantly, incomplete or difficult models that often result when water bodies are present can be routinely handled by this numerically assisted method. This paper describes the relative orientation procedures.

USE OF THE PG2 AS A MONOCOMPARATOR

The Kern PG2 in the photogrammetry laboratory of the University of Wisconsin-Madison was used for this project. This instrument has a coordinatograph connected to an H. Dell Foster digitizer for direct coordinate readout. The digitizer, in turn, is connected to an IBM 026 card-punch.

Prior to using the PG2 as a monocomparator, various instrument settings must be made. Omega, phi, and kappa of the plate carriers are set to their respective zero positions, b-phi, common phi, and common omega are also set to zero, and the four principal distances c_{x_1}, c_{y_1}, c_{x_2}, and c_{y_2} are set to the focal length of the camera (assuming the diapositives are contact printed). Base distance, bx, is set approximately to a final scaled value necessary for absolute orientation. While the base distance need not be set at any specific value for relative orientation, setting it near the final value aids in reducing the introduction of y-parallax when absolute orientation is performed. The base carriage post must be placed in a position which allows the user to point on all fiducials and pass points to ensure that all coordinates are measured in a common system.

NUMERICAL SOLUTION

Based upon (1) calibrated fiducial coordinates, and (2) their corresponding values measured in the ar-

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bitrary system of the PG2 digitizer, the parameters of the coordinate transformation are computed. Because at least three fiducials are available, redundancy exists and least squares can be employed in the solution. From the transformation parameters, coordinates of the pass points can be computed in the calibrated system.

The transformed coordinates of the pass points are then input to a modified relative orientation program based upon the collinearity equations. The solution includes the specific unknown rotation elements needed for relative orientation of the PG2, i.e., ω_1, ϕ_2, κ_1, and κ_2, with Δc_{x_1} and Δc_{y_2} computed from ω_1 and ϕ_2. Also, the z coordinate of the right projector and the model coordinates of the pass points are obtained but not used in relative orientation

Testing the Procedure

To test the procedures, vertical photos of an area of moderate relief near Mazomanie, Wisconsin were used. This photography was flown by the Wisconsin Department of Transportation in the Fall of 1982. Diapositives of these photos, which have both side and corner fiducials, were contact printed on a polyester base. Pass points at the six standard positions for orientation were "pugged," but this would not be necessary because natural points could be used.

Before beginning measurements, the PG2 digitizer was initialized at one fiducial on one of the photos. Three sets of readings were then monoscopically made for each point on each photo and recorded on cards. In any model only five of the eight possible fiducials were visible. Readings were obtained at these five locations and at the six pass points in each photo. The first fiducial was finally read again to ensure that the digitizer had not lost count during the measuring process. The three readings at each point were then averaged and the mean value adopted.

Four models were oriented using the numerically assisted method, and the results compared with those obtained from manual orientation. The RMS discrepancy between instrument settings computed numerically and those obtained manually was ± 0.04 grads, and the maximum discrepancy was ± 0.08 grads.

Figure 1 contains a listing of the results of one representative analytical solution for the relative orientation parameters. Information within the listing worthy of special note are the sizes of y-photo coordinate residuals after relative orientation. Their RMS values are $+6$ micrometres, with maximum values of ± 10 micrometres. This indicates that the PG2 is indeed able to accurately perform as a comparator.

Future Research

Current research involves developing an absolute orientation program. One approach being considered would involve also measuring arbitrary coordinates of the control points at the same time pass points are measured. The model coordinates for these points would likewise be computed during relative orientation. They would then be used to compute a three-dimensional conformal coordinate transformation between the arbitrary measuring system of the PG2 and absolute ground coordinates. Rotation angles, omega and phi, calculated with this program can then be set on the instrument's common omega and common phi dials. The kappa rotation and translations in X and Y can be manually handled by rotating and translating the map sheet, and the scale can be used to calculate the new base distance.

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NUMERICAL RELATIVE ORIENTATION OF PHOTO 071 & 072 OF MAZOMANIE STRIP
USING TWO DIMENSIONAL CONFORMAL TRANSFORMATION COORDINATES

PRINCIPAL DISTANCE: 152.44
BASE:  90.00

THE NUMBER POINTS IN PHOTO  71:  6

THE POINTS READ FOR PHOTO  71

  POINT        X          Y
    31       2.361     -88.930
    21     -11.739       1.990
    11       0.939      95.138
    12      95.986      97.631
    22      82.254       3.720
    32     107.116     -87.718

THE NUMBER OF POINTS IN PHOTO  72:  6

THE POINTS READ FOR PHOTO  72

  POINT        X          Y
    31     -90.384     -90.846
    21    -101.059      -0.352
    11     -88.645      93.759
    12       6.451      95.844
    22      -6.503       2.017
    32      17.758     -87.784

THE PHOTO COORDINATE RESIDUALS

             LEFT PHOTO               RIGHT PHOTO
  POINT       VX          VY           VX          VY

    31       0.000      -0.004       -0.000       0.004
    21      -0.000       0.010        0.000      -0.009
    11       0.000      -0.005       -0.000       0.005
    12      -0.000       0.004        0.000      -0.004
    22       0.000      -0.009       -0.000       0.009
    32      -0.000       0.004        0.000      -0.004


THE ORIENTATION PARAMETERS OF THE LEFT PROJECTOR:
KAPPA =  297.425 SIGMA =  0.001 OMEGA =  99.195 SIGMA =  0.001
C CORRECTION: 0.02


THE ORIENTATION PARAMETERS OF THE RIGHT PROJECTOR:
KAPPA =  297.015 SIGMA =  0.001 PHI =  201.040 SIGMA =  0.001
C CORRECTION: 0.01


Z =  1.280   SIGMA = 0.034


******************************************************************
  POINT        X (MM)   SDX        Y (MM)  SDY        Z (MM)   SDZ
------------------------------------------------------------------
    31       -1.219 0.106     -85.743 0.112     -151.312 0.075
    21      -12.116 0.027       4.557 0.110     -158.508 0.073
    11        5.025 0.122     101.786 0.112     -158.774 0.082
    12      104.003 0.112      99.555 0.073     -157.524 0.098
    22       85.891 0.023       2.428 0.019     -159.001 0.059
    32      106.939 0.102     -93.056 0.076     -158.724 0.105
STANDARD ERROR OF UNIT WEIGHT:  0.02230
DEGREES OF FREEDOM:  1
NUMBER OF ITERATIONS:  5
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FIG. 1. A listing of the results of an analytical solution for the relative orientation parameters.

A second possible approach would involve a mathematical solution to the manual methods suggested in the Kern PG2 Instruction Manual (Kern, 1968). In this method three control points would be measured stereoscopically after relative orientation, with one point initialized to its ground survey values. Distances between these points in the arbitrary coordinate system and ground surveyed system would then be used to calculate a scale factor. Discrepancies in elevations at the two points not initialized could be used to calculate the common omega and common phi rotations.

The final intent of the research is to have the PG2 connected on-line with an Apple computer. In this mode an interactive system would provide the ultimate in convenience and time savings.

Conclusions

The test results indicate that numerically assisted relative orientation can be accurately performed and can aid significantly in reducing eye strain and time requirements. It requires only the use of a personal computer in conjunction with simple measurements obtained from the stereoplotter. Although the system described above is not now on-line, if it had been the time savings for orienting models could have been more substantial. Further advantages of numerical solutions are their capabilities to help with the orientation of incomplete models containing large bodies of water, and terrestrial models which sometimes can pose problems to manual orientation.

References

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ANNOUNCEMENT AND CALL FOR PAPERS

Pacific Congress on Marine Technology

Princess Kaiulani Hotel, Honolulu, Hawaii
24-27 April 1984

This conference—being organized by the Hawaii Section of the Marine Technology Society—is designed to bring together scholars and resource persons who will address key issues concerning the marine technology related to the ocean economic potential of the region from a multi-disciplinary perspective. The meeting will facilitate an exchange of views and ideas between representatives of the Pacific Island nations and of the larger rim countries and thereby strengthen future information exchange and collaborative research linkages.

Sessions on the following topics are planned: Ocean Energy, Marine Recreation, Development Financing, Ocean Mining, Ocean Science and Engineering, Marine Transportation, Offshore Resource Management, Fisheries, Trade, Technology Transfer, Navigation and Positioning, Remote Sensing, and Tsunami Detection.

Those wishing to present a paper should send the title and abstract (about 400 words) as soon as possible, but postmarked no later than *15 November 1983*, to

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