DIGITAL STEREOPHOTOGRAMMETRY – EXPERIENCE WITH AN EXPERIMENTAL SYSTEM

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ABSTRACT

An experimental Digital Stereophotogrammetric System (DSS), which is based on a commercially available image processing system, has been set up at the Technical University of Berlin. Any kind of stereoscopic imagery, such as scanning electron microscope data, close range imagery, aerial photographs and satellite image data, can be processed stereophotogrammmetrically.

This paper reports on the practical experience concerning photogrammetric processing, especially of aerial photographs. Due to hardware restrictions, so far only subsections of image frames can be handled in reasonable time. The performance of the system as well as the accuracy that could be achieved are discussed and compared to the results obtained with an Analytical Plotter.

Based on the practical experience with the experimental DSS conclusions are drawn concerning the design and architecture of an operational system. An outlook is given to further system development, considering new hardware components.

INTRODUCTION

At the ISPRS meeting of Commission II, WGII/2 in Baltimore 1986, the authors reported on an experimental Digital Stereophotogrammetric System (DSS) which has been set up at the Technical University of Berlin. This system then was suitable for automatic processing of imagery reduced in size (512x512 pixels), such as digital scanning electron microscope images. Based on the existing hardware described in (KOENIG, NICKEL, STORL,1986) the authors have implemented algorithms for the photogrammetric processing of large data sets, especially of digitized aerial photographs.

DATA ACQUISITION

For converting the analogue aerial photographs into raster data, a color scanner of HELL company, Chromagraph DC 360, is used.

This system can handle transparency copies up to the format of 65x51 cm^2, a size which is limited by the diameter of the rotating scanning drum. The aerial photographs can be digitized in different resolutions. According to the experience of the authors, a resolution of 25 μm or 400 lines/cm is sufficient for stereophotogrammetric purposes. The advantage of higher resolution is too small to justify its costs. This means that a digitized stereo pair takes about 180 MB of disk storage. Analysis of the scanned imagery has indicated that the Chromagraph scans with high quality and very little geometric distortions. The radiometric reproduction quality is good so that only few preprocessing steps are necessary for image improvement provided that the quality of the photographs is sufficient.

Orientation

The orientation is done in two steps, i.e. relative orientation and absolute orientation. After relative orientation the images are resampled to the normal case of stereophotogrammetry. This leads to a more rational automatic evaluation and enables stereo vision of the whole model.

To overlook the scene both images are miniaturized to the size of one screen. A 23 cm x 23 cm aerial photograph scanned with a pixel spacing of 25 microns leads to about 9000x9000 pixels. Every 20x20 pixels are averaged and thus the whole scene can be visualized at one time. The sampled miniaturizations are held permanently in two of the four image memories. The scene parts to be actually processed are defined by positioning a 25x25 pixel window and are loaded into the two remaining memories.

For each image (at least two of) the fiducial mark regions are targeted this way. Fiducial mark matching then is performed by a sub-process (via an artificial template or via binarization and circle calculation). Image inner orientation is known and leads to the parameters of an affine transformation which computes image coordinates from pixel (i.e. scanner) coordinates.

Relative Orientation

From six up to any given number homologous points can be matched interactively for relative orientation. This can be done either by defining templates in the first and search windows in the second image or by using signalized object control points, if there are any. They can be searched in one image and matched to the other one or be searched independently in both images. Image coordinates again are given by the affine transformation mentioned above.

After this calculation resampling is carried out for the whole stereo area (normally using bilinear interpolation) to eliminate y-parallaxes. Thus the images are at hand for stereoscopic vision by anaglyphic means and processing along horizontal epipolar lines.

ABSOLUTE ORIENTATION

If the ground control points have not been measured for relative orientation this has to be done now. Using the resampled (i.e. the relatively orientated images) instead of the original images, stereoscopic view of the earth surface is provided. By the time this is realized in an anaglyphic way. A three dimensional floating mark is generated in the graphic overlay memory and can be moved by a mouse in x- and y- direction across the screen. Z- direction motion of the floating mark is performed by pressing two function buttons of the mouse. This way the DSS can be handled like a conventional analogue stereophotogrammetric system.

Control points without a known shape (i.e. they can not be modelled) have to be located manually which leads to an error less than 0.5 pixel. Thus, accurracy is depending on the digitization rate of the original images. In practice, a sufficient accuracy of absolute orientation is yielded by measuring at least six ground control points. Using ten points, absolute orientation resulted in standard plan deviations of 0.07 m for both the Analytic Plotter KERN DSR 11 and the DSS. The standard height deviations were 0.04 m and 0.06 m, respectively (image scale ≈ 1:5000).

3-D PROCESSING

Automated evaluation of a Digital Terrain Model (DTM) is a main feature of the DSS. At present DTM determination is performed by finding homologue points in two images in an initially predefined regular grid in object space. The algorithm uses the Vertical Line Locus (VLL) method (BETHEL,1986) to calculate approximate heights. The fine correlation is done by a least squares algorithm (ACKERMANN,1983). In order to save computation time there is no subpixel interpolation calculated during coarse search and the center pixel of the template window in the left image is set to the nearest neighbour. Thus, the final result does not represent a regular grid in object space any more.

Normally, with aerial photographs 10% to 20% correlation failures can not be avoided. Accordingly, some criteria have been developed empirically to find gross errors in correlation. These criteria, applied in the DSS, are the following:

- Despite existing epipolar geometry two-dimensional correlation may yield y-parallaxes caused by noise or spikes,
- the standard deviation of a parallax is higher than a predefined limit which was set for the actual imagery,

- the correlation coefficient is less than a threshold value normally 0.8), such results are tested by calculating the autocorrelation function in the neighbourhood of the point,

- large parallax differences occur between adjacent points.

However, processing aerial photographs in the DSS proved that some obviously wrong points are not excluded by these criteria. Empirical research indicated a direct relation between correlation failures and the variance, which is a rough parameter describing the texture within a window. This is why the variance is used as additional criterion to check correlation results and to decide wether a point should be accepted or not. The variance threshold value differs from image to image and has to be defined by the operator in each case.

Automatic processing of images and excluding points by the criteria mentioned above result in an irregular distributed cluster of 3-D points. The detected points can be displayed for stereoscopic view on the monitor to give the operator the chance of a last check on gross errors and to correct some points interactively. Furthermore, he is allowed to decide whether the amount and the distribution of points will be sufficient for DTM calculation. A point distribution overview can be displayed on monitor and/or plotter.

Tests with different images indicate that the strategies to examine correlation results are very stringent and nearly 40% of points are excluded - even reliable correlation results. Accordingly, it is neccessary to define a grid more dense than the finally intended one to have a sufficient number of points for DTM interpolation. If this number is too small, a rough DTM can be calculated. This DTM will be used to evaluate approximate heights for re-starting the automatic process to get a higher amount of homologue points.

Orientation (including miniaturization) takes about the same computing time as the corresponding work with an Analytic Plotter, except for image region loading. Resampling time with bilinear interpolation is 3 minutes for a 512x512 pixel section and correlation, starting when the first section is resampled, needs about one second per point depending on patch similarity and approximation quality. The standard height deviations of DTM points throughout evaluations of the testfield Brecherspitze near Munich (KUPFER,1987) were 0.02 % of the flying height.

FUTURE DEVELOPMENTS

With the existing hardware environment and the software tools the authors have designed a development system for studies of the performance of stereophotogrammetric processing with images of different sources. The next step of the activities will be the design of an operational system consisting of new hardware components. This system will be designed around a powerful workstation which for performance purposes should be based on a Reduced Instruction Set Computer (RISC) that has a relatively simple architecture. In contrast to conventional systems, a RISC consists of relatively few instructions, namely those which are used most frequently. Most of these instructions could be executed in a single cycle and have a fixed format for simple decoding. They have a large register set and are equipped with optimizing compilers which leads to a high performance with an instruction rate around 10 MIPS.

In addition to such a host computer, special hardware components, as described in (GRUEN,1987)´, are necessary for setting up a real time photogrammetric system. The use of parallel processing architecture is necessary in order to obtain the performance needed in photogrammetric applications. Today´s state of the art parallel processors could be classified as follows:

- Single Instruction Multiple Data (SIMD) processors, where each processor executes the same instruction at the same time, but on different data elements;
- Multiple Instruction Multiple Data (MIMD) processors, which can be segmented in Multicomputers, where each processor has its own attached memory and each independently executes its own program code, and Multiprocessors in which MIMD processors share a common memory;
- and Systolic Arrays, where each processor executes a portion of an algorithm or computation in a pipelined parallel fashion. All processors are synchronized to accept inputs and complete their computations at the same time.

Modern image computing systems make use of these architectures, for example PIXAR (SIMD), or AT&T´s Pixel Machine (MIMD), which is build around up to 82 Digital Signal Processors, rated at 10MFlops each. These systems offer a high computational power which is necessary for graphic and image processing applications. They are equipped with a large image memory - up to 48MB are common - and in most cases could be configured with parallel transfer disks, which accomodate the storage of large data sets, such as aerial photographs, and permit the high data transfer rates needed for fast image processing. High level language libraries - usually C-callable - for universal image processing needs facilitate the task to extend these system to a photogrammetric workstation.

An advanced stereophotogrammetric workstation with high performance should include as well a colour monitor which provides image sequential stereo display by use of liquid crystal shutter technology. The use of a simple spectacle with polarizing glasses makes a comfortable and flicker-free view of the stereoscopic images possible and seems to be the optimal solution.

Conclusions

Experience has shown that processing of stereoscopic imagery by use of conventional system architecture and photogrammetric standard algorithms leads to satisfactory results concerning the accuracy. Compared with conventional plotting in an Analytical Plotter the algorithms implemented in the DSS for automated evaluation are too time-consuming. At present a new photogrammetric workstation based on state-of-the-art technology is under design, which will solve these problems.

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