RESEARCH ON THE DOM UPDATE BASED ON ZY-3 SATELLITE IMAGES AND IMAGE CONTROL POINTS DATABASE

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ABSTRACT: It is proposed a new method that quick updating 50,000 scale DOM based on the ZY-3 satellite images and Images Control Points Database obtained from the existing 10,000 scale DOM and DEM. The construction of GCP Image Database is introduced, and the fast searching GCP Image Chips from the database is proposed. And the auto-matching and elimination of error points are presented. What's more, experiments in the representative area, such as Heilongjiang and Gansu Province, has been implemented and analyzed. The result demonstrates the feasibility and high-efficiency. At last, popularization the updating method in the whole country is recommended to meet the quickly developing requirement, especially in the West China.
KEY WORDS: Image Control Points Database; DOM Update; ZY-3 Satellite

1. PREVIEW

The 1:50,000 scale fundamental geographic information database is the key part of the Digital China Geo-spatial Frame-work(DCGSF) and the fundamental and strategic information source, which has been applied in the planning, designing and construction in the field of water conservancy, communications, energy sources, telecommunications and others. Also, the 1:50,000 maps plays a very important role in the Second National Land Investigation, the First National Water Conservancy Survey, Three River Sources Ecologies Construction and Disaster Prevention and Reduction(Liu, 2007). GCP(Ground Control Points) is the basic datum source for the geometric rectification of satellite images. In the conventional way, the coordinates of GCPs are obtained by full-field surveying, such as RTK-GPS, full-station and so on. What's more, the method of getting GCP by manual selection from the DLG(Digital Linear Graphic) is low-efficiency and low-accuracy. For the satellite images from different sensor source and time of the same region, the same points may be selected repeatedly, which will be time-consumed and low-efficiency(Chen, 2006;Mo, 2007).

With the development of remote sensing, the acquired period and accuracy of satellite images has improved dramatically, which offers abundant and reliable data source to construct the image GCP database. What's more, the improvement of auto-recognition technology offers the foundation for the application of the image GCP database, because the automatic image matching algorithm can be implemented during searching the same point of the GCP. In a word, the Image GCP Database contains the attribute information and image texture of the GCPs, which can aim to "only constructed for one time, partly-refreshed, but used repeatedly". Based on the national fundamental maps of 1:50,000 or 1:10,000 DOM and DEM, there will be huge economical value and social value to update the existing DOM by ZY3 satellite image after constructing the Image GCP Database.

2. INTRODUCTION TO THE ZY3 SATELLITE

ZY3 satellite is the first civilian high resolution stereo surveying and mapping satellite, which has been launched in Taiyuan Satellite Launching Center on 9th, Jan 2012. On the satellite, there are three-array panchromatic cameras and one multi-spectral camera, which can guarantee the data source for the 1:50,000 DOM update (Deren Li,2012;Guoyuan Li,2012). The parameters of the satellite are illustrated in table 1.

Orbit Altitude	506km, Sun-synchronous orbit
Inclination Angle	97.421°
Equator Crossing Time	10:30AM
Spacecraft Lifetime	4years
Weight	About 2630kg
Spectral Bands	Panchromatic(0.45-0.80μm) Blue (0.45-0.52μm) Green (0.52-0.59μm) Red (0.63-0.69μm) NIR (0.77-0.89μm)
Ground sampling distance(nadir)	Panchromatic Nadir 2.1m Front-back view 3.5m Multi-Spectral 5.8m
Swath width（km）	Panchromatic Nadir 50km Front-back view 52km Multi-spectral 52km
Repeat period	59days
Revisit time	5days
Base to height ration	0.89

Table 1. The parameter list of ZY-3 Satellite

The standard RPC(Rational Parameter Coefficient) is the distributed auxiliary parameters of ZY3, then all the geometric after-processing of the image is according to the rational function model. The standard rational function model is described as equation 1 and the detailed information about the resolution and application is presented in papers(Tao C,2001; GRODECKI J,2003; Yongsheng Zhang,2004; GuoZhang,2005).

$$r_n = \frac{Num_S\left(P_n,L_n,H_n\right)}{Den_S\left(P_n,L_n,H_n\right)}$$

$$c_n = \frac{Num_L\left(P_n,L_n,H_n\right)}{Den_L\left(P_n,L_n,H_n\right)}$$

(1)

Where, (P_n,L_n,H_n) means the standard ground coordinates
(c_n,r_n) means the standard image coordinates

$$P_n = \frac{P - P_0}{P_s}$$

$$L_n = \frac{L - L_0}{L_s}$$

$$H_n = \frac{H - H_0}{H_s}$$

$$c_n = \frac{c - c_0}{c_s}$$

$$r_n = \frac{r - r_0}{r_s}$$

$$(2)$$

Where, $(P_0, L_0, H_0, r_0, c_0)$ is the standard offset parameters, $(P_s, L_s, H_s, r_s, c_s)$ is the standard scale parameters.
And the polynomial of equation (1) is

$$\begin{aligned}
Num_S(P_n, L_n, H_n) &= a_1 + a_2 L_n + a_3 P_n + a_4 H_n + a_5 L_n P_n + a_6 L_n H_n + a_7 P_n H_n + a_8 L_n^2 \\
&+ a_9 P_n^2 + a_{10} H_n^2 + a_{11} L_n P_n H_n + a_{12} L_n^3 + a_{13} L_n P_n^2 + a_{14} L_n H_n^2 \\
&+ a_{15} L_n^2 P_n + a_{16} P_n^3 + a_{17} P_n H_n^2 + a_{18} L_n^2 H_n + a_{19} P_n^2 H_n + a_{20} H_n^3
\end{aligned} \quad (3)$$

What's more, $Den_S(P_n, L_n, H_n)$, $Num_L(P_n, L_n, H_n)$, $Den_L(P_n, L_n, H_n)$ also can be described as the three degree polynomial about the standard ground coordinates (P_n, L_n, H_n).

3. THE CONSTRUCTION AND APPLICATION OF IMAGE GCP DATABASE

3.1 Construction of Image GCP Database

The GCP Image chip is the extension of conventional GCP, and there are two kinds data: image texture and attribute data. The attribute data contains(MoHua,2007):

1. the geographic position information of GCP, such as three dimension coordinates X,Y and Z;
2. the supplement information of the geographic coordinate, such as the coordinate system, the ellipse parameters and the projection type.
3. the supplement information of the GCP image, such as sensor type, band, width and height of the image, image resolution and so on.
4. the description of GCP feature, such as the cross or the center point of the roads, which can be uses as the searching requirement from the database.

Image GCP Database is the collection of storing, management and service of GCP Image chips. The conventional database, the image texture and attribute information are stored individually. In this paper, the image and attribution information of the GCP is stored in the database together, which avoids the weakness of conventional method that storing them isolated induces destroy the integrity and the safety of the GCP information. The image texture information is stored as one BLOB(Binary Large Object) field of the data table, which contains other attribute information of the GCP such as geographic coordinates of the central point, the ellipse type, projection mode and so on.
After arranging the existed 1:10,000 DOM and DEM, the area which has clear texture, obvious terrain characteristic such as the cross of the road or the ridge, is chosen as GCP Image Chip and collected from the DOM. And the size of the GCP Image Chip is about 512*512pixel, the coordinate and projection information about the chip is derived from the DOM and the height coordinate is derived from the DEM of the same region. Then all the information is input and stored in the Image GCP Database. There is a example in Fig 1, and the left is the GCP Image Chip clipped from the existed DOM(the resolution is

about 1m), the middle is the panchromatic image of ZY3 in the same region(the resolution is about 2.1m), and the right is the multispectral image of ZY3 in the same region(the resolution is about 5.8m). The corresponding point can be chosen clearly from the Image Chips as GCP which contains ground coordinate and image coordinate.
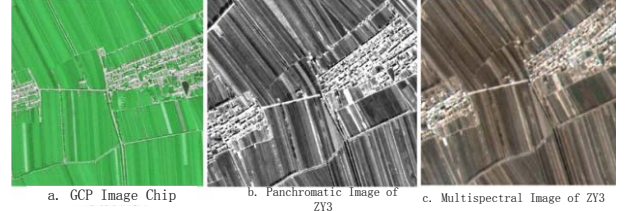

a. GCP Image Chip   b. Panchromatic Image of ZY3   c. Multispectral Image of ZY3

Figure 1. Comparison of GCP Image Chips and ZY3 Image of the same region

3.2 Construction of Image GCP Database

The more the quantity of the GCP Image chips in the database contains, the more difficult searching for the suitable GCP from the database will be. And it will be time-consumed to index from the whole database, so appropriate strategy to optimize the indexing is valuable. Dividing the GCP Image database into different zones is useful to reduce the searching time. Also, other strategies such indexing based on the covering region or the image resolution are applied together.
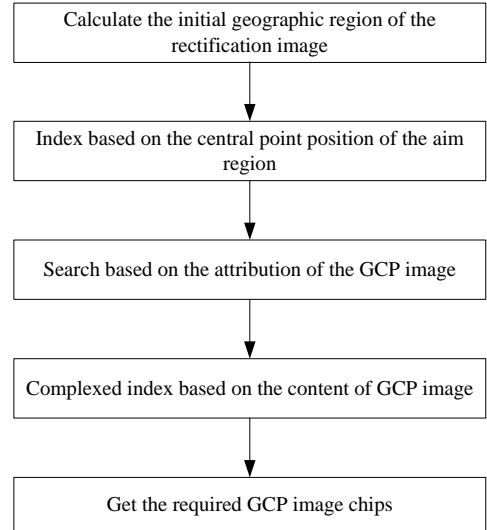The workflow of searching for GCP Image Chips from database is in Fig 2.

Figure 2. The workflow of searching for GCP Image Chips

3.3 Auto-Matching of Image GCP

The advantage of GCP Image Chip is that it doesn't only contain the geographic coordinate information but also the image texture, which can be useful to search the corresponding point by auto-matching algorithm. Image auto-matching is always the hotspot and difficulty in the field of photogrammetry and computer vision. There are many algorithms and have their own advantages and disadvantages(GuoyuanLi,2010; T.Tuytelaars,2000; Jianqing Zhang,2003;).In this paper, the feature extracting and matching algorithm based on SIFT is proposed according to the resolution, imaging angle and texture changing of GCP Image Chip and original image. After auto-matching, the error points are eliminated by the Rough Fuzzy

C-means algorithm. At last, the sub-pixel refined matching by the classical Least Squares Image Matching is implemented(Canhai Li,2008). The workflow of the algorithm is as follows:

1. Calculate the original image coordinate of the corresponding point based on the ground coordinate of the GCP, the metadata information of the rectified image and the sensor model, and clip the searching image chip from the rectified image.

2. Derive the original image matching result using Sift algorithm from the GCP chip and the clipped searching image chip.

3. Eliminate the error matching point using the Rough Fuzzy C-Means Method, and preserve the robust corresponding points.

4. Apply the LSM method and obtain the sub-pixel matching result.

5. Output the matching result to the GCP file according to the prescribed format.

After implementing the image matching between GCP Image Chip and Clipped Image Chip, it can derive sufficient number GCPs for geometric rectification. If there are inadequate GCPs, the more GCP Image Chips is added by indexing from the database until the number satisfy the rectified requirement(Guoyuan Li,2007; MoHua,2006).

4. THE WORKFLOW OF DOM UPDATE BASED IMAGE GCP DATABASE AND ZY3 IMAGE

According to the resolution, approximate region and the imaging time, the GCP Image Chips of the same covering region with the rectified image can be indexed from the Image GCP Database. Due to the 50km swath wide, there will be many GCP Image Chips. In order to reduce the calculating and matching time, the indexing is optimized by the grids and one chip is chosen from one grid. When there isn't sufficient number of the GCPs, more points are added to the grid from the database. Then the panchromatic image rectification is implemented by the RFM and GCPs, and the result image is viewed as reference image to the multispectral image. After registration and rectification of multispectral image, the PanSharp fusion method is used. Then the dodging, mosaic and quality checking is implemented to obtain the 2.1m DOM result map.

In Fig 3, the GCP Image Database stems from 1:10,000 scale DOM and DEM. It is clear that managing the control data source as database can improve the searching efficiency and implementing the auto-matching by machine vision to substitute for the conventional manual selecting points can reduce the matching time between the GCP image chip and original image.
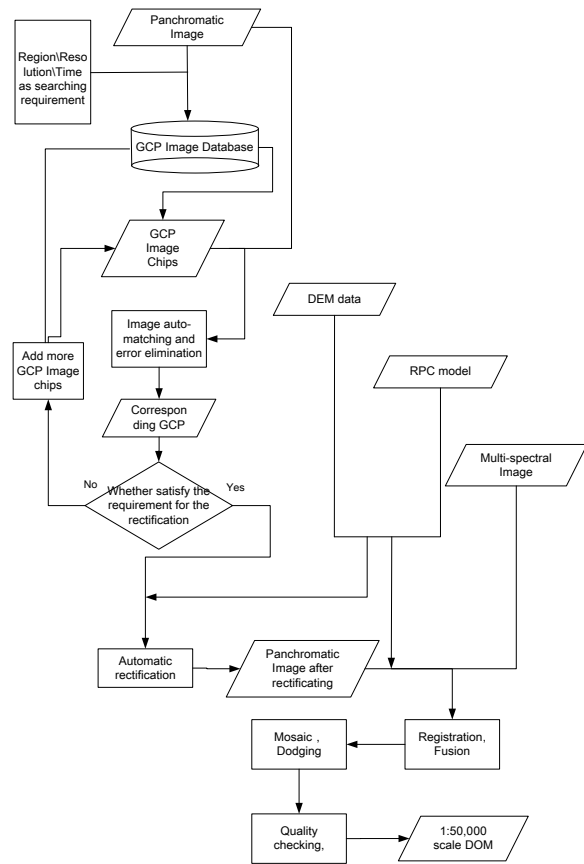

Figure 3. The workflow of the updating 1:50,000 DOM based on ZY-3 and GCP Image Database

5. EXPERIMENTS AND RESULT

The ZY3 satellite images that covering the Three River Source of Heilongjiang province and the Loess Plateau of Gansu province and the historical DOM and DEM data of the same region are used as experimental data. The GCP Image Database is constructed from the existing 1:10,000 DOM and DEM, and the 1:50,000 DOM updating by ZY-3 satellite images are implemented. The experimental region is illustrated in Table 2.

Name	The covering region	The characteristic of the terrain
Plain region Three river sources of Heilong Jiang Province	The experimental region located in the Three River Sources Protection Zone, the total area is about 24 thousand sq km.	Belong to plain and hills, the average elevation is about 170m, and relief dispersion is about 50m.
Plateau region Loess Plateau of Gansu Province	The experimental region is located in the national preventing water and soil loss region, the total area is about 41.5 thousand sq km.	Belong to plateau, the average elevation is about 1800m, and the lowest is about 560m, the highest is about 4460m, relief dispersion is about 3900m.

Table 2. The illustration of experimental region

In the Heilongjiang experimental region, the 1:10,000 DLG is chosen as the referenced data source, which is used to check the

quality of the GCP Image Chips. 100 terrain characteristic points from GCP image chips are selected randomly, and the residual of the same point from the GCP image chip and the DLG is calculated and the statistic result shows that the maximum error is about 8.1m,the minimum error is about 1.5m,the RMS is about 4.3m, and the CE90 is better than 5m. The overlap result of GCP Image Chips and 1:10,000 DLG is illustrated in Fig 4.

The overlap result of the plain region   The overlap result of the hills region

Figure 4. The result of overlap between GCP Image Chip and the 1:10,000 DLG

Due to the wide covering area of the image, the quantity of the GCP Image Chips is fluent, so there will be many GCP image chips to be chosen. In order to reduce the calculating time, 9 GCPs that distribute 3 rows and 3 columns are chosen and some tie points in the overlap region are extracted, and the accuracy of selecting is about 0.5 pixels. After refining the RPC model parameters by the GCPs, the geometric ortho-rectification is implemented. Then, 50 GCP Image Chips that distributed well in the region are searched from the database and viewed as check points to value the error and the statistical result is showed in Table 3 and Table 4.

	Residual of GCP		Error of Check Points	
	X	Y	X	Y
RMS	0.95	0.71	1.03	0.82
Maximum error	1.86	1.28	1.94	1.34
Minimum error	0.021	0.019	0.04	0.14

（Unit: Pixel）

Table 3. The error statistical result of Heilong　Jiang experimental region

	Residual of GCP		Error of Check Points	
	X	Y	X	Y
RMS	1.41	1.17	1.69	1.64
Maximum error	3.86	3.28	3.94	3.41
Minimum error	0.09	0.11	0.59	0.42

（Unit: Pixel）

Table 4. The error statistical result of GanSu experimental region

6. CONCLUSIONS

In this paper, two representative area of Heilongjiang and Gansu are chosen as experimental data, which has special terrain characteristic that one belongs to the Plain and another belongs to the Plateau. The experiment has implemented that rectifying the ZY3 satellite image to update 1:50,000 DOM based on the GCP Image Database sourced from the two regions. And the result demonstrates that:

1. Based on the GCP Image Chips from the 1:10,000 DOM, the processing result of this paper can satisfy the requirement of 1:50,000 DOM product, and the RMS in the mountainous area also is better than 10m. Considering the original error of the GCP Image Chips data source which is about 5m, the ultimate positioning error is better than 12m,which can satisfy the requirement of the 1:50,000 DOM products completely.
2. Based on GCP Image Chips from the 10,000 DOM, in the plain area, the rectified result of the ZY3 is better than 5m in plane. Considering the original error of the GCP Image Chips, the ultimate positioning accuracy is better than 7m, which can satisfy the requirement of the 1:25,000 DOM products.
3. The construction of Image GCP database from the national fundamental geographic information database can reduce the field work of producing 1:50,000 DOM, which are especially suited for the West China where is untraversed and mountainous region.

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