Transition from Analogue to Digital Photogrammetry

Mahmoud Hassani

Georas Consulting - P.O. Box 333, 2130 AH
Hoofddorp, The Netherlands

James Carswell

Intergraph European Headquarters - Mapping Sciences Division
P.O. Box 333, 2130 AH - Hoofddorp, The Netherlands

ABSTRACT

This paper outlines the history of transition from analogue/analytical to digital photogrammetry in Intergraph. The accuracy required for photogrammetric applications has always prevented the operational use of digital photogrammetry. Intergraph has now taken the decision to make the digital photogrammetry approach operational. The first step in this direction was the development of the Intergraph/Zeiss PhotoScan (with maximum resolution of 7.5 micron). Standard aerial photographs can be created accurately now with as many as 30,000 x 30,000 pixels (nearly one giga byte) per data-set. Several development efforts are currently under way to provide substantial power and flexibility in order to process such data volumes successfully. So in this connection Intergraph announced the ImageStation photogrammetric product line.

In this article, the hardware and software development necessary for making use of the advantages of digital photogrammetry are discussed.

INTRODUCTION

Intergraph's involvement in photogrammetry started in the early 80's with the interfacing of existing analogue and analytical stereoplotters with a VAX-based Monochrome InterMap graphics terminal. Through this interface, photogrammetrists could have access to all of the Intergraph's interactive mapping applications. The InterMap brought such innovations as super-imposition, dynamic pan and zoom, voice recognition, and voice synthesis to the production environment and is still widely used in production today. The VAX-based InterMap Analytic (IMA) was introduced in 1985.

The IMA combines the proven high-quality optics and electronics of a Zeiss viewer with a high-performance colour graphics terminal with integrated color superimposition and computer controlled functions. The InterMap Analytic was a significant step for the integration of photogrammetry and Geographic Information Systems (Madani, 1986).

In early 1990, Intergraph announced a standalone StereoPlotter Interface/Mechanical (SPI/M) which provides an interface between an encoded analogue stereoplotter and a UNIX-based Intergraph workstation running MicroStation graphics software. This standalone graphics workstation replaced the afore mentioned VAX-based interface.

WHY DIGITAL PHOTOGRAMMETRY?

The main reason behind the push to extend analogue and analytical photogrammetry into the digital realm is for the expectations of huge cost savings in producing typical photogrammetric outputs and the new ability for using this digital output as input into other analysis systems.

The implementation of automated data input, compilation and output should lessen the time needed to produce a given quantity of photogrammetric output, like planimetric and topographic maps which will in turn have direct affect on reducing the cost of that particular output. In addition, the output of the digital photogrammetric process is already suited for direct input into corporate GIS databases and for automatic production of orthoimage base maps. GIS base map revision from aerial photographs is far more accurate than by hand digitizing or scanning out-of-date hardcopy mapsheets and digital orthophoto production eliminates the need for the slow and expensive analogue orthophoto production equipment.

Merging the full range of image processing techniques with traditional photogrammetric theory is required for the development of sopftcopy photogrammetry. The resulting

products will include both geometric and radiometric object space descriptions, ie. 3-D locations and grey scale values of physical features on the ground.

Generally, hardware development is faster than software and the same hold true for digital photogrammetry. But once digital photogrammetry becomes a common tool, new compilation and analysis routines will be developed to further ease the typical workflow and improve productivity, ie. automated DTM generation and line following routines. And indeed, these and many other applications are now currently under development at Intergraph.

CONTRIBUTING FACTORS

The main factors which allowed for digital photogrammetry to become operational are:

- High resolution scanners.
- High resolution of the graphics display.
- Advanced image processing computers with multiple dedicated processors.
- Improved processor speed.
- Larger storage devices, such as 1 GB hard and optical disks, 5 GB magnetic tapes.
- Implementation of image compression techniques into hardware.
- Automation of phases such as feature identification and extraction.
- Automatic digital terrain modelling data capture and orthoimage base mapping.
- The availability of volumes of data already in digital form, i.e from satellites.

Below we will elaborate in more detail on the most important characteristics of the digital photogrammetric setup.

High Resolution Imagery

Aerial photographs have an important role in Land Information Systems (LIS) and Geographic Information Systems (GIS). The basis for digital photogrammetry today are analogue photographs converted to pixel elements with a digital description of the grey levels. To achieve this, the high resolution PhotoScan was jointly developed by Intergraph and Zeiss, Oberkochen.

The PhotoScan is a flatbed scanner based on the Zeiss Planicomp technology. The photo stage size for holding the photograph is 260 x 260 mm.

The desired working area on the photo is projected orthogonally onto a CCD linear array (length = 15.36 mm) sensor below the photo stage, while the photo (in negative or diapositive form) is illuminated from above. The desired working area is scanned swath by swath. The swath's width is 2048 pixels with spacing of 7.5 microns giving a maximum scan line of length 260 mm or 30,000 pixels. The pixel size along the swath of 7.5 microns is obtained by synchronizing the scanning pulses produced by a linear encoder.

The PhotoScan is a very reliable scanner with high geometric and radiometric precision - its photo carrier positioning enjoys better than 2 microns accuracy per axis and its lens distortion accuracy is around 1 micron. Its radiometric precision is 256 significant levels (Faust, 1990). The image resolution can be selected from 7.5 to 120 microns, depending on the application requirements.

Data Storage

The host computer associated with the PhotoScan can be Intergraph's InterServe 6105 or the ImageStation 6487 with the 36 MIP C400 CLIPPER CPU with 32 MB onboard memory that can be expanded to 256 MB. The standard internal system disk drive storage is 1 GB with expansion capability of up to four additional 1 GB slottable disk drives.

Other means to store and reduce sizes of data sets are also available. These include "on-the-fly" hardware compression/decompression with Intergraph's new JPEG board. Such a board is capbable of reducing the file size of black and white imagery 4-12 times and colour imagery upto 30 times. The on-the- fly capabilities of this board make it possible to have imagery files in uncompressed format on the user's display while they remain compressed on the disk. In addition, sophisticated high speed storage devices are commercially available such as optical disk juke boxes and ExaByte digital tape systems that are capable of storing 5 GB of imagery on a single tape.

I/O Processing

Image transfer time from disk to display has always been a bottleneck for image processing systems. Intergraph has provided additional hardware and software tools for solving the problem of trying to display up to 1 GB image files on a 2 megapixel display.
These include the use of overviews, efficient memory

management, the VITec 172 MIP image computer, and EDGE II+ graphics.

An operator generally wants to obtain an overview of an image to subsequently zoom into in order to measure control points or digitize a feature. The PhotoScan, during the scanning process, automatically generates overviews which get inserted into the header information of the original image file. An overview can be looked at as a 1:4, 1:8, 1:16, etc. resampled image. This additional header information will tell the system how to select the pixels from the original image when it comes time to display. The zoom factor and the size of the screen window that is selected by the operator for displaying the image will determine which overview is most appropriate. In this way the actual data transfer of an overview of a 1 GB image can be as low as .5 MB.

Several overviews can be active in different windows on the same screen at the same time and if you continue to zoom in on a particular window the overviews will dynamically interchange until, if you zoom in far enough, they get replaced finally by the original image in full resolution.

All image files are organized into super pixels called tiles of generally 128 x 128 pixels. The Intergraph Tile Manager continually keeps track of which tiles you are currently working with on your display and assigns priorities as to which should remain in memory and which tiles should get written back to disk when not in use. In this way, when the operator pans and zooms about an image on the display, imagery that is not currently in memory will be fetched from disk as complete tiles of data and drawn at once instead of on a line by line basis as is currently the case with other systems. Keeping track of which tiles are to be saved in memory and which are to be written back to disk also keeps the imagery out of UNIX swap. This factor alone accounts for a dramatic increase in display times. The combination of overviews and the Tile Manager comfortably permit an operator to process gigabyte files with a minimal 32 MBs of direct access memory.

If the demand of moving data to disk is very high, ie. in the case of stereo roaming through a model, a number of additional hardware tools will greatly assist. First there is a super fast specialized raster processor, the VI-50 image computer. This 172 MIP processor was developed by VITec and enhanced by Intergraph. It is of considerable assistance with most tasks that are performed on large raster files. The VI-50 works in parallel with the Intergraph CLIPPER and forms the heart of every ImageStation 6487.

The graphics display technology behind the system is Intergraph's EDGE II+ which creates high-quality colour graphics in real-time.
Colour imagery can be simultaneously displayed on dual 27" monitors (1248 x 1664 pixels) with "breath-taking" sharp stereo models and 16.7 million colours combined with a non-destructive 8 bit planes of vector overlay.

The stereo models can be viewed with special glasses called CrystalEyes. CrystalEyes eyewear which interacts radiographically with the EDGE II+, enables several users simultaneously to observe stereo imagery. The eyewear consists of a liquid crystal shutter electronic stereoscopic viewing device, which uses wireless infrared signals synchnonized with the monitor's interlaced refresh rate. It enables the viewer to receive a truly stereoscopic image:

the left image is displayed on the odd lines, and the right image is displayed on the even lines. The viewing device is shuttered at 120 hertz thereby enabling the left eye to view the left image while the right eye is blocked and vice versa (CrystalEyes 1991).

A trackball is RS232 interfaced with ImageStation 6487 in order to control the Z movement of the floating mark leaving the X,Y input to the mouse. A stereo cursor almost identical to that currently in use with the IMA will also soon be available.

PHOTOGRAMMETRIC APPLICATIONS

Utilizing the above hardware and software, a variety of image processing and photogrammetric applications can now be integrated using raster files obtained from the PhotoScan.

Rectification

Orthophotos have an important role in a GIS/LIS environment. One important example is for image backgrounds for thematic mapping.
The ImageStation Rectifier (ISIR) package allows the user to perform rectification and ortho-rectification of aerial photographs and satellite imagery. It also performs general purpose functions like:

- Image rescaling and rotation.
- Raster file translation.

- Translation of an ASCII file with x,y,z into a raster grid file
- Transforming a raster file from one projection system to another and many other functions (Intergraph 1991).

Softcopy Photogrammetry

The aim of Softcopy Photogrammetry is to create a totally integrated working environment which incorporates various photogrammetric data capture products. The present state of development is positive and the ultimate solution is very promising (Molkarai / Hassani, 1989).

The present application software for digital photogrammetry includes:

- The base software for utilizing digital stereo imagery.
- Data management tools.
- Complete photogrammetric orientation software.
- Multi image transfer and measurement for triangulation purposes and interfaces to third party TRIFID SPOT, BLUH, BINGO, PAT-MR, PAT-BR block adjustment program.
- Digital Terrain Modeling data capture.
- Stereo Alignment Cross sectioning data capture.
- MicroStation Feature Collection which enhances map digitizing productivity.

Photogrammetric Nucleus (ISPN)

The ISPN module serves as the base software for the photogrammetric applications. The ImageStation 6487 with ISPN provides continuous panning of the stereo image; superimposed digitized vectors; multiple windowing and overviews (Intergraph 1991).
Most of the photogrammetric orientation programs are implemented in ISPN.

ImageStation Photogrammetric Manager (ISPM)

ISPM creates project data and manages the transparent flow of information between softcopy photogrammetry applications. Project data include: camera and fiducial coordinates, control points, photographs and models. ISPM provides a two sided interface between the softcopy database and the third party aero-triangulation packages (Intergraph 1991).

ImageStation Digital Mensuration (ISDM)

ISDM allows a high degree of flexibility in mensuration procedures. It is capable of split screen monoscopic or stereoscopic displays. Online blunder detection is utilized during observations within the overlapping areas. There is a possibility to display multiple images of varying scale with different magnifications for efficient identification, transfer and measurement of points in multi-overlap regions (Intergraph 1991).

MicroStation Feature collection (MSFC)

MSFC uses the capabilities provided by MicroStation to produce highly productive and cost effective basemap digitizing software. It provides capture, review, and a specific set of editing capabilities for graphic data within the softcopy photogrammetry software. The most important part of the MSFC is the feature definition module. This module allows the user to customize and control the characteristics of map features, so a project can be tailored to meet specific needs. This also allows for direct bulk loading of feature characteristics into the MGE environment (Intergraph, 1991).

ImageStation DTM collection

ImageStation DTM collection provides a semi-automatic means for the collection of terrain elevation from digital imagery. The output file of the collected data (regular/irregular) can be directly input into the Modular GIS Terrain Modelling (MSM) package.

Different data capture techniques are implemented:

- Manual approach, which relies on the operator's decision where the point would be collected (with pre-defined profile distance and profile tolerance,...).
- Automatic approach, using correlator techniques which will extract the elevation by image matching techniques.

The manual approach is appropriate for linear geomorphic features and problem areas such as buildings, trees and shadowed areas and automated techniques for large areas of easy image matching. This package will simplify and greatly reduce the DTM data capture time.

CONCLUSIONS

In March 1991, Intergraph's large volume imagery workhorse, the ImageStation was announced. Already (since February 1992), the second generation ImageStation is now available; the ImageStation 6487. The ImageStation 6487 is equipped with a large number of features that permit heavy duty GIS and raster operations. These features include the new Intergraph 36 MIP C400 Clipper CPU, the 172 MIP VI-50 raster processor, the 24 bit stereo display capabilities, the tile manager, etc.

This article described the present status of the development of the digital photogrammetric platform. The PhotoScan that permits high resolution, high precision data input from aerial photographs fulfills a major prerequisite for softcopy photogrammetry. In addition, a new range of digital software applications are currently under development.

The digital photogrammetric application software that is presently available is the Photogrammetry Nucleus (ISPN), which includes project management, complete photogrammetric orientation software, and aero-triangulation data capture and feature collection software. This platform therefore is one of the first operational digital photogrammetric products and the most powerful image processing platform available to the GIS industry.

Intergraph's corporate strategy to discontinue production of the InterMap Analytic (IMA) has afforded the opportunity for the ImageStation product line to takeover the spotlight. The ImageStation 6487 and accompanning photogrammetric and image processing software provides industry with a fully digital input, management, analysis and presentation environment for spatial data.

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