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The Operational Comparison of SPOT GCP Acquisition and Accuracy Evaluation

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Abstract

This paper presents an investigation into the operational comparison of SPOT triangulation to build GCP library by analytical plotter and DPW (digital photogrammetric workstation). GCP database derived from current SPOT images can be used to other image sensors of satellite, if any reasons, such as lack of topographic maps or GCPs. But, general formulation of a photogrammetric process for GCP measurement has to take care of the scene interpretation problem. There are two classical methods depending on whether an analytical plotter or DPW is being used. Regardless of the method used, the measurement of GCPs is the weakest point in the automation of photogrammetric orientation procedures. To make an operational comparison, five models of SPOT panchromatic images (level 1A) and negative films (level 1AP) were used. Ten images and film products were used for the five GRS areas. Photogrammetric measurements were carried out in a manual mode on P2 analytical plotter and LH Systems DPW770. We presented an approach for exterior orientation of SPOT images, which was based on the use of approximately eighty national geodetic control points as GCPs which located on the summit of the mountain. Using sixteen well-spaced geodetic control points per model, all segments consistently showed RMS error just below the pixel at the check points in analytical instrument. In the case of DPW, half of the ground controls could not found or distinguished exactly when we displayed the image on the computer monitor. Experiment results showed that the RMS errors with DPW test was fluctuated case by case. And the magnitudes of the errors were reached more than three pixels due to the lack of image interpretation capability. It showed that the geodetic control points is not suitable as the ground control points in DPW for modeling the SPOT image.

Keywords : ground control point, SPOT image, analytical plotter, digital photogrammetric workstation

1. Introduction

The images at a resolution of 10 m/pixel provided by the previous SPOT satellites have been widely used for the generation of cartographic products at the scale of 1:100,000 or 1:50,000. The resolution of the images of the future SPOT 5 satellites (5 m/pixel for panchromatic images and 2.5 m/pixel for HRG sensor images) should permit to refine the precision of these products. One of major capabilities of the current SPOT system is suitable for cartographic work at scales of 1:50,000 to 1:100,000. Due to its ability to view areas at the oblique, successive imagery can be acquired at an interval of approximately two and a half days. A major focus in research activity is to increase the accuracy of rectified images by achieving sub pixel accuracy when the image coordinates of the GCPs are calculated. Therefore, the strategy will not work if there is no (or not enough) GCPs that can be found on the images to be rectified. This is particularly true in many developing countries where large scale maps are less prepared and good quality of GCPs may be difficult to be found in an image to be rectified. On the other hand, the accuracy requirement for mapping in these less developed areas probably is relatively low and the manual method still can be used to locate the GCPs in the image (Zhou, 1990).

Digital image processing has been made available to photogrammetry a number of techniques for automatic measurements of fiducial marks in inner orientation process and tie points. In recent years the potential of automating important photogrammetric processes has been demon-

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strated (Bjake, 1996). As of now, none of these approaches to automate the exterior/absolute orientation solve both the detection and the pointing problem without restricting constraints. Some hybrid solutions may well be possible, but are still not available. This paper presents an investigation into the operational comparison of SPOT triangulation to build GCP library by analytical plotter and DPW (digital photogrammetric workstation). GCP database derived from SPOT image can be used to other image sensors of satellite, if any reasons, such as lack of topographic maps or GCPs. But, general formulation of a photogrammetric process for GCP measurement has to take care of the scene interpretation problem.

There are two classical methods depending on whether an analytical or DPW is being used. To conduct the operational comparisons, five models of SPOT panchromatic images (Level 1A) and negative films (Level 1AP) were used. Ten images and film products are used among the three viewing angles to get the best stereoscopic image quality. Photogrammetric measurements were carried out in a manual mode on the P2 analytical plotter and the LH Systems DPW770.

2. Measurement of Ground Control Point-Methodology

2.1 The SPOT Geometric & Functional Model

SPOT scenes are segmented and delivered in an average GSD of 10 m for the panchromatic image or 20 m for the multispectral mode in 60 km × 60 km of ground coverage. For photogrammetric processing, the required SPOT product is processed to level 1A; only radiometric correction has been done. Level 1AP refers to hard copy negatives with specially marked image corners for fast and more accurate inner orientation measurement. The link between a ground control point and its image coordinate can be represented as follows (Azubuike & Alfons, 1996).

$$Xg = Xs + S\ Ri\ Rb\ Rs\ xP$$

where

xP : image coordinates vector.

Xg : ground coordinates vector in the earth centered inertial geocentric coordinate system

Xs : satellite position vector in the earth centered inertial geocentric coordinate system

S : cale factor

Ri : rotation from the orbital reference system to the earth centered inertial geocentric coordinate system

Rb : rotation between the attitude reference system and the orbital system

Rs : rotation between the sensor and the attitude reference system

2.2 Methodology

GCP plays a very important role in image rectification. The number and distribution of the GCPs and the accuracy of their coordinates, both on the image to be rectified and on a base map, are the most important factors determining the overall accuracy of the rectification. Operator can manually determine the locations of GCPs on digital image. Regardless of whether the original or enlarged image, the positional accuracy of the GCP heavily depends on the experience and performance of the operator. Furthermore, the full automation of rectification is impossible without an implementation of the automated determination of the GCP (Zhou, 1990). Again, this is extremely difficult since maps were products of cartographic work. Information of the map has been compressed, generalized, and symbolized, and thus looks quite different if it is viewed by computer programs.

There are two classical methods depending on whether analog or analytic plotter is being used. These two methods are developing and diversifying under the joint effects of two factors: the more and more widespread use of data in digital form; the development of information processing systems integrated in new plotters. Due to the geometric characteristics, it is not possible to use SPOT films directly on classical analog or analytic plotters designed for the conical geometry of aerial photographs. Recent progress in digital photogrammetry has opened to new possibilities. Several methods and computer programs for digital triangulation are being developed. Although the block adjustment phase of aerial triangulation has been automated to a great extent, GCP acquisition phase have practically remained conventional. Regardless of the method used, the measurement of GCPs is the weakest point in the automation of photogrammetric orientation procedures.

2.2.1 Use of SPOT Films on Analytical Plotter

The standard orientation programs for relative and absolute orientation in analytical plotters are unable to process the special geometry of SPOT images. A special orientation software is therefore required for plotting SPOT stereo models. In addition, the real-time loop of the plotter software needs to be extended by correction grids because SPOT images do not feature central perspective. When we used this method, it can be worked with unprocessed images, but convergence of trajectories, the difference in scale (or resolution) along lines and the land smear effect for asymmetric view configurations make stereoscopic viewing more difficult and tiring for operators (GDTA, 1995). One of its main characteristics is that it can be used to plot profile or contour

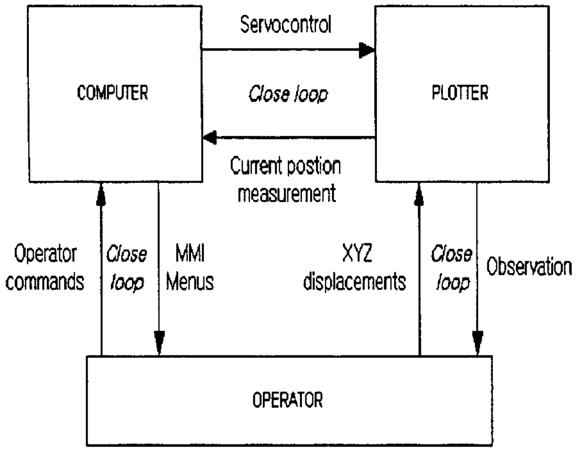

Fig. 1. Diagram of an Analytical Plotter (O.KOLBL, 1989).

lines directly, and these lines are subsequently reused by the Computer Aided Drawing (CAD) system and the output system. Finally, the digital mapping software can also include complementary measures made in the field and can inset them in printed outputs. Fig. 1 represents the schematic view of the optical system in analytical photogrammetric station.

2.2.2 Use on Digital Plotter

These new types of instruments open up a wide range of prospects and make it possible to work in "all digital" in order to avoid handling films. They allow the use of new tools based on specialized processors to process information directly in digital form in complete system with DBMS and stereo plotter (GDTA, 1995). Digital photogrammetry is coming out from its research and development period and into day-to-day practice. Commercial photogrammetric companies are rapidly turning to digital photogrammetric workstations and systems to meet production requirements.

3. Test Data and Photogrammetric System Used

3.1 Test Data

Once the test area were defined a detail search was undertaken. The search criteria used in this study were as the following priorities:

- Cloud free
- Recent acquisition
- Differences of acquisition date
- Near vertical, left and right viewing angle
- SPOT panchromatic data only

Five SPOT GRSs of level 1A and 1AP products which taken and archived by SPOT 3 HRV 2 instrument in 1995 were used in this experiment. The photo scale was approximately 1:300,000 in SPOT level 1AP film products. Fig. 1 & 2 presents the test area and SPOT GRS system for the test zone.

3.2 Ground Control Points and Check Points

To aid identification of ground control points, series of 1:50,000 plots of the scenes were produced. These were initially georeferenced using the satellite positional data that came from SPOT header file. The operator can identify good points by their location and improve their visibility. The GCPs were selected among the 1st, 2nd, 3rd, and 4th geodetic control point, which maintained by the NGI (National Geography Institute) in Korea. The NGI maintains all national control points in order to provide reliable and accurate references for the horizontal and vertical positions necessary for all the projects related to land such as mapping, cadastral surveys, and various public development projects. The national control points are divided into two categories, primary and secondary. The number of the former are about 1,300 existing 1st- and 2nd- order horizontal control points, and the latter are approximately 15,000 3rd- and 4th- order control points. Survey records and final data of control points, including horizontal control points, vertical control points (Bench Marks) and traverse points, are filed in books available for public use. To verify the modeling accuracy, we used 89 check points covering the same test area. The

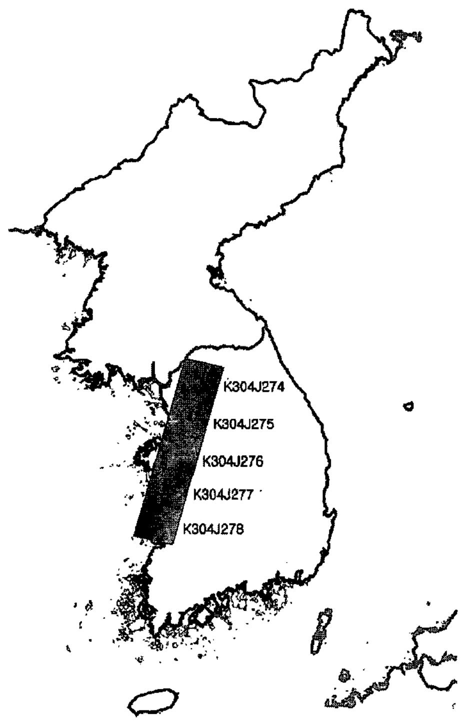

Fig. 2. Test Area & SPOT Scene Number.

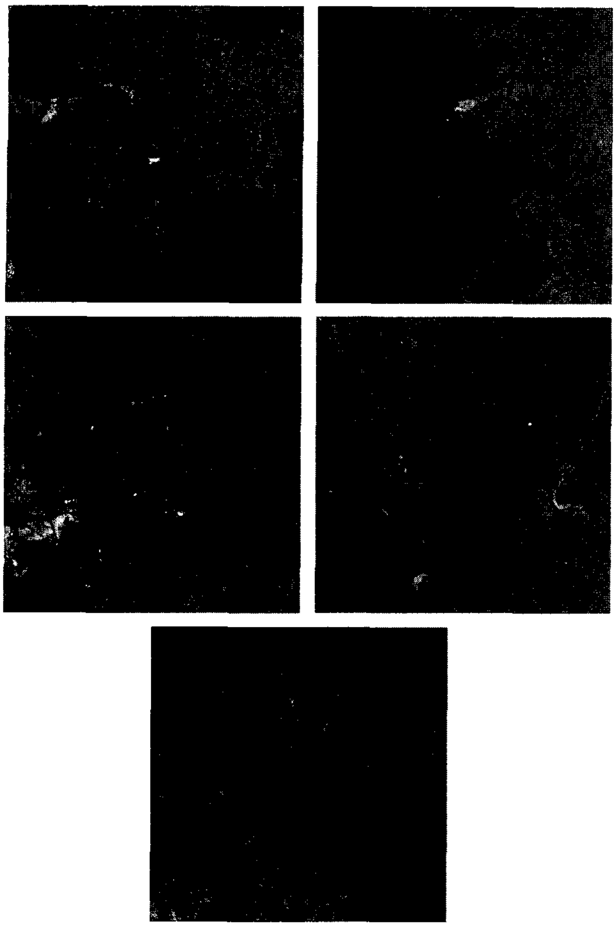

Fig. 3. SPOT Images for the Test Area.

check points came from 1:5,000 digital map, which produced by NGI's digital map database. The database is composed 10 layers: road, railway, river, building I & II, vegetation, facility, topography, administrative or regional boundary, and anotation. Most of the check points were acquired at road layer and all the points were verified the readability in SPOT stereo viewing .

3.3 Hardware and Software

The SPOT stereoscopic modeling was performed on the P2 analytical plotter and the LH Systems digital photogrammetric workstation DPW770. For the analytical plotter the software released BINGO-SPOT 3.0 was used, that can be used in triangulation with SPOT stereomodels in the PHOCUS environment. In DPW770, we used the software released SOCET 4.2.0.

3.4 Triangulation

3.4.1 Analytical Plotter

Level 1AP images were are stretched in the line direction to compensate for scale differences in the *x* and *y* directions in oblique viewed photography. This stretching must be eliminated during the measurement of the image coordinates. To perform the interior orientation, the fiducials have been measured by the means of the manual method. Affine transformations were used, and the resulting standard deviation (σ) were less than 2 μm for the entire test data. For the exterior orientation, we measured the image coordinates of the control point with P2 analytical plotter. After that, we collected the orbit parameters for all images and entered the control point coordinates in a file. The adjustment of the SPOT data was performed with the BINGO program. The orientation parameters have been computed by athe bundle adjustment including manual measurement of 89 check points.

3.4.2 Digital Photogrammetric Workstation

All of the digital measurement was performed with the SOCET SET software. The SPOT math model in SOCET SET is a push-broom sensor model that uses the header data supplied with the SPOT 1A or 1B scenes. SOCET SET uses up to 13 parameters to adjust the SPOT sensor model. SOCET SET uses a classic, fully weighted, least squares bundle adjustment to solve for these parameters. The adjustment of the SPOT imagery was performed scene by scenes. Ground control and tie points between scenes were independently observed over the test area.

4. Test Results

93 GCPs were used, but five were removed as consider-

Table 1. Test Results with Analytical Plotter

Test Area	Number of GCPs & Check Points	RMSE (m)					
		GCPs			Check Points		
		X	Y	H	X	Y	H
I	18/18	2.86	4.37	6.44	4.89	5.28	8.36
II	18/16	3.67	1.97	4.14	5.38	3.68	7.39
III	16/17	2.18	3.62	4.23	3.87	4.48	7.22
IV	16/18	3.06	2.85	4.01	3.28	2.22	5.15
V	20/20	3.27	2.35	4.01	3.62	4.97	7.48

Table 2. Test Results with Digital Photogrammetric Workstation

Test Area	Number of GCPs & Check Points	RMSE (m)					
		GCPs			Check Points		
		X	Y	H	X	Y	H
I	18/18	33.46	39.82	43.67	38.32	45.72	47.36
II	18/16	33.34	37.67	29.45	35.47	42.34	39.38
III	16/17	29.98	34.22	31.99	32.43	35.49	46.54
IV	16/18	32.45	40.21	28.38	43.23	36.71	52.38
V	20/20	37.16	38.39	48.26	38.97	48.28	55.69

ing blunders. These GCPs are known to have a determination RMS error of less than 1 meters in planimetry and height, but identification errors could add another 20 or 30 meters, because we used the geodetic control points in the mountain as GCPs. The summaries of the test results were given in Table 2 and 3.

5. Analysis and Conclusions

Using approximately sixteen well-spaced geodetic control points per model, all segments showed RMS error just below the pixel region at check points in analytical instrument. This result showed that only identification errors were introduced because test were done using the geodetic control points that located in the top of the mountain as control points. In case of DPW, half of the ground controls could not found or distinguished when we displayed the image on the monitor.

It presented that the RMS errors with DPW test was fluctuated case by case. And the magnitudes of the errors were reached more than three pixels. Due to the lack of image interpretation capability in image product comparing with film. It showed that the geodetic control points is not suitable as the ground control points in DPW for modeling the SPOT image. The RMS errors for the 88 GCPs which modeled at analytical plotter were about 2-5 m in planimetry and 5-8 m in height. The RMS values for the same number of GCPs at the DPW were about 32-45 m in planimetry and 39-55 m in height.

If the results in this study can be verified by further experiment, the method presented here may be profitably and reasonably applied to GCP acquisition, map revision and thematic mapping with SPOT image for the developing country. The test result revealed that geodetic control points can be sufficiently used as ground control point in analytical plotter. But, problems may occur in the case of digital photogrammetric workstation due to the lack of interpreting and finding the conjugate points for geodetic control point on mountainous area.

The results presented in this topic have also proved the feasibility of applying the analytical plotter to locate the GCPs with subpixel accuracy for SPOT images by manual interpretation of geodetic control point in the film product. But, the positional accuracy of the GCP heavily depended on the experience and performance of the operator. So, automatic or semi-automatic technique, which can be used to locate the GCPs for higher accuracy than the manual method in digital environment should be studied in the future.

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