THE INTERGRAPH DIGITAL PHOTOGRAMMETRIC WORKSTATION

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ABSTRACT

In this paper the ImageStation digital photogrammetric product line is presented. This includes a discussion of the hardware, the software, and the typical end-to-end digital workflow that is intended for the system. The ImageStation product line is the basis for an end-to-end digital photogrammetric mapping system.

Introduction

A digital photogrammetric workstation is an analytical stereoplotter that utilizes digital stereo imagery for photogrammetric purposes. The digital photogrammetric workstations of the past have been very expensive experiments in custom hardware. Recent trends in computer workstations price/performance have made cost effective digital photogrammetric workstations a reality. High performance computers, high speed image processing, lower memory costs, inexpensive mass storage, image compression, and high resolution stereo monitors are now available commercially. The benefits inherent in digital techniques will make the digital photogrammetric workstation the preferred hardware for many production tasks.

ImageStation Systems

Intergraph is offering several ImageStation base packages that include the hardware and software to a allow a stereo workstation to function as a digital photogrammetric analytical stereoplotter. The packages include a workstation with a stereo viewing system, a trackball for Z control, and the photogrammetric nucleus software. Optional ImageStation software application products will also be offered. This ImageStation product line will be expanded as new hardware and software systems become available.

Stereo Capable Workstations

The stereo displays are based on Intergraph's EDGE II display system and a StereoGraphics CrystalEyes stereo viewing system. The EDGE II provides; a 27-inch 2-megapixel stereo monitor, a 24-bit true color display (16.7 million colors from a palette of 16.7 million, a non-destructive vector overlay, 1,664 X 1,248 resolution, multiple true color look-up tables (LUTs), and a high speed vector graphics display processor. The display system is capable of switching from 60hz planar mode to 120hz stereo mode under software control. The windowing system is supported allowing either stereo or planar windows.

The stereo effect is achieved with an interface of the EDGE II display with the CrystalEyes system by StereoGraphics Corporation of San Rafeal, California, USA. The stereo viewing system is provided by the combination of the display in 120hz interlaced stereo mode, a pair of high quality active

liquid crystal shuttering glasses, and an infrared emitter. When in interlaced stereo mode, the left image is displayed on odd lines for 1/120 of a second, and the right image is displayed on even lines for 1/120 of a second. The active glasses are shuttered at 120hz providing stereo by allowing the left eye to view the left image while the right eye is blocked and the right eye to view the right image while the left eye is blocked. The infrared emitter provides a signal that allows the active glasses to sync to the monitor.

The liquid crystal (LC) lenses have a minimum dynamic range of 100:1, which is superior to any other device available today. The dynamic range is the ratio of the transmittance when the shutter is open to the transmittance when the shutter is closed. This is a measure of the effectiveness of the shuttering and is one factor in preventing ghosting. Ghosting occurs when the right eye sees an image intended for the left eye and vice-versa. High dynamic ranges of 100:1 are necessary to reduce ghosting to an acceptable level.

Any number of users may view a single stereo display in that when the glasses are pointed toward the emitter they will sync. More than one workstation may be in a single room. The emitter has a 170 degree dispersion cone that will drive glasses within 8 foot radius, which allows group viewing and demos.

Trackball for Z control

Once a stereo display is provided, the user must be given the ability to control the Z of the stereo cursor. A trackball with an RS232 interface is used for this purpose. The X-Y input, the menu selection, and window manipulations are controlled with the standard workstation mouse.

ImageStation Packages

The ImageStation SC-3 is the high-end package with the IP6187 workstation, the stereo option, trackball, MicroStation32, and the ImageStation Photogrammetric Nucleus. It is offered with and without the VITec VI-50 image computer. The 6187 includes a 18MIP Clipper processor, a 27-inch EDGE II display, a chassis that includes a 10-slot SRX bus card and a 5-slot custom video/VME card cage, dual density 3 1/2-inch 720kb/1.44MB (formatted) floppy disk drive, a 1GB system disk drive, and 32MB or 64MB of onboard ECC memory expandable to 256MB.

The optional VI-50 provides: smooth stereo roam, 300 MOPS of raster processing, 18 MFLOPS floating point capability, and a 24-bit/pixel image buffer with 8 bit/pixel overlay buffer. The EDGE II on the 6187 allows the digital MUX of raster data from the VI-50 for integrated display on the 27 inch monitor. The ability to roam in stereo over the entire stereo model, higher speed image displays, higher quality enhanced image displays, and faster batch resampling are the primary benefits the VI-50 brings to the photogrammetric user.

The ImageStation SC-2 is the mid-range package with the IP6280 workstation, the stereo option, a trackball, MicroStation32, and the ImageStation Photogrammetric Nucleus. The 6280 includes a 18MIP Clipper processor, a 27 inch EDGE II display, a chassis includes a 5-slot SRX bus card, dual density 3 1/2-inch, 720kb/1.44MB (formatted) floppy disk drive, a 1GB system disk drive, and 48MB memory

expandable to 80MB. The 6280 does not support the addition of a VI-50 image computer.

ImageStation Photogrammetric Nucleus

ImageStation Photogrammetric Nucleus (ISPN) provides the software packages for utilizing digital stereo imagery on supported Intergraph stereo display workstations. ISPN is included in the ImageStation photogrammetric packages. The ISPN package of modules including:
ImageStation Stereo Display, ImageStation Digital Orientations, ImageStation Photogrammetric Management, and MicroStation Feature Collection.

ImageStation Stereo Display

The ImageStation Stereo Display package provides the following functions:

Stereo Image Display

Imagery is displayed stereo images in fixed window with moving cursor, or with stereo roam when using an ImageStation with the VITec VI-50 image computer. Image overview or image pyramids are utilized for fast image displays. Commands for image zoom and window commands allow control of image display scale. Physical limits to zoom do not exist with digital imagery, an entire image may be displayed in a window or an image can be magnified until individual pixels are discernable. The multiple lookup tables on the EDGE II are used to dynamically balance the image contrast and brightness for stereo and split screen displays.

Stereo Vector Display

MicroStation vector graphics are photogrammetrically transformed for stereo display superimposed on stereo imagery. The vectors are transformed through the same mathematics as the stereo cursor and will be displayed with the same accuracy as they were extracted. When roam is performed, the stereo vector graphics are displayed in the VI-50 overlay buffer and roamed smoothly with the stereo imagery.

Real Time Photogrammetric Mathematics

The real time photogrammetric function accepts user inputs (X,Y from mouse and Z from trackball), converts the user inputs from object space to image space with photogrammetrically accurate transforms, and displays the cursor in stereo. Also provided for are the dynamic display of:

- ground X,Y,Z
- auxiliary ground X,Y,Z
- ideal photo and intensity
- raw photo and intensity
- pixel coordinates and intensity
- image zoom in window

Image Manipulation Functions

Image manipulation utilities are provided to handle necessary interface and utility functions. These include: Tape I/O for standard image formats and raw images allowing import of digital images; Non-tiled to tiled file conversion since fast displays require tiled format; epipolar transform of images to optimize stereo viewing; creation of image pyramids and overviews used for fast zooms and windowing; Extraction of image region of interest (ROI) while preserving interior orientation reducing file size when dealing with small projects; Spatial enhancements allowing exploitation of adverse image area (shadows, etc); and 0,90,180,270 image rotations and image mirroring/transposition to allow correction of image orientation on imported files.

ImageStation Digital Orientations

Sophisticated photogrammetric orientation functions are provided by ImageStation Digital Orientations to allow maximum accuracy and reliability with simple and productive user interfaces. The algorithms handle vertical aerial, oblique aerial, metric close range and non-metric close range cases. Included are: interior orientation; reseau corrections; relative orientation, absolute orientation, bundle orientation, direct linear transforms (DLT), Image-Object grid fit for other sensors, and Rational functions for other sensors. Image-Object grid fitting and Rational Function interface allow utilization of any image type for which the user or a third-party developer has a rigorous mathematical model. Interface to TRIFID corporations excellent SPOT triangulation is handled in this manner. SPOT math may also be obtained with a close interface to separately priced SPOT math package. Automated blunder detection aids including standardized residuals, redundancy numbers, etc are provided to assist with problem models. A highly user friendly yet flexible FORMS driven user interface allows user configuration of form and image display window size and screen location. Solution displays and edits such as remeasure, add, withhold, reinstate, and change type/class/weights are provided to quickly resolve measurement or control problems. New solutions are performed and results displayed immediately following any measurement or edit once minimum criteria are met. The user is allowed to define a 'standard' parallax points default locations and define default point number. The use of overview images to aid in location of control points and pass point greatly speeds the process and reduces blunders. Standard solution reports are provided to allow a record of the model. Control and pass points are optionally shown as graphic symbols on a window basis.

ImageStation Photogrammetric Manager

ImageStation Photogrammetric Manager (ISPM) provides the photogrammetric data management tools required for a production workflow. It provides the entry/edit menus, the bulk input/output of photogrammetric data, a standard set of data reports and the archive/restore of projects. The benefits are a single, consistent, simple to use, photogrammetric data manager and central data store, enabling the setup and data management of photogrammetric projects on a standard Intergraph workstation. It also provides the interfaces between the ImageStation applications to/from the IMA, SPI/M, third party triangulation packages (PAT-MR, PAT-BR, BLUH, BINGO, TRIFID SPOT Block Triangulation), MGE Rectify, and the PhotoScan. ISPM utilizes a relational data base to store and manage the photogrammetric data. Parameter files are extracted and downloaded to ImageStation Digital Orientations which operates locally with ASCII files. Solution results and measurements can be posted back to ISPM for storage, reporting, archiving or export. Since ImageStation Digital

Orientations operates locally with ASCII files, the use of ISPM is optional and the ImageStation can be operated standalone without accessing an RDB. In this case the user must use directory structures to manage the ASCII files and other interface benefits of ISPM are not available. In addition to being part of the ImageStation Photogrammetric Nucleus, ISPM is available separately for use on any Clipper workstation.

ImageStation Feature Collection

MicroStation Feature Collection provides an easy to use, map feature digitizing system for use with digital stereo imagery. MSFC provides an efficient map feature digitizing system that extends MicroStation32 capabilities. It furnishes numerous commands to collect and edit feature data. MSFC utilizes screen-based icon driven menus to provide user interface designed for map production. Efficiency is enhanced by setting the feature's graphic characteristics and activating a digitizing command upon selection of a feature. A feature based table is utilized allowing the user to define a series of map symbologies and manage them on a job by job basis.

Optional Application Packages: ImageStation Digital Mensuration

ImageStation Digital Mensuration (ISDM) provides a multi-image point transfer and measurement environment for a photogrammetric triangulation workflow. The image point coordinates generated by ISDM can be formatted by the ImageStation Photogrammetric Manager (ISPM) for input into one of the Intergraph supported third-party triangulation packages. The high degree of flexibility built into the user interface allows a highly automated mensuration procedure. Flexible window based image display of multiple images provides efficient transfer and measurement of points in multi-overlap regions. When an image is completed, the next image is automatically loaded. The use of auto-correlation and on-line integrity checks improves accuracy, increases productivity and provides a high degree of reliability. The accessibility of the image enhancement and image manipulation functions greatly assist the operator in performing the mensuration task. All these factors provide a mensuration system that can be used with relative ease and high productivity.

Optional Application Packages: ImageStation DTM Collection

ImageStation DTM Collection is a workstation product providing a stereo environment for the semi-automatic collection of terrain elevations from digital imagery. The resultant file of elevation data may have a regular or irregular spacing. If evenly spaced posts from irregular data are required, they can be directly input into MGE Terrain Modeler to obtain the desired spacing. The high degree of flexibility built into the user interface for the post point collection environment allows for a highly automated mensuration procedure. The use of auto-correlation for this mensuration process also provides a high degree of reliability.

A typical workflow would be as follows:

Input: The system starts with the input of image data, either from digital tape from satellite sensors such as SPOT, or by the scanning of aerial photography on the PhotoScan PS1.

Triangulation: The digital imagery then put through the aerotriangulation process. ImageStation Digital Mensuration (ISDM) is used to point transfer and measure pass, tie, and control points

directly on the digital imagery with the assistance of image matching techniques. ISDM provides high accuracy and consistency with no need to physically point mark the diapositive, since the digital pug mark maintained by the system can be used in the subsequent digital mapping steps. (If the models are to be set on an analog stereoplotter, several photo identifiable points or PUG marks made before scanning must be measured to allow scaling the models.) The measurements are then exported to one of several third-party triangulation adjustment packages available on the Clipper workstation (PAT-MR, PAT-BR, BLUH, BINGO, TRIFID SPOT). After adjustment, the triangulation results are imported into ImageStation Photogrammetric Manager for use in the subsequent production steps.

Epipolar Resampling: If stereo viewing or automated elevation extraction is to be performed, the overlap area of the stereo pair covering the desired work area must be resampled to provide perfect vertical photos. Film and lens distortion are also removed in this step. This process can be performed on the Clipper or will utilize the VITec VI-50 image computer if available on the system. If, only an orthoimage is desired and a DTM covering the area already exists, this step and the data extraction steps would be skipped and the orthoimage resampling step performed.

Feature Collection: Many line mapping and GIS creation projects have their largest time investment in the capture of feature data from stereo aerial photography. The ImageStation product line provides a true color 27 inch stereo display with stereo superimposition allowing heads-up collection of feature data in a highly efficient manner. Menus for command selection and forms for data entry are displayed on the same monitor for a integrated user interface. The Microstation Feature collection package provides a feature table definition of the graphic characteristics that are automatically activated when the operator selects a feature to digitize. The heart of the Feature Collection package is a multitude of specialized digitizing and editing commands designed to minimize the operator interaction required to collect or edit feature data. Also provided are forms for the entry and edit of attribute data associated with the features that can later be loaded into the MGE GIS system. Photogrammetric feature collection is inherently a highly manual process with thousands of user actions performed during the workday. MicroStation Feature Collection, by minimizing this repetitive interaction, enhances the productivity of every operator collecting data, thus increasing the throughput of the system and the consistency of the data produced.

Future developments in this area hold promise of further enhancing productivity by utilizing the image processing power of the VI-50 image computer to do such things as: automatically follow identified linear features, with the operator interaction in difficult image areas, automatically outline the boundary of identified area features (water bodies, fields, etc), and automatically extract building outlines within areas identified by the operator. These type of capabilities, although not currently available, should weigh heavily in the selection of a system that will provide a platform for future expansion.

DTM Collection: The collection and edit of accurate and reliable DTM data is a major process in many photogrammetric projects. Critical to the automated production of such data is a high quality stereo display with color stereo vector capability, a versatile user interface, and sufficient image computational power. The ImageStation platform provides these elements. Intergraph's approach to DTM collection will be two-fold. First provide an interactive collection product that would rely on the operator to intelligently select where the point would be collected and manually keep the stereo cursor near the ground. Image matching techniques would be used to extract the elevation reliably

since the operator would avoid problem areas such as buildings, trees, shadowed areas, etc. Manual collection would be performed if the image matching created erroneous points. Linear geomorphic features would delineate with this interactive approach. Large areas of easy image matching would be outlined for automatic extraction, followed by a stereo display and edit of the results. This approach would provide elevation data of known consistent high quality with greatly reduced collection time. The manual override would allow even difficult areas to be collected. Second, provide a batch DTM extraction that automatically create a DTM over the model and a list of problem areas. The DTM and the problem list would be input to the interactive DTM collection package for interactive edit. The list would be used to window in on suspected problems for operator correction. The operator would also review the model in stereo checking for errors and editing as necessary. DTM collection packages are not scheduled to be available until early 1992.

DTM Merge: The MGE Terrain Modeler package would now be used to merge the several DTM's required to create the orthoimage and output a single DTM covering the desired area (often a double model area).

Ortho-resample: After the DTM is collected and merged or input from an existing DTM file, ImageStation Image Rectifier may be used to perform ortho resampling. The original scanned image is used rather, than twice resampling the epipolar image. The resampling utilizes the results of the aerotriangulation, the camera calibration data, the DTM, and the image. The area to be resampled is specified in ground coordinates and the resolution in ground distance. If no output parameters are entered, the entire photo is orthorectified at a resolution computed to preserve the input image resolution. The image interpolation method (nearest neighbor, bilinear, or cubic convolution) may be selected. Bilinear or cubic convolution require more processing time but produce higher quality images.

Tone Match and Mosaic: Image Station Imager may then be used to tone match and mosaic if multiple images are required to cover an output area. Tone matching allows tone differences in the input images to be balanced for a more aesthetic image. Mosaicking allows the operator to define a linestring boundary between two images along which they are merged.

Output: The production of film hardcopy for printing is accomplished by MGE Map Publisher. Map Publisher is a highly capable cartographic production product with many features, too many to cover in this description. Several features significant to orthophoto production are: screening or half toning at plot time, grid and gradicule generation, merging of vectors and imagery at plot time, and haloing of text and graphics with contrasting color to enhance legibility in both light and dark image areas. Film writing is supported on a number of different size and performance devices.

Summary

Intergraph is introducing the ImageStation product line for digital stereo photogrammetric applications, along with our extensive automated mapping and GIS products, provides an end-to-end digital mapping production system. The ImageStation product line is multi-tiered, with the high-performance IP6187 Clipper/VITec dual architecture at the top and the IP6280 at the next level. A full line of digital photogrammetric applications are planned. The ImageStation development demonstrates Intergraph's continuing to a strong and highly productive photogrammetric product line.

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