Developing of Automatic Mapping in P.R. China

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Abstract

A digital photogrammetric workstation system is developed in P.R. China which performs automatic mapping from space imagery data efficiently.

Since the earlier periods of space programmes, surveyors and cartographers have been looking forward to the day when imagery data obtained from space can be utilised in mapping. With the launched and launching satellites, such as SPOT, MOMS, ERS-1, Radarset, etc., especially the announcement of Eyeglass, people are more interested in mapping using space imagery directly. This paper first compares two stereo imagery mapping methods (traditional photogrammetry and digital photogrammetry), then discuss the theory and practice in details in stereo viewing and automatic stereo measurement (image matching) of stereo imagery by Digital Photogrammetric Workstation.

1. Background

Since its foundation in 1956, Wuhan Technical University of Surveying and Mapping (WTUSM) has become the main training, education and researching base in surveying and mapping area in P.R. China, it centralises nearly whole famous professors and outstanding researchers over China in its surveying and mapping departments of photogrammetry and remote sensing, cartography, geodetic science and engineering surveying (WTUSM also has departments of computer science, electronic engineering, optical instrumentation and printer in order to support those surveying and mapping departments). WTUSM already achieved lots of success in its research fields of surveying and mapping, such as automatic mapping using digital photogrammetric technique, convertor development of analogue instruments, aerialtrangulation with GPS data, map digitisation with scanner, object-oriented GIS development, map generalisation and integrated expert system for map presentation. In the following sections we will concentrate in the topic of digital photogrammetry and *VirtuoZo* is an example of the achievement of automatic mapping using state of the art of digital photogrammetry in WTUSM.

1.1 The history of *VirtuoZo*

With the rapid development, traditional photogrammetry has developed from photogrammetry to photogrammetry and remote sensing. Now, It can be called "Geomatics" by the generalisation with other disciplines. It had successfully developed from analogue photogrammetry to analytical photogrammetry and entered into a new stage of digital photogrammetry. Digital photogrammetry has a long time history, the original idea is from automation of photogrammetry. The concept of a digital photogrammetric workstation has been around for more than ten years. Prof. Wang Zhizhuo, the founder of photogrammetry and remote sensing of P.R. China, WTUSM, proposed to establish fully digital automatic mapping system in 1978, his description led to the development of the Wuhan Digital Automatic Mapping System (*WuDAMS*) which was the national key project of chinese natural science and technology. *This project spanning three national five year plans* from *1982* to *1996* are led by Prof. Wang Zhizhuo and Prof. Zhang Zuxun.

This research project "Fully Digital Automatic Mapping Theories and Methods" recently won the second class excellence award of the Sixth Chinese National Science Award (1993), which is the highest science award in P.R. China. This project resulted in a commercial digital photogrammetric software package called *VirtuoZo* (formerly *WuDAMS*) through the cooperation with Queensland University of Technology (QUT), Australia, in recent two years. *VirtuoZo* runs on Silicon Graphics Workstations (presently tested and operating on Personal Iris 4D/25, 4D/30 & 4D/35, Indy, Indigo and Indigo2), and is capable of producing DEMs (Digital Elevation Models), Orthophotographs, Contour lines and Perspective Stereo Views from digital (scanned) stereo pair of positive or diapositive photography, or SPOT stereo imagery. The following is the brief review of the history of *VirtuoZo*:

1978: Prof. Wang Zhizhuo: Fully Digital Automatic Mapping System (*WuDAMS*)

1985: Version: One
Language: *Fortran IV*
Platform: *SCANDIG3, NOVA3/12* (64K RAM), *Filmwrite II*,
Image Matching: Single-Point Cross Correlation and Least Squares Matching (LSM)

1989: Version: Two
Language: *C*
Platform: *SIEMENS* Workstation
Image Matching: Bridging-Mode based Dynamic Programming and Multi-Points LSM

1992: Version: Three (change name to *VirtuoZo*)
Language: *C + GL (Silicon Graphics Library) + Motif*™
Platform: *Silicon Graphics* Workstation
Image Matching: Global Relaxation Image Matching

2. Traditional and Digital Photogrammetry

There are two approaches in mapping: traditional way (analogue and analytical photogrammetry) and digital way (using digital photogrammetric workstations). The first one is to use photographs or hardcopy images in various kinds of complicated optical instruments or in analytical stereo plotters. New softwares are needed to be developed in order to deal with the satellite imagery data if satellite images are used in an analytical plotter because this kind of image projection is referred to the scan line central projection. The second one is to use image data in digital photogrammetric workstations.

The cardinal difference between digital photogrammetry and traditional photogrammetry is that digital images or digitised image data are used in digital photogrammetry but optical photos (hard copy images) are used in traditional photogrammetry. Therefore, digital photogrammetry is also called softcopy photogrammetry. Due to the different processing media, there has led a series of differences between digital photogrammetry and traditional photogrammetry.

- In traditional photogrammetry, various kinds of complicated and accurate optical mechanisms, such as rectifier, stereocomparator, stereoscopic plotter, analytical plotter, and orthophotoprojector, etc., are used to accomplish different tasks. However, in digital photogrammetry, the hardware is only computers (PC or workstation) and standard input and output equipment (scanners, plotters and printers). It can accomplish all photogrammetric tasks with digital photogrammetric softwares. Actually, a digital photogrammetric workstation is composed of the following two parts:

Digital Photogrammetric Software + Computer

• Digital photogrammetry extends the adaptability of photogrammetric system because the hardware of the system is a workstation, it can be used to process with image data from different sensors with appropriate modification of software.

• Digital photogrammetry makes it possible for the intelligence and automation of photogrammetry. The digital photogrammetric software is composed of two parts:

Analytical Photogrammetric Software + *Image Processing Software*

Various image processing algorithms and softwares can be used in the second part. For example, relaxation technique of pattern recognition is used in *VirtuoZo* for image matching. It enhances greatly the global consistency and reliability of image matching and the matching speed of parallax measurement is about 400 points per second on a Silicon Graphics workstation Indigo 2.

• Digital Photogrammetry promotes the combination of photogrammetry with other disciplines and widely extends the application of photogrammetry. On the other hand, it does not require much photogrammetric knowledge for the operators. Even more, "Using professional digital photogrammetric equipment, the need for knowledge of the photogrammetric theories, clearly is beginning to vanish" [San, 1993]. Especially, the photogrammetric system is convenient and transparent based on using icon technology of Motif.

We can see from the above that digital photogrammetric roots are computer technology and fundamental principle of traditional photogrammetry, but it's a limited understanding if people think that a digital photogrammetric workstation is a new type of analytical plotter. "Digital photogrammetry brings about a bigger revolution than any instrument or methodology development in photogrammetry up to now. When it is fully developed, its effects will be felt also in neighbouring fields. Photogrammetry itself will be dramatically different" [Helava, 1992]. In the following sections 3 and 4 we will focus primarily on some key parts of a digital photogrammetric workstation such as Stereo View and Image Matching etc.. And once all those basic problems are solved, it declares that digital photogrammetric workstations reaches a remarkably mature technical status. and are brought to practice.

3. Digital Photogrammetric Processing of Stereo Imagery

3.1 Stereo View

It is well known that the main task in photogrammetry is stereo measurement. The basic processing is getting stereo view first and then matching corresponding points between left and right photos (or images). In order to realise the stereo observation, on an analogue plotter or an analytical plotter, the human operator can get the stereo model without y-parallax using relative orientation results. On a digital photogrammetric workstation, the processing is similar to traditional method: first, performs relative orientation of one stereo image pairs, then with relative elements, rectifies both raw images into epipolar images. Without epipolar rectification, stereo viewing is more strenuous and sometimes maybe impossible, and epipolar images also play a key role in the automatic image matching algorithms.

With the image obtained from a metric camera, there is a rigorous definition of epipolar line: the line of intersection between a plane passing through the photographic baseline and photo plane. However, it is difficult or impossible to have corresponding pairs of straight epipolar lines for the space scanned images, such as SPOT and MOMS images, because there is no single baseline for this kind of stereo image pair. Furthermore, the geometric characteristics of space image data between different sensors are also different. Such as the geometry of MOMS-02 which uses three linear sensors for looking forward, down and backward to obtain stereo pairs is completely different from the geometry of SPOT which obtains stereo images from different orbits with the oblique side looking imaging sensors.

Radar imagery provides cartographers a new source of data for the purposes of map production and environment study. But positions in radar imagery are the functions of the distance from the object to the sensor.

Therefore, to obtain the epipolar images from stereo pair of space stereo scanned images is a critical problem in space mapping. A flexible method of generating epipolar lines from SPOT images was developed in WTUSM [Zhang and Zhou, 1989] and has been used by *VirtuoZo*. In fact this method of epipolar lines extraction is not only suitable to SPOT images, but also can be considered as a general procedure for generating stereo viewing from scanning images.

3.2 Algorithms in Digital Photogrammetry

There are a lot various kinds of l algorithms in digital photogrammetry according to various tasks, for examples,. feature extraction algorithms, feature location operators, image matching and understanding algorithms, etc.. In the following paragraphs, only image matching algorithms are discussed.

A large number of static stereo image matching methods exists. Most methods, however, fall into one of two categories: region-based and feature-based, according to the nature of the measurement primitives. A correlation technique or some simple modification is applied to certain local around the pixel to evaluate the quality of matching. The feature-based methods use intensity edges, linear features, or intensity peaks which corresponding to discontinuity in the first order derivatives of intensity. Recently, many researchers have been using neural networks based on either intensity or edges for image matching. On the other hand, from the point of view of patten recognition, image matching problem is a classification problem (i.e. finding which right image point belongs to the left image point), so all above image matching algorithms can also be classed into three kind of algorithms: parallel, sequential and relaxation.

3.2.1 Parallel and Sequential Methods

Parallel methods make the classification decision at each point independently of the decisions at other points; thus they could be applied at each point simultaneously, if a suitable parallel processing capability were available. Most sequential methods, on the other hand, do make use of previous decisions, both in choosing the point to be classified next and in defining the classification criteria to be used. This makes sequential methods fundamentally more powerful than parallel methods, since they can "learn as they go" to define highly precise criteria for classification. On the other hand, sequential methods cannot be speeded up greatly even if parallel processing is available, and their results usually depend on the order in which points are examined.

3.2.2 Relaxation Method

Relaxation is an iterative approach to segmentation which makes fuzzy or probabilistic classification "decisions" at every point in parallel, at each iteration, and then adjusts these decisions at successive iterations based on the decisions made at the preceding iteration at neighbouring points. The relaxation approach is order-independent, and can be greatly speeded up by parallel processing, since each iteration is parallel, and typically only a few iteration are necessary. On the other hand, it is more powerful than one-shot parallel methods, since its initial classifications are refined, at each iteration, based on the local context. It makes tentative, rather than firm, classifications at each stage, and repeatedly reconsiders them, unlike the other types of method, which usually make decisions at each point only once.

A series of image matching algorithms have been studied and tested since 80's in WTUSM, they are included: single point cross correlation method, single point and multiple points least squares methods, multi-information and multi-criterion adaptive image matching [Lin, 1988], bridging mode feature-based matching, dynamic programming image matching [Zhang, 1990], and finally a relaxation approach for image matching was chosen by *VirtuoZo* [Zhang et al 1992, Wu, 1993]. Our further research shows the technique of array algebra can improve tremendously the very lower computational efficiency of normal multi-point least squares matching [Wu, 1993]. Our relaxation image matching results show that the both reliability and efficiency have been improved greatly and the high computational efficiency and practical accuracy can satisfy the applied demands of digital photogrammetric automatic mapping.

4. Examples for Automation in *VirtuoZo*

4.1 Relative Orientation

Relative orientation is especially suited for automation because only a small number of parameters, namely 5, need to be determined and a large amount of corresponding points are available after performing automatic matching procedure. Instead of using a limited number of conjugate (tie) points as in analytical photogrammetry (usually 6 or 9 points), it is possible to use a large number of corresponding points with less accurate coordinates, and still can obtain the same accuracy as traditional relative orientation does, and some false matched points can be tolerated. In *VirtuoZo* we use a hierarchical feature based matching approach to perform relative orientation. From original resolution the following levels of the image pyramid are computed by reducing the number of pixels by a factor 3 in each coordinate direction. In every level the following procedure is employed:

- Extract feature points separately in left and right images using the Förstner operator [Förstner, 1986].
- Set up a preliminary list of candidates of corresponding points, this is done by establishing the spatial relationship of all feature points in left and right images and the results of previous level are used.
- Calculate the parameters of relative orientation using least squares estimation and a threshold of residuals is used to eliminate probable gross points and mismatches.
- Improve the accuracy of image matching using least squares matching.

Some stereo images were tested and their results of relative orientation are presented in Tab.1.

Stereo Pair Name	Image Size	Pixel Size (μm)	No. of matched feature points	y-parallax by Pixel
Yinxia Aerial	2240 x 2240	0.1	82	0.12
DPI Aerial Image	9644 x 9644	0.025	112	0.54
Oblique Image	2282 x 2266	0.0212	72	0.556
SPOT Image	6000 x 6000	0.025	115	0.8

Tab.1 Results of automatic relative Orientation

4.2 DEM Generation

Since the manual measurement of DEM data is a very time consuming process, automation has been attempted for nearly 3 decades and today operational solutions exist for medium and small scale imagery. There are two ways to generate DEM: 1) perform image matching in image space and then interpolate into DEM; or 2) perform image matching in object space and directly get DEM. Both approaches have advantages and disadvantages (the discussion is beyond this paper). In *VirtuoZo* the image matching and DEM generation are separated two parts, combining with image matching, we think, interpolation of DEM is much easier and image matching in image space gives the rein to epipolar lines' great computational efficiency, this is great relevance for practical applications.

Three test areas are chosen from Tab.1, they are agricultural use, hilly and rich in texture (Yinxia Aerial Image), Oblique helicopter close-range images (Oblique Image), and finally a SPOT stereo pair (SPOT Image). All three test areas provide enough control points for check DEM. Tab.2 shows their image matching speeds and accuracy of automated generated DEMs (the tests are based on a *SGI* Indigo 2 workstation)..

Stereo Pair Name	No. of Matched Points	Matching Speed (p/s)	Generated DEM Size	No. of Control Points	DEM accuracy (m)
Yinxia Aerial	75,082	417	97 x 152	8	1.9198
Oblique Image	104,949	430	47 x 98	7	0.1581
SPOT Image	173,375	351	249 x 190	19	11.720

Tab.2 Results of Image matching and DEM accuracy

5. Conclusions

The digital photogrammetric workstation will serve as a main tools in the process of cartography and mapping, ***VirtuoZo***, an example of this kind of workstation was developed in P.R. China. Besides it provides all the advantages of the traditional photogrammetric instruments, ***VirtuoZo*** uses the advanced image matching technique to generate DEMs and orthophotos in a high efficiency and it solved the problem of stereo view when using the satellite image data due to the complication of scanning image' geometry. After sixteen years' research and development, the research and developing team of *VirtuoZo* believes that the final version *VirtuoZo* will take a great effect in many practical automatic mapping (or 3D reconstruction) areas which require digital photogrammetric technique.

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