ORTHO-RECTIFICATION OF HJ-1A/1B MULTI-SPECTRAL IMAGE BASED ON THE GCP IMAGE DATABASE

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ABSTRACT:

HJ satellite is the abbreviation of the Small Satellite Constellation of Environment and Disaster Monitoring and Forecasting in China, which plays a very important role in forecasting and monitoring the environment problems and natural disasters. The ortho-rectification of HJ images aided by GCP(Ground Control Point) image database is presented in this paper. The GCP image database is constructed from historical LandSat-TM images and the GCP chip consists of image and geographic attribute information. Then auto-searching and matching algorithm is introduced and mis-matching elimination method is presented. The imaging model based on collinearity equation and the polynomial description of the attitude and position of scanning line is utilized for ortho-rectification. Four scene images are experimented and compared, and the result demonstrated the feasibility and high efficiency of the whole work flow.

1. INTRODUCTION

With the increase of global environment problems and natural disasters, the significance of remote sensing technology and satellite images has been further recognized around the world. In order to forecast and monitor the environment problems and natural disasters, China has launched the Small Satellite Constellation of Environment and Disaster Monitoring and Forecasting in 2008, which is short for HJ satellite. HJ-1A/1B, which can provide wide-area and multi-spectral satellite image with the 30m resolution, has played a very important role in obtaining satellite images during emergency management and disaster monitoring[1].

It is clear that geo-rectification is an indispensable step for the application of satellite images, especially the ortho-rectification. Only based on the geographic information from image, other information can be obtained more efficient and decision can be made more scientific [2]. As the rapid response of disaster and environment problems, automatic and high-efficiency geo-rectification is very important for HJ-1A/1B image. There are few researches on HJ-1A/1B satellite geo-rectification, but the fact is clear for HJ-1A/1B that the measurement accuracy of attitude and position is very low, the attitude in particular, which can not satisfy the positioning requirement using the rigorous sensor model as SPOT5-HRS without or a few GCP points[3].

GCP Image Database, which consists of geography and image attribute information, plays an important role in geometric processing of remote sensing image, because it can offer sufficient Ground Control Points and the possibility of auto-matching.

In this paper, the GCP Image Database based on the historical DOM image of Land-Sat TM, which has the same resolution with HJ-1A/1B multi-spectral image, and then auto-matching between GCP image chips and HJ-1A/1B image is implemented, calculating the attitude and position of satellite using rigorous collinearity model based on the matching results is experimented.

2. ANALYSES ON THE DIFFICULTIES OF HJ-1A/1B ORTHO-RECTIFICATION

Analyses on the difficulties of HJ-1A/1B ortho-rectification

There are some mathematic or physic model about geo-rectification or ortho-rectification, such as Polynomial model, RFM(Rational Function Mode),Rigorous Sensor Model based on the image vector and ephemeris parameters and so on[3,4,5]. For the HJ-1A/1B images, due to the wide imaging area which is about 360km, the same polynomial model presenting the relation between image point and object point for one scene image can not satisfy the rectification requirement. What's more, the frequency of ephemeris information recording is about 8 second one time, and the interval is about 1831 scanning lines according to the Line-Scanning time of HJ-1A/1B CCD camera. The low frequency of attitude recording and imprecise of ephemeris parameters especially the attitude, result in the imprecise position using the rigorous sensor model based on ephemeris information or RFM which is the implicit expression of rigorous sensor model.

Furthermore, the wide imaging area increases the difficulty of collecting GCP points, especially the GCP data source and GCP matching [6]. As a result, the conventional rectification method by manually GCP collection operation is not realistic for rapid response requirement of HJ-1A/1B. Consequently, constructing GCP database and improving the efficiency of GCP searching and matching are extraordinarily important.

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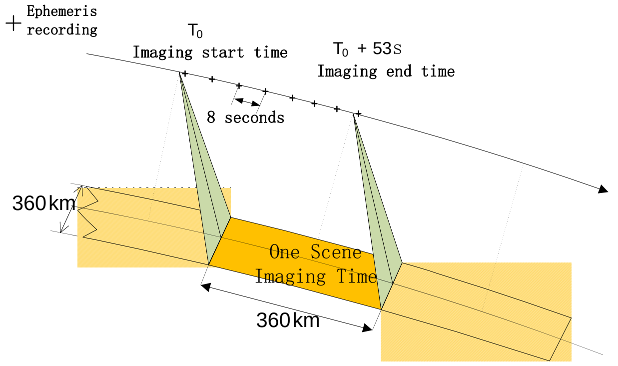
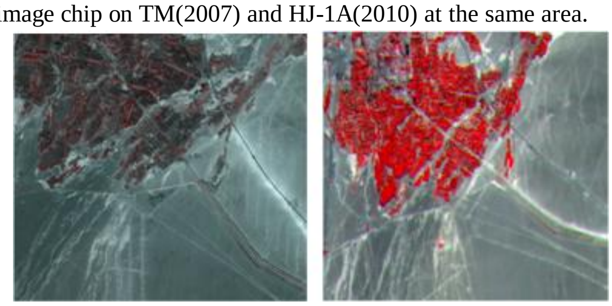


Figure 1. The illustration of ephemeris information recording frequency of HJ-1A/1B Example of a figure caption.

3. CONSTRUCTION OF GCP IMAGE DATABASE

The resolution of HJ-1A/1B multi-spectral CCD image is equivalent to LandSat-TM, and both are 30m. The historical TM images and DOM images can be obtained from website for free. There are TM images covering the whole China, and the plane precision is about 1 to 1.5 pixels, which can be utilized as the GCP data source for HJ-1A/1B. Although the change is certain due to the different imaging time evenly many years, there are many stabilized and character-distinct points or areas in the images. These stabilized points or areas can be used as GCP for rectification. Fig 2. shows the sample unchangeable image chip on TM(2007) and HJ-1A(2010) at the same area.



TM Multi-Spectral Image (2007) HJ Multi-Spectral Image (2010)

Figure 2. The unchangeable image chip on TM DOM(2007)and HJ(2010).

The GCP Image Database is constructed with many small GCP image chips, which consists of the image information and attribute information. The attribute information of GCP image chip describes the geographic information which contains the 3-D coordinate of GCP point, the coordinate system and ellipse datum information, the auxiliary information such as the sensor name, spectral range, the resolution and width/height of the GCP image chip. After collection of GCP image chips, then save them using the same table attribution, the GCP Image Database can be applied as GCP data source for geo-rectification.

4. SEARCHING AND AUTO-MATCHING THE REASONABLE GCPS FROM DATABASE

One scene image of HJ-1A/1B covers 360km*360km, while the GCP Image database covers the whole China, so quickly searching and auto-matching the reasonable GCPs is a key problem for rectification. The geographic information of GCP image chips provides the direction, and then the searching area can be reduced and the initial position of coarse-matching points can be fixed, which can decrease the calculation and increase the matching accuracy.

The steps of GCP image chips searching and matching are as follows:

1) Indexing the GCP image chips from database based on the covering area of initial image and the geo-information of GCP image chips.
2) Select the Columns icon from the MS Word Standard toolbar and then select “1 Column” from the selection palette. Searching for the reasonable GCP image chips by analyzing the imaging time and distance between GCP image chips. The latest GCP image chips to the imaging time will be preserved and distance between GCP image chips will be restricted as 30km, or there will be too many GCP image chips in the covering area.
3) Clip the image chip from initial image according to the geo-information of GCP and the metadata information of initial image, the clipped chip from initial image should be bigger then GCP chip because of the possible error.
4) Imaging matching between the clipped chip from initial image and GCP image chip by SIFT algorithm[7].
5) Eliminate the mis-matching points by Rough Fuzzy C-mean Method[8].
6) Precise image matching by LSM[5].
7) Output the matching result.

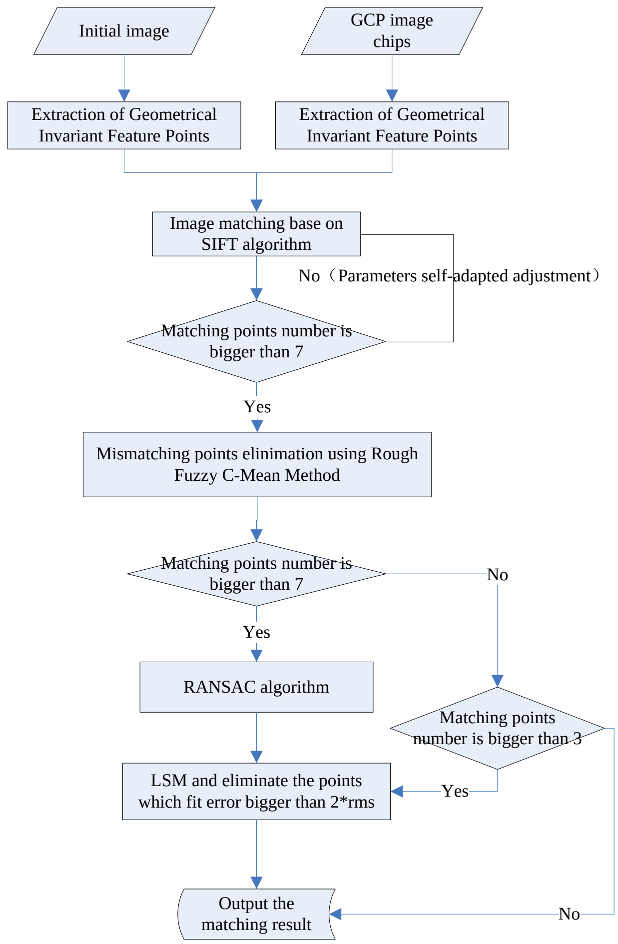


Figure 3. The work-flow of auto-matching GCP image chip

5. ORTHO-RECTIFICATION OF HJ-1A/1B MULTI-SPECTRAL IMAGE USING GCPS

Although the low attitude measurement accuracy of HJ satellite, the stabilization is acceptable, which means the attitude is stabilized in the space that it is can approximately described using certain mathematical model. In this paper, the third order polynomial model of time t is utilized to present the attitude and position or the exterior parameters of the scanning line, then the col-linearity equation is introduced to illustrate the relation between the object space point and the corresponding image point.
Describe the position and attitude of satellite using polynomial of time t is as follows:

$$\begin{aligned} Xs_i &= Xs_0 + a_0 t + a_1 t^2 + a_2 t^3 + \cdots\cdots \\ Ys_i &= Ys_0 + b_0 t + b_1 t^2 + b_2 t^3 + \cdots\cdots \\ Zs_i &= Zs_0 + c_0 t + c_1 t^2 + c_2 t^3 + \cdots\cdots \\ \varphi_i &= \varphi_0 + d_0 t + d_1 t^2 + d_2 t^3 + \cdots\cdots \\ \omega_i &= \omega_0 + e_0 t + e_1 t^2 + e_2 t^3 + \cdots\cdots \\ \kappa_i &= \kappa_0 + f_0 t + f_1 t^2 + f_2 t^3 + \cdots\cdots \end{aligned} \quad (1)$$

Where,
$(Xs_i, Ys_i, Zs_i, \varphi_i, \omega_i, \kappa_i)$ ---the exterior parameters of the ith scanning line;
$(Xs_0, Ys_0, Zs_0, \varphi_0, \omega_0, \kappa_0)$ ---the exterior parameters of the central scanning line;
The collinearity equations[5] are as follows:

$$\begin{aligned} x - x_0 - dx &= -f\,\frac{a_{i1}(X - X_{S_i}) + b_1(Y - Y_{S_i}) + c_{i1}(Z - Z_{S_i})}{a_{i3}(X - X_{S_i}) + b_3(Y - Y_s) + c_{i3}(Z - Z_s)} \\ y - y_0 - dy &= -f\,\frac{a_{i2}(X - X_{S_i}) + b_{i2}(Y - Y_{S_i}) + c_{i2}(Z - Z_{S_i})}{a_{i3}(X - X_{S_i}) + b_{i3}(Y - Y_{S_i}) + c_{i3}(Z - Z_{S_i})} \end{aligned} \quad (2)$$

Where,

(x, y)—the coordinates of the image point (image matching result).
(x_0, y_0, f) —the elements of interior orientation (the coordinates of principal point and the focal length).
(dx, dy)—the distortion of image point.
(Xs_i, Ys_i, Zs_i) —the coordinates of the *i*th scanning line.
(X, Y, Z)—the coordinates of the object point.
$a_{ij}, b_{ij}, c_{ij}(j = 1, 2, 3)$—the elements of rotation matrix yield from the 3 angular exterior elements.
In the experiment, the initial exterior parameters of central scanning line are interpolated by Lagrange polynomial using the ephemeris information. The collinearity equations are formed from GCP and corresponding image point after image matching. Then solve the error equations after linearizing collinearity equations to calculate the polynomial coefficient of time *t* and the exact exterior parameters of central scanning line[9]. As a result, adding the DEM data from SRTM 90m, the ortho-rectification can be implemented using the collinearity equation.

6. PARALLEL PROCESSING BASED ON THE MULTI-CORE PROCESSOR

High Performance Computing has been intensively applicated in the field of scientific researches, engineer calculation and military technology for the huge calculation. Parallel processing is a delegation of high performance computing, which can be simply divided into the Single Chip Multi-Core, the Cluster parallel and integration of both[10].
OpenMP is a programming language for shared memory and cluster multi-processor parallel processing. It is transplantable and can support Fortran and C/C++ language. OpenMP can accelerate the calculation and utilize the CPU resource at the most especially for the multi-core. For the ortho-rectification of HJ images, the calculation is repeated from point to point, so the parallel processing by OpenMP will be very useful and has no more requirement for the computer configuration, just multi-core processor.
The process of image rectification is just translated from one geometric space to another space, and the rectified model just expresses the translation. Once the translation model fixed, the calculation will just be circulated repetitively and time-consumed, and the total calculated time just depends on the size of initial image. Consequently, the parallel for rectification will be inspiring.

7. EXPERIMENT

7.1 Computer Configuration

- CPU：Intel® Core™ 2 Quad CPU Q9500 2.83GHz
- Memory Size：3GHz.
- Disk Capacity：200G.

7.2 Experimental Data Source

Four scenes HJ multi-spectral images covering the Central and West China are collected, and the imaging time is Feb,2009 and Aug,2010. The GCP Image Database derived from LandSat-TM images has been prepared before experiment. The SRTM 90m DEM data in the ortho-rectification is downloaded from website. The experimental data is mainly local in West of China, where is mountainous and difficult to measure Ground Control Point in field. So the GCP-Image Database is very useful for ortho-rectification.

7.3 Experimental Result

According to the geographic information of initial image area, searching for the GCP image chips is implemented from the database, then auto-matching between the GCP image chips and initial image using SIFT algorithm and elimination of mis-matching points using Rough Fuzzy C-mean Method is experimented. The successful matching point number and time consumed of matching is showed in the table 1. After matching and eliminating error from the GCP points, the ortho-rectification aided by the DEM data of SRTM 90m is calculated using no-parallel and parallel processing. The compared consumed time is illustrated in the last two columns of Table 1. The matching accuracy is about 0.3pixel and the measurement accuracy of GCP image chip is about 1.2pixel for 30m resolution.
After ortho-rectification, the check points from GCP image chips covering the same area are collected and the error between rectified image and GCP image chips is calculated. The statistical result is showed in Table 2, which contains the RMS, the maximum and minimum absolute of the planar error in X and Y direction.

In the experiment, the same parameters of CCD distortion derived from laboratory is adopted for scene image. From Table 2, it is clear that the residual error in X direction is bigger than Y direction, according to the X means the across-track direction , the distortion of CCD may be not exact in the experiment or the parameters of distortion is changeable with time.

Scene No.	15-83	27-68	32-68	27-65
Sensor Name	HJ-1A-CCD1	HJ-1A-CCD2	HJ-1B-CCD2	HJ-1B-CCD1
Imaging time	2009-2-4	2010-8-16	2010-8-16	2010-8-18
The successful matching points number	85	57	45	63
Time-consumed of image matching(sec)	1236	1078	930	1150
Time consumed of rectification (sec)	217	209	208	204
Time-consumed of rectification after parallel processing(sec)	59	56	55	54

Table 1. Compare of experimental consuming time

Scene No.	$RMS\|Error\|$		$max\|Error\|$		$min\|Error\|$	
	X	***Y***	***X***	***Y***	***X***	***Y***
15-83	2.51	2.06	5.52	4.35	1.41	1.27
27-68	2.04	1.74	4.35	3.34	0.35	0.28
32-68	2.79	0.76	4.59	3.24	1.23	0.48
27-65	2.91	1.12	3.35	2.34	0.45	0.16

Unit: Pixel

Table 2. The statistical result of rectification error

8. CONCLUSION AND FUTURE WORK

The experimental result demonstrates the feasibility and high efficiency of the algorithm and parallel processing presented in this paper. Using GCP Image database, the auto-matching can substitute the manual collection of GCP points, and the accuracy of rectification model based on the collinearity equation can achieve the basic requirement for the application of HJ images, such as environment monitoring, disaster evaluation. Furthermore, the parallel processing of rectification just aided by the OpenMP prominently accelerate and the accelerated ratio is about three for the 4 core processor.

The total time consumed for one scene image from searching and matching the GCP image chips to ortho-rectification is approximate 20 minutes, which can satisfy the rapid response of HJ satellite.

The problems and future work will focus on:

1) The collinearity equation in this paper is based on the acquirement of interior parameters and distortion coefficient, which are not fixed all the time. In Table 2, the error in image of Path-Row(15-83) is clearly bigger then other images, and this scene was obtained in Feb,2009 and others are in Aug,2010. The interior parameters and distortion coefficient will change along with time, so the dynamic calibration during the satellite life-time is indispensable to preserve and improve rectification accuracy.
2) Although, the attitude and position parameters are calculated from the collinearity equation, the initial value especially the exposure position of central line should be close to the actual value, or the iteration will be non-convergent.
3) The auto-matching between GCP image chips and initial image is time-consumed, and the Parallel processing of matching is not considered in this research, which is the next research direction.
4) The rectification is experimented only on single scene image every time, but in practice, rectifying many scenes at the same area is more common especially in the disaster monitoring. Consequently, the block adjustment based on GCP image database will be the future work for the extensive application of HJ images.

9. ACKNOWLEDGMENT

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