AUTOMATIC DEM AND ORTHOPHOTO GENERATION ON ANALYTICAL STEREOPLOTTERS

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Commission IV, Working Group 4

KEYWORDS: Orthoimage, Correlation, Digital, Rectification, CCD, DEM/DTM

ABSTRACT

Soft copy photogrammetry offers two main advantages over analytical stereoplotters, the automatic generation of DEMs (digital elevation models) and Orthophotos. In a production environment soft copy systems have significant disadvantages, the need to scan and store all the images, the need for more highly trained operators, the reduced ability to digitise exact detail only to name a few.
To keep the amount of disk storage space required for the scanned data at a workable level, companies are forced to scan their images as coarsely as possible. This reduces the ability to digitise very small features on a soft copy system. The pixels can be too large, making it impossible for the operator to identify very small features.
ADAM Technology believe that by adding CCD cameras to their analytical stereoplotter, most automatic features offered on soft copy systems can be offered on an analytical stereoplotter, hence combining the best of both worlds.
There is an increasing demand for orthophotos and orthophoto maps world-wide. The automatic DEM and Orthophoto generation project based on ADAM Technology's analytical stereoplotter, the PROMAP system, will offer a cost effective solution to meet these demands. This technology will combine the accuracy and ease of use of the analytical stereoplotters with the automatic features offered by soft copy systems.

KURZFASSUNG

Digitale Photogrammetrische Systeme bieten 2 Hauptvorteile gegenüber analytisches Auswertegeräten, die beinahe automatische Erzeugung von digialen Orthophotots und die automatische Erzeugung von digitalen Geländemodellen. Im productiven Gebrauch hingegen weisen diese Systeme schwerwiegende Nachteile auf. Der Speicher Bedarf fuer die Bilder in digitaler Form ist enorm und der Aufwand fuer die Ausbildung des Benutzers ist erheblich höher. Um den Speicher Aufwand fuer die digitalen Bilder in einem vernünftigen Rahmen zu halten, sind Firmen gezwungen die Flugbilder mit einer relativ groben Auflösung zu scannen. Durch den resultiereneden Verlust von Detail Information wird es dem Benutzer verunmöglicht die feinsten Einzelheiten noch zu vermessen.
Eine alternative Lösung wird hier vorgestellt. CCD-Kameras sind in einem analytischen Auswertegerät eingebaut und erlauben die meisten Operationen die auf digitalen Photogrammetrischen Arbeitsplätzen möglich sind. Digitale Geländemodelle und Orthophotos koennen kostengünstig und weitgehend automatisch erstellt werden. Das von ADAM Technology hergestellte analytische Auswertegerät, das PROMAP System, ausgeruested mit CCD-Kameras und entsprechender Software bieted dem Anwender die beste Kombination von einfacher Handhabung, genaueste Vermessung von Einzelheiten, und zusätzlich die automatische Funktionen für Orthophotos und digitalen Geländemodell Erstellung.

Overview

ADAM Technology is developing a new range of products for Automatic DEM and Orthophoto Generation which will be released as options for the successful ADAM PROMAP System analytical stereoplotter. This paper describes the development of these products at the time of writing.
The ADAM Automatic DEM and Orthophoto Generation options consist of a software package, two CCD cameras with lenses mounted in the ADAM PROMAP analytical stereoplotter and a frame grabber mounted in the host PC. The CCD cameras view the same portion of the model as the operator, however a smaller field of view. The frame grabber converts the video images from the cameras into digital images which can be analysed by computer software.
For orthophoto production the working image area is acquired in colour from one side only and the colour image corrected for height displacement. The DEM required for this step can be

pre-existing or can be generated simultaneously. These corrected orthophoto patches are stored on disk. The system works one patch at a time until the whole model area is covered.

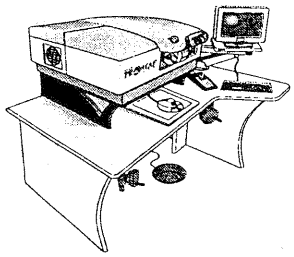

Fig 1 ADAM Technology PROMAP System

For DEM generation, images are captured from both left and right CCD cameras. Image correlation software determines matching points and generates height measurements using the model orientation parameters. It generates DEMs quickly, with minimal user input. The operator has the ability to check the correlated points in stereo using an anaglyph display (using red/blue glasses), on a basic stereo monitor (mirror stereoscope based) or a digital 3D display. The DEM can also be checked via drive-back in the stereoplotter itself. The DEM is stored on hard disk and can also be used immediately for simultaneous Orthophoto generation.

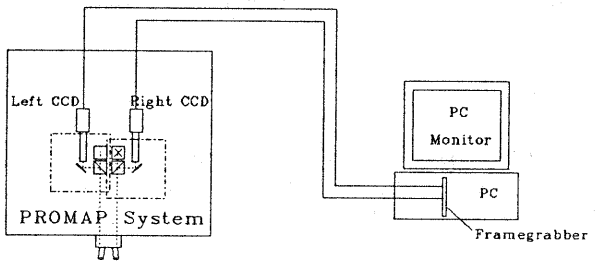

Fig 2 CCD cameras in PROMAP System

Advantages of this technique

- The ADAM Orthophoto generation only stores the final orthophoto, thereby reducing the hard disk storage requirements by up to 75% of that required by standard soft photogrammetric systems. Whereas a soft photogrammetric system reads the digital image data from disk or memory, the ADAM PROMAP Automatic DEM and Orthophoto Generator commands the machine to go to the desired location and acquire the data via CCD camera and frame-grabber when it is required. This eliminates the need to scan and store the whole of every photograph for the job. Including stereo overlaps and sidelaps in a photogrammetric block, each ground point is covered approximately 2.7 times in a softcopy system. This is in addition to the disk space which is needed to store any intermediate files generated by the system and, of course, the final orthophoto.
- No Scanner is required. The images are scanned patch by patch in the PROMAP System simultaneously with the Automatic DEM and Orthophoto generation.
- The ADAM PROMAP system is still a fully functional analytical stereoplotter, even when the Automatic DEM and Orthophoto Generation functions are installed. Therefore, if required, the PROMAP operator can digitise fine detail which would not be visible on photographs scanned for a soft photogrammetric system.
- The ADAM PROMAP system is PC based and uses Microsoft Windows. This makes it easier to learn and use, and considerably less expensive than the Unix based workstations which are generally required for full format soft photogrammetric systems.
- The ADAM PROMAP system offers users of conventional analytical stereoplotters a simple low-cost entry path into the new digital orthophoto and digital photogrammetric field.

File sizes

The following table shows the amount of disk space required even for a small block. The resolution of the orthophoto is assumed to be 15 microns, same as the scanned pixel size.

	Monochrome	Colour
1 diapositive @ 15 microns	224Mb	672Mb
Block of 3 strips x 8 models/strip	6,048Mb	18,144Mb
Orthophotos covering the block	1,830Mb	5,489Mb

Table 1 Sizes of image files in megabytes (uncompressed)

System components

Hardware:

- The system uses off-the-shelf monochrome CCD cameras.
- A high speed frame-grabber running on the Pentium's PCI bus is used.
- The lens system of the CCD cameras is fixed. Focusing and alignment are done by an ADAM technician. The resulting pixel size is 15 microns on the diapositive. The Orthophoto can be generated to any required ground pixel size by re-sampling the scanned pixels. Some commonly used Ink jet plotters operate at resolutions of 300dpi (85 microns) in colour. Printing one pixel scanned at 15 microns as one 300 dpi dot results in a nominal scale of 5.6 between orthophoto and diapositive.
- The system runs on a relatively inexpensive Pentium PC under Windows NT. A Windows 95 version of the product is also planned.
- The images required for colour orthophotos are created from the monochrome images acquired by camera and frame-grabber by mechanically switching red, green and blue filters. These filters are placed in front of the stereoplotter's plate illumination system. Three frames, one for each filter are grabbed and the colour images are formed by combining them.

Software:

- The software includes a calibration routine for the CCD camera, lens and frame-grabber to compensate for geometric and radiometric errors of the lens/CCD/frame-grabber system. The geometric calibration requires the operator to measure a number of points on the stereoplotter from which the calibration parameters are calculated.
- The radiometric calibrations does not require any user interaction. A lookup table is then used for the correction of radiometric distortions.

- Orthophotos can be generated in monochrome or in colour. The DEM can either be a previously digitised DEM or it can be generated patch by patch during orthophoto generation using image correlation techniques.
- The image correlation routines utilise monochrome images for higher resolution.

System configuration in production

In a production environment it is recommended to do the orthophoto sheet editing, preparation and printing on a separate computer. A network is the most suitable method to transfer the data from the PC running the orthophoto generation on the PROMAP system to the editing workstation.

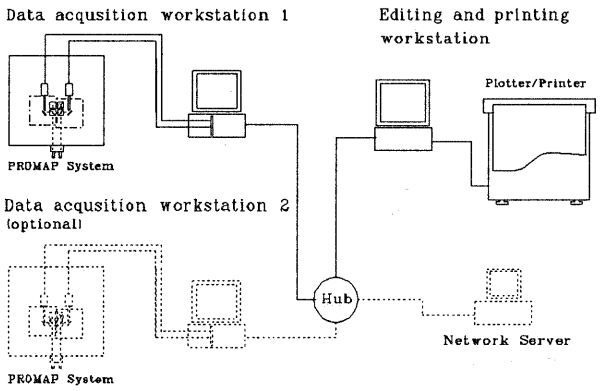

Fig 3 Production system configuration

Orthophoto Operation

The ADAM PROMAP Orthophoto Generation functions allow an operator who is accustomed to analytical stereoplotter operation to create an orthophoto covering the model loaded in the PROMAP in a simple user-friendly manner.
It can operate in either of two modes.

- **Using a pre-existing DEM.** In this mode, a DEM from any source must be imported for use. It can be digitised using ADAM cartographic software or imported from some totally external source. In this mode, the system can generate an orthophoto covering an entire photograph if required.
- **Simultaneously with automatic DEM generation.** In this mode, the DEM for each patch is generated and then the Orthophoto segment for the patch is generated immediately after. In effect, an orthophoto can be generated even when you have no DEM for the model.

Orthophoto mosaicking and printing

Orthophotos generated from the ADAM PROMAP can be exported into GIS systems or other image management software. They can also be printed directly to any Windows supported raster plotter.
Orthophotos are generated one model or photograph at a time. Users can export these orthophoto sections for processing by another package or can use the simple mosaic options provided and join them into completed map sheets. Simple grid and feature overlay functions are also provided.

Automatic DEM generation

The Automatic DEM works on one patch at the time. With the current hardware configuration the patches generated by the frame-grabber are 720x540 pixels. Control points or any available height information of sufficient accuracy is used for initial approximations of ground levels. Depending on the terrain, image pyramids up to 3 levels are generated. Least squares image matching techniques are utilised to determine conjugate points.
The operator can check the correlated points on the PC monitor viewing the stereo model with a basic 3D display.
The precision of the correlated points are expected to be better than 0.5 pixel.
The correlated ground points are placed on a regular grid based on one diapositive. As an additional feature, ground points can also be correlated on a regular ground mesh.

Performance testing

At the time of writing this paper, it is anticipated that a DEM of a model consisting of 60,000 points and a colour orthophoto will be generated in under 1 hour. Extensive tests are planned to evaluate the performance of the system.

DEM grid size on plate	1mm	0.5mm
Number of DEM points	20200	80799
Number of patches	297	297
DEM generation time	9 min	27 min
Orthophoto generation	52 min	52 min

Table 2 Predicted timings and sizes for orthophoto production (estimated from prototype at time of writing)

(Those interested in final test results should contact ADAM Technology directly.)

Product release

The ADAM PROMAP Orthophoto Generator will be unveiled at ISPRS in Vienna, July 1996. Beta testing will begin after ISPRS. ADAM PROMAP Automatic DEM is expected to be in Alpha testing soon after ISPRS.

Conclusion

The ADAM PROMAP Automatic DEM and Orthophoto options will offer a very cost efficient solution to the problem of producing digital orthophotos.
The ADAM PROMAP can still be used as a conventional analytical stereoplotter, however, the advanced automatic features offer great productivity increases.
There are a number of further options that could be developed for the system in the future. For example, automatic interiors, automatic relative exteriors, high resolution scanning, feature digitising assistance functions are among the options that have been identified for the future. Once the basic hardware is installed, these options will only require a software upgrade.