Residual error selecting method for precise geometric correction

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Abstract

The images of the meteorological satellite NOAA contain geometrical distortions caused by its ambiguous position, its vibration, its sensor's movement, and so on. Geometric correction of satellite images is one of the most important parts in many remote sensing as the primary processing. Ground control points (GCP's) are necessary to check the accuracy of geometric correction and used for precise geometric correction.

In this paper, a method for automatically selecting the residual error is presented. Calculating the effective angle and residual errors vector using the succeeded matching GCP's, precise geometric correction using an affine transformation is applied to systematically a corrected image. And the error is decreased by an affine transformation. The above enable the geometric correction of high quality.

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1.Introduction

Recently problems on earth environment become big issues. For the long time continuous and global observation of the earth environment, and remote sensing from space using satellites are playing an important role. The images of the meteorological satellite NOAA contain geometrical distortions caused by its ambiguous position, its vibration, its sensor's movement, and so on. Geometric correction of satellite images is one of the most important parts in many remote sensing as the primary processing. A global environmental satellite database requires very accurate correction as the primary processing; i.e. sensor calibration, atmospheric correction, conversion of observed data to physical parameters, geometric correction and so on. And the required accuracy becomes severer and severer and is expected to register a pixel-level for time series analysis using multiple images.

The systematic correction, however, contains inaccuracy of the information, especially due to the inaccuracy in the satellite orbit and attitude determination during image acquisition. Ground control points are necessary to check the accuracy of geometric correction and used for precise geometric correction.

In this paper, a method for automatically selecting the residual error is presented. Using the GCP template, a residual error vector is measured by template matching of 64*64 picture elements image and GCP template using SSDA (Sequential Similarity Detection Algorithm).

At first, the direction and value information of a residual error vector on each GCP is calculated. And the effective angle of the residual error vector is calculated using the mean angle of residual error vector. Calculating the effective angle and residual errors vector using the succeeded matching GCP's, precise geometric correction using an affine transform

is applied to systematically a corrected image. And the error is decreased by an affine transformation.

2. Geometric Correction

The required mapping accuracy for NOAA image is 0.01 degree, 1 km resolution at the nadir. Chang carried out to decide the correction order of orbital elements. From this correction order, an algorithm with the polynomial expressions can be used to estimate the variation of each orbital element and satellite reported time from the GCP's residual error, when the locally optimal solution meets. Hashimoto carried out geometric correction of AVHRR that utilizes colinearity condition as well as ephemeris data. However, residual error by systematic correction is about 1-10 pixels still.

In the systematic correction method, the longitude and latitude of each observed pixel are calculated using the satellite orbit parameters and the information, in which each point data in the earth coordinate system is picked up from the corresponding image pixel, is taken place. But this method needs a lot of computation, if the calculation is made at each earth coordinate point in mapping. Therefore, to speed up this process, the map in the earth coordinate system is divided into blocks and the correspondence of only 4 corner points is calculated precisely and the corresponding image pixel to the point within the block are calculated by simple bilinear interpolation.

3. Acquisition method of the residual error

The systematic correction, however, contains residual geometric error inevitably due to the inaccuracy of the information, especially due to the inaccuracy in the satellite orbit and attitude determination during image acquisition. In order to achieve a very accurate image mapping, the usage of GCP's is essential.

The coastline database was provided to overlay the coastlines on geometrically corrected images in various scales. And the GCP database was prepared to measure the errors in geometric correction by template matching to check its accuracy and to develop more precise geometric correction algorithms using error vectors at the GCP's. The method for finding GCP's is fully automatic, and it is based on the use of small windows on two images. The residual error vector is measured by template matching of 64*64 picture elements image and GCP template, which is a piece of 32*32 picture elements, using SSDA (Sequential Similarity Detection Algorithm). Then GCP template is moved around the template and the correlation is computed at each point of the search area. It produces a list of GCP's. These points are then used for adjusting the tie points on the grid. The correct location of GCP's is assumed to exit at the pixel where the correlation is highest. Before accepting the point as a correct GCP's, several tests are made. For example the correlation value has to be high enough.

Figure 1 shows an example of the succeeded matching GCP's of the GCP's database. Each matching result is also put into error measurement data base, where 64*64 image, its histogram and characteristics such as a threshold level, equal rate, correlation coefficient, error vector. And this database is open for public by WWW.

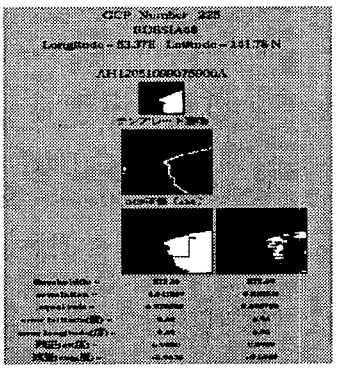


Figure 1. Example of the succeeded matching GCP's from the GCP database

4.Judgment of residual error

4.1 Judgment of residual error

The correlation coefficient and equal rate are used as an evaluation value of the judgment of the reliability. Figure 2 shows relationship between the correlation coefficient and equal rate. This means that correlation coefficient and an equal rate are very high correlation. Therefore, when the correlation coefficient is set very high, it is not so much useful.

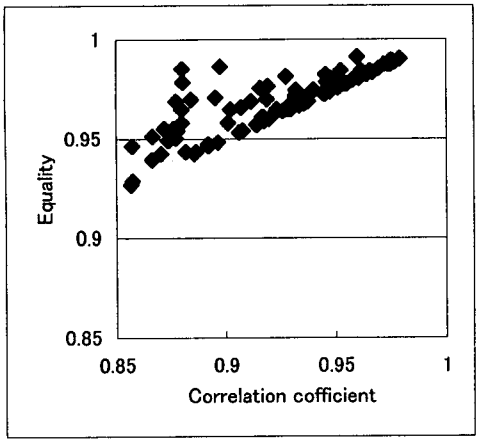


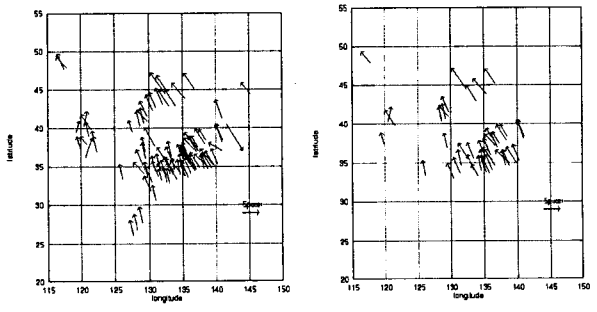
Figure 2. Relationship between the correlation coefficient and equal rate

Here, equal rate (Eq) is defined as follows:

$$Eq = I / (N*N)$$

Where I is a number of picture elements as which the template image density and the GCP image density are the same value. N is the number of picture elements of template images.

In order to obtain high accuracy, high estimation value was applied resulting in high sensitivity to GCP errors. Then, it can get a poor number of GCP's for precision geometric correction.



(a) c =0.93 (b) c =0.85

Figure 3. Example of residual error vector by different correlation coefficient

Figure 3 shows examples of a residual error vector by different correlation coefficient. The used data is NOAA-14, 05:05 April 19,1998.

Figure 3 (a) shows many GCP's that also is evenly distributed over the entire image frame. In practice, more than 80 GCP's are obtained as a reliable residual error.

4.2 Selecting of reliable residual error

The residual error has the tendency indicating the only direction and the size of the residual error do not change too much as shown Figure 2. To select the reliable residual error, we used the information of the direction and size of the residual error vector.

At first, the direction and value information of a residual error vector on the succeeded matching GCP is calculated. Using the succeeded matching GCP, we calculated the mean angle and size of a residual error vector.

And the effective angle of the residual error vector is calculated using the mean angle and size of a residual error vector. The effective angle of the residual error vector is controlled by using the mean angle and size of residual error vector. Experimentally, the effective angle of the residual error vector (Ea) is defined as follows:

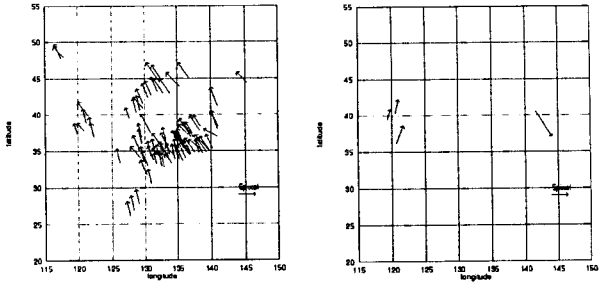
$$Ea = Aa \pm (55-3.5*100*Ra)$$

Where Aa is the mean angle of a residual error vector, Ra is the mean size of residual error vector using the succeeded matching GCP.

5. Results

5.1 Case 1

Case 1 means that some GCP's can be extracted from image.

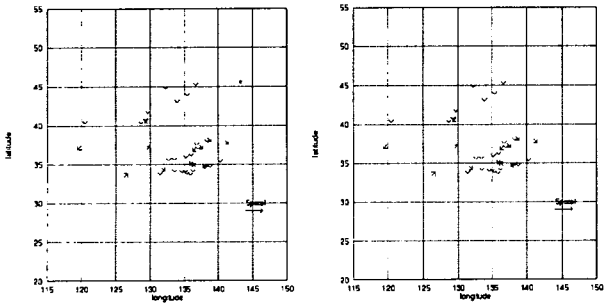


(a) Residual error (b) removed GCP's

Figure 4. Result of the residual error using selecting method

Figure 4(a) shows the results of the residual error using selecting method. Relatively inaccurate GCP's is removed from the succeeded matching GCP's as shown in Figure 4(b). The GCP's were evenly distributed over a part of image. Here, the correlation coefficient was (c=0.85), an average value of the residual error vector was 0.044 degree, an average angle was –25 degree and the effective angle was 14~-64 degree.

And an affine transform using the succeeded matching is applied to systematically corrected image. And then precise geometric correction error is decreased by an affine transformation.



(a) error (b) error

Figure 5. Result of precise geometric correction using the affine transformation

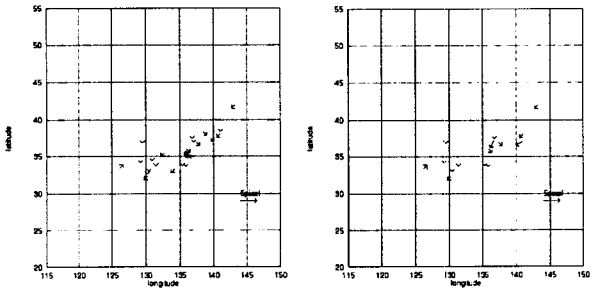
Table 1. Comparison of result of precise geometric correction

Error	No direction Lat., Long.	With direction Lat., Long,
Mean	0.0016, 0.003	0.0016 , 0.0001
Maximum	0.01 , 0.02	0.01 ,0.01
Minimum	0.00 , 0.00	0.00 ,0.00

Figure 5(a), 5(b) shows the result using the selecting method, the result using the correlation coefficient and equal rate, respectively. The affine transformation is very sensitive to the location of the GCP's, which are very evenly distributed over the image. The results are shown in the table 1. The comparison of no direction and with direction gives that with direction method was decreased the residual error of the precise geometric correction in the direction of longitude.

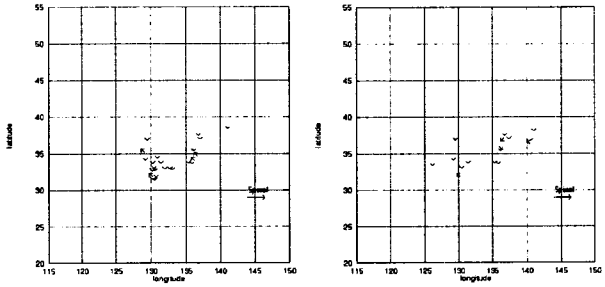
5.2 Case 2

However, we cannot use an effective angle because the direction of residual error vector is not fixed. In addition, the mean value of residual error vector is very small. And we only used the mean value of residual error vector for the selecting the succeeded matching GCP's, if the mean value of residual error vector is very small (more less 0.01 degree). And then inaccurate residual error is removed with being more than a constant value.



(a) residual error (b) residual error

Figure 6. Selected the residual error (Data: NOAA-14, 18:14 February 8, 1999)



(a) error (b) error

Figure 7. Result of precise geometric correction using the affine transformation

Table 2. Comparison of result of precise geometric correction

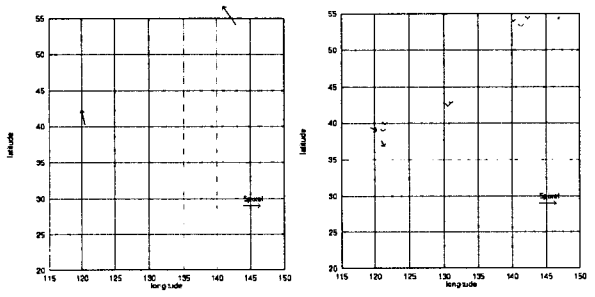
Error	With size Lat., Long.	No size Lat., Long,
Mean	0.0016 ,0.0016	0.0013 , 0.002
Maximum	0.01 , 0.01	0.01 , 0.02
Minimum	0.00 , 0.00	0.00 , 0.00

The comparison of with size and no size method gives that with size method was also decreased the residual error of the precise geometric correction in the direction of longitude as shown Table 2.

5.3 Case 3

Practically no algorithm can achieve good geometric correction results by using poor GCP's. An affine transformation function is evaluated at every pixel on the output image (i.e., on the rectified image) by using three referenced points.

Figure 8 shows results of precise geometric correction using the affine transformation. Figure 8 (a) shows the residual error, which was the succeeded matching GCP's. The used data is NOAA-14, July 28, 05:49, 1999.



(a) Residual error (b) Residual error by Geometric correction

Figure 8. Result of the geometric correction with poor GCP's

Table 3. Comparison of result of geometric correction with poor GCP's

Error	With direction Lat., Long.	No direction Lat., Long,
Mean	0.0033, 0.0033	0.045 , 0.025
Maximum	0.02 , 0.02	0.05 , 0.04
Minium	0.00 , 0.00	0.04 , 0.00

Table 3 shows comparison of a result of precise geometric correction. Since the succeeded matching is only 2 GCP's, the image cannot be rectified again using the affine transformation. As a result, the residual error is very large. In this case, this method was decreased the residual error of the precise geometric correction in the direction of latitude and longitude.

6.summary

Ground control points are necessary to check the accuracy of geometric correction and used for precise geometric correction. A method for automatically selecting the residual error is presented. Calculating the effective angle and residual errors vector using GCP's and selection the succeeded matching GCP's, precise geometric correction using an affine transformation is applied to systematically corrected image. And the error is decreased by an affine transformation.

To minimize the residual error is the most important factor for geometric correction because the GCP extraction takes the most of the processing procedure. And we developed highly reliable and an accurate precision correction algorithm and are trying to select accurate GCP's using GCP database.

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