The "InterMap Analytic"
The Analytical Stereoplotting System From Intergraph

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ABSTRACT

The InterMap Analytic (IMA) is a photogrammetric workstation which combines interactive graphics and advanced stereoplotter technology. This "total" system embodies ergonomics and extensive software controlled features for greater operational efficiency and productivity.

The combination of precision optics (Zeiss, West Germany) with unique features such as a color superimposition monitor, multi function controller, screen menus, dynamic zoom, dove prism, and measuring mark (dependent or independent from each other) all under software control, and comprehensive mathematical models make this instrument highly efficient at handling different photogrammetric tasks in a user friendly environment.

INTRODUCTION

The InterMap Analytic is a new workstation that incorporates a unique combination of innovatives features which represent significant advances in analytical stereoplotters. The IMA combines precision optics with an internal graphics monitor, making it the first photogrammetric workstation to offer color superimposition. A multi-function controller, on-screen menus and other advanced features eliminate the need to turn away from the optics while working.

The optics are under software control. This allows to link the left and right zoom, dove rotation, measuring mark size and illumination. The real power of this function will be used with oblique and convergent photography.

This paper gives brief descriptions of the design principles and performance features of the IMA workstation.

SYSTEM DESCRIPTION

The IMA configuration consists of an opto-mechanical unit, system processors with associated peripherals, and software.

Opto-Mechanical Unit

The opto-mechanical unit (stereoviewer) consists of two independent, precision stage carriages, viewed by two high resolution optical trains that are fixed. The stereoviewer, built to Intergraph's specification by Carl Zeiss (West Germany) includes the optics, main chassis, and eight relative and six absolute positioning systems. These positioning systems control stage movements, measuring mark size and illumination, dove prism rotation and optical zoom.

The stage carriages are designed as cross slides and driven by precision lead screws. The stage carriages travel 240x330 mm. The optical system has been designed such that magnification can change from 10x to 40x in 2 seconds. The measuring marks may change from 10 to 70 microns. The stage illumination is controlled by gray edge. The dove prism can be rotated from 0 to 360 degrees.

System Processors

The IMA includes the processing power necessary to perform most calculation locally, offloading from the host computer Intergraph 200/250, VAX 750/785, or Micro II of functions not requiring an update to the graphics database. A minimum of three workstations can work from any host computer.

The IMA has two processors: The Math Processor, a National semiconductor 32032, performs the calculations for software-controlled tasks such as calibration, orientations and continous zoom. This ten-megahertz processor performs approximately one million instructions per second (MIPS) and includes a 64-bit floating point unit to speed arithmetic calculations and increase computational accuracy. The Control Processor, based on the Intel 80186, supports input/output processing and most system diagnostics. This eight-megahertz processor controls internal communications, provides the interface to the servo electronics and monitors the status of the all buttons and switches.

Controller

The controller, conferming to the shape of the human hand, has two thumb-controlled switches for X, Y, Z movements, optical zoom, parallax measurements, and dove rotation. Eight additional buttons are specifically programmed for invoking frequently selected commands for viewer control, data entry, and mensuration.

Superimposition and External Graphics Monitor

The graphics image from a 15-inch color monitoris injected, via a beam splitter, into the optical train just before the left eyepiece. The superimposition monitor has high resolution and displays up to 16 colors at a time. The screen is refreshed every 16.6 seconds which provides a dynamic pan and zoom capability necessary for smooth movement of the graphics. The color superimposition provides the capability for simultaneous through-the-optics viewing of stereo models, superimposed line work and on screen menus.

The external graphics monitor is a 19-inch color workstation displaying, simultaneously, the same image as the superimposition monitor. The external monitor features a single-sceern color display, an alphanumeric keyboard, three internal processors with 1.25 megabytes of memory.

SOFTWARE CONFIGURATION

All software resident on the host computer is written using FORTRAN 77 and C languages. The graphics and data base for project management use standard IGDS (Interactive Graphic Design Software) and DRMS (Data Management and Retrieval System) which are the basic building blocks for the Intergraph software products.

Communication between the various processors and the host computer is by means of request codes (RC). Separate RCs define the originating and the receiving processor. Each RC is divided into Function Codes (FC) which defines the specific command that is to be implemented by the processor. From the application point of view, the RCs act as the interface between the FORTRAN and C programs and the processors, although the programmer need not make that distinction.

The menus use two strips at the top of the screen with a third level using the remaining part of the screen. The selections are made by using the hand held controller to identify the selection through the superimposition monitor as all software can be controlled through these menus, is no need for the operator to turn away from the instrument, reducing eye strain, as there is no need to continually refocus the eyes, and maintaining a continous work flow.

PROJECT MANAGEMENT

The data needed to manage a project on the IMA is based on DMRS, giving flexibility with other Intergraph products. The project management program uses "project name" as the basic unit for the database. Before using Calibration, Orientation, or Applications software, all the relevant data for a particular project has to be entered in the data base. The data may be entered at a separate alphanumeric terminal on the VAX, Micro II, Intergraph 200/250, or at the Interpro 32 terminal at the IMA.

Data base maintenance is handled by four different options, namely add, delete, update, and inquire. These four options allow the operator to modify the data for a particular project. Project management also creats model data, handles the transparent flow of information between different programs and controls the interactive environment. In addition, it collects information at appropriate stages of different programs and saves the results in data base for future use.

CALIBRATION

The calibration software provides the ability to calibrate all servomotors in the IMA. This includes xy-stages, dove prisms, zoom lenses, and measuring marks. Additionally, the calibration software provides the ability to create a distortion table and an optical wobble table, ensuring that graphics and imagery always coincide during superimposition.

The calibration software can be run in two modes: The first mode is used for checking a calibration, while the second mode is used for actual calibration.

xy-Stage Calibration

xy-stage calibration is performed by measuring a high-quality standard precision grid plate and comparing the known coordinates of the grid intersections with the measured positions. The IMA has also 12 (3 x 4) internal grid crosses on each stage for on-line calibration. The xy-stages calibration software uses an extensive data processing procedure in a user friendly environment. The operator inputs necessary information for a particular calibration. If desired, the operator can use default values and need not enter anything to run the program.

The data processing is performed in two phases: data reduction and least squares adjustment. In the data reduction phase, redundant and repetitive measurements on all pre-selected grid intersections are carried out to provide equal quality (precision) for all grid crosses. The raw data is reduced and statistical information for grid crosses is computed. If the results are satisfactory, the

Linear systematic errors of the xy-stages are determined by least squares adjustment. This is done either by parametric method or by a combination of observations and parameters method. Generally, the second method is used when non-linear systematic errors of the xy-stages are to be estimated. In this case, the calibrated grid coordinates are also subject to errors according to their given standard deviations.

When using an external grid, all measurements are transformed into the grid coordinate system employing a rigid body (3 parameters) transformation model. In the second adjustment, a general affine model (6 parameters) is used to determine the coefficients of the linear systematic errors.

Dove Prism Calibration

The equation of the dove prism is linear and each step of the servomotor is exactly 0.045 degrees. To rotate the dove prism to a particular angle, the number of servo counts at the reference position is needed. The servo count is obtained by mounting the Binocular Alignment Telescope (BAT) on the IMA. The operator aligns the line at the lower left corner of the stage with the cross-hair on the BAT and takes a data point. The stage is then driven to the lower right and another data point is taken. Up to five data points may be taken at each corner. The mean servo count is then down loaded to the CMP for the dynamic rotation of dove prism.

Zoom Calibration

The zoom magnification is related to the servo count by a logarithmic function,

$$\log (M/2) = a D + b \quad (1)$$

where M is the magnification, D is the distance moved in millimeters and a and b are unknown parameters to be estimated by least squares adjustment. The diameter of the field of view is determined by measuring three points separated by 120 degrees on the edge of the field of view. The operator may measure these three points in several sets (up to 10 sets) such that the entire circle is covered. Due to time consideration for the real-time computation of the equation (1), a look-up table is generated for a selected zoom increment inside the host computer and then downloaded to the CMP. Currently, the increment of the look-up table is 0.25X. For a zoom value not in the table, a linear interpolation is used.

Measuring Mark Calibration

The relationship between the diameter of the measuring mark and the number of the servo counts is given by a logarithmic function

$$\log (D) = 1 + a N \quad (2)$$

where D is the diameter of the measuring mark, N is the number of the servo counts, and a is the unknown parameter.

The operator selects one of the internal grid crosses and places the measuring mark tangent to each four arms of the grid cross and pointings are taken. For each set, there are eight values for the radius of the measuring mark. The mean value of the diameters with the corresponding servo counts for different measuring mark sizes are input in the equation (2) and the unknown parameter a is estimated by the least squares adjustment. Inputting this parameter in equation (2), a look-up table is generated for a one micron increment of the measuring mark size and then downloaded to the CMP.

Superimposition Monitor

Two calibration routines exist for the superimposition monitor: screen distortion and optical wobble.

The first calibration routine corrects for the curvature of the screen. The screen is divided into 128 x 128 pixel elements and a grid is drawn on it such that the center grid coincides with the center pixel (the center pixel is assumed to be distortion free). The grid intersections are measured. These measurements are input into a linear interpolation routine and the amount of distortion is calculated for each pixel. The results are downloaded into the CMP for the real-time calculation of the screen distortion.

The second calibration routine corrects for optical wobble. The measuring mark usually moves within the field of view when the dove prism or zoom mechanism is activated; therefore, an optical wobble correction is needed. For this purpose an optical wobble table is generated so that for any given magnification and dove prism rotation, an offset is added inside the Interpro in real-time to correct the display.

ORIENTATION

The IMA has four orientation software programs, interior orientation, relative orientation, absolute orientation, simultaneous (bundle) orientation, as well as restoration of a model. Each one of these orientation programs consists of three parts: initialization, real-time mensuration, and near real-time parameters computation. In initialization, global parameters are entered through project management; model-specific data are selected at the begining of these orientations via tutorials. An attempt has been made to minimize the data entry through an alphanumeric key board. The mensuration (data collection) part is written such that the operator is guided through the whole process by giving him appropriate prompts. The near real-time calculation part is based on two non-compromising principles: rigorous mathematical models and least squares adjustment. Full editing capabilities are provided in these routines. The operator can add, remeasure, withhold, or reinsert one or more points.

The interior orientation program uses two different mathematical models for computation of film deformation: conformal (4 parameters) and affine (6 parameters) transformation models.

The mathematical models for relative orientation and simultaneous (bundle) orientation are the well-known collinearity condition equations.

Model coordinates can be transformed to object space system using some known control point coordinates (at least four horizontal and three vertical point coordinates). The mathematical model for such transformation (absolute orientation) is a three-dimensional transformation.

The parameters of transformation of any of above mathematical models are estimated by least squares adjustment.

Interior Orientation

The interior orientation (IO) program of the IMA accomodates photographs (or plates) having two to eight fiducial marks with different patterns (side, corner, or both). The photographs may be placed in differnt orientations on the stages of the IMA. Multiple pointings can be taken on each fiducial mark. Fiducial marks may be skipped if they cannot be observed, but at least two fiducial marks have to be measured.

Check IO software is also available on the IMA. This routine allows the operator to confirm that there has been no disturbance to the interior orientation. This would commonly be used while running the application software or restoring a model. In this case, the fiducial marks are measured only once and compared to the original measurements to show any shift that may have occurred.

Relative Orientation

Global data necessary for a relative orientation (RO) is accessed through the project management program. On the initialization screen, the operator selects the specific parameters for the model to be oriented.

The stages are automatically driven to the fiducial center of the left photograph and its conjugate point on the right one. The operator then clears the parallax and repeats the process on the right photograph. The function of this process (epi-polar orientation) is to remove gross kappa which in effect makes it easier for the operator to clear the parallax from other points.

Next, the operator drives (automatically or manually) to the six standard points (Von Gruber points). At each point, he removes the parallax and takes as many pointings as specified. After measuring these six points, he is given the option of measuring more points or processing the RO adjustment. The operator can analyze the results and edit the data.

Absolute Orientation

Once a relative orientation is accepted, the operator can perform an absolute orientation (AO). If sufficient control points have been measured in relative orientation, the operator may process the absolute orientation adjustment, otherwise he must measure more control points. The list of control points will be available to the operator. From this list, he measures two horizontal (or full control) points. The software suggests the two control points farthest apart appearing on the model. He can select these two points or any other control points in the list. After measuring two horizontal control points, other control points will be positioned under computer control. After sufficient control points are measured, the AO can be processed. The residuals and the weighted RMS values of the control point coordinates are computed and shown on the screen. The operator has the option to edit the measurements if needed.

The operator can scan the model in an epi-polar plane regardless of the orientation of the object coordinate system.

Simultaneous (Bundle) Orientation

The simultaneous orientation (SO) is used for precision work, oblique and terrestrial photographs. This program is a specially arranged combination of the described RO and AO software that permits the collection of all data necessary for a complete exterior orientation in one step adjustment.

The initialziation screen of this program is a combination of the initializations of the RO and AO. The mensuration part of the program, collects the photo coordinates of the standard points as well as the control points appearing on the model. The near-real time computation of the program determines the exterior orientation parameters and the object point coordinates in one step adjustment. The photogrammetric residuals, as well as the mean standard deviations and the RMS values of the object point coordinates, are calculated. The operator has the option to edit the data. After accepting the SO, the operator can scan the model in an epi-polar plane regardless of the orientation of the object coordinate system.

Restore a Model

There are two distinct cases where this software is used. The first concerns the restoration of the model which was previously performed on the IMA. The second concerns the restoration of a model with known exterior orientation parameters determined in an off-line block adjustment. Because the photographs are placed on the stages anew, an interior orientation has to be carried out.

Options for model restoration on the IMA are:

a. Interior orientation only.
b. Relative orientation (if interior orientation was done.
c. Absolute orientation (if interior orientation was done.
d. Interior/Relative orientation.
e. Interior/Absolute orientation.

At the end of any orientation, corresponding transformation parameters are saved by project management. A flag is set and also saved for the model indicating which orientation was done. When restore model is requested, this flag is examined and used to determine whether restoration will be executed. Then the data will be transferred into the memory locations used by the orientation programs.

DATA COLLECTION

The IMA provides full capabilities for data collection and retrieval, including compilation and continuous digitizing. Each data collection package is optimized for the photogrammetric workflow, prompting the operator for appropriate actions. Collected data is output in a format compatible with other Intergraph software products for mapping.

Line Mapping and Feature Coding

This package makes use of a feature table where the operator may set up the types of features and their attributes for digitizing a priori. By selecting map features from the strip menu, the operator can use continous digitizing to create graphics line work representing roads, contour lines, drainage, etc. Continous digitizing is automatically controlled by minimum and maximum distance, maximum number of points per second and bandwidth tolerancing.

Mono/Stereo Comparator Mode

The IMA can be used for data acquisition for the purpose of photogrammetric triangulation as either a mono comparator or a stereo comparator. Collected data are edited and formatted for different third party photogrammetric triangulation packages such as BLUH and BINGO (University of Hannover), PATB (University of Stuttgart), and ATP (Intergraph).

Cross-section Alignment

This package allows a road alignment to be displayed complete with the cross sections that the designer has specified. The measuring mark is automatically driven to each cross section and the operator may view the profile from any view as they are collected.

Digital Terrain Modeling

The IMA supports the collection of DTM data in profile mode and also allows operators to interactively define obscure areas, ridge, drain information and spot elevations. Collected DTM data may be processed and analyzed using other Intergraph DTM software product.

CONCLUSIONS

The IMA provides a capability to process data in an environment which is friendly to the user and provides a building block which can be integrated. The unique two-handed controller and on-screen menus provide a central means of controlling virtually every stereoplotter and software function. The dynamic zoom, dove prism, and measuring mark size and illumination, dependant or independant from each other, give the flexibility to efficiently use oblique and converernt photography.

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