A Selection Method of Residual Errors for GMS Geometric Correction Using Ground Control Points

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Abstract: The GMS geometric correction method with high-speed and high accuracy is needed. In this paper, a selection method of residual errors for the GMS geometric correction using GCPs (ground control points) is described. Namely, it is a technique for limiting the number of residual error acquisition using GCPs in each block to reduce the processing time. As the result, since the processing time was about 7.0 minutes on conventional geometric correction and about 5.6 minutes on the proposed method, it was shown that the processing time of about 1.4 minutes was shortened.
Keywords: Geometric Correction, Residual Errors.

1. Introduction

Since GMS (Geostationary Meteorological Satellite) [1] observes the earth very widely and frequently, its S-VISSR data are very useful for the understanding of the earth environmental change. In order to utilize S-VISSR data to the time series analysis, the geometric correction with high-speed and high accuracy is needed.

The systematic geometric correction using orbit and attitude information can transform map coordinate into image coordinate and transform image coordinate into map coordinate. In the case of GMS, the methods of transformation from latitude-longitude on geodetic coordinate to line-pixel on VISSR coordinate and transformation from line-pixel to latitude-longitude using orbit and attitude information are published by Meteorological Satellite Center [2]. But, because the errors are included in orbit information, misregistration with GCPs after geometric correction is large. We improved the accuracy of the geometric correction by using GCPs [3]. But, since the elevation of the earth surface is not considered in above methods, residual errors of geometric corrected images on map coordinate are very large at the high elevation areas. Then, the geometric correction method that considers the elevation was developed [4], [5]. Since the efficient processing of residual error acquisition in reference [3], [4] and [5] is not discussed before, and residual error acquisition is carried out toward all GCPs, the geometric correction costs long processing time. Because the geometric correction is applied to a lot of S-VISSR data for the time series analysis, it is necessary to speed up the geometric correction.

In order to speed up the GMS geometric correction using GCPs, a selection method of residual errors for the geometric correction is described in this paper.

2. Methods

1) Geometric Correction

The GMS geometric correction using GCPs means the following [3], [5]: (1) As preprocessing, residual errors on image coordinate of systematic geometric correction using the orbit information are acquired by matching S-VISSR image pieces to their corresponding GCP templates on image coordinate [6]. Residual errors are corrected using errors of the systematic geometric correction by the elevation. (2) The affine coefficient is calculated using the errors. (3) The output image on latitude-longitude coordinate is divided into the blocks. Each correspondence between latitude-longitude on latitude-longitude coordinate and line-pixel on image coordinate is calculated using the orbit information [2]. (4) The affine transformation is carried out toward line-pixel for the precise correction. (5) In the case of internal points excluding four corners in the block, each correspondence of line-pixel and latitude-longitude is calculated by bilinear interpolation using correspondences of the four corners. (6) The correction eliminating the error of the systematic geometric correction by the elevation is carried out to the line-pixel of the correspondences. (7) Finally, GMS image is resampled on latitude-longitude coordinate using the correspondences.

2) Selection Method of Residual Errors

Any residual error obtained at the above processing no. (1) is almost the same. Therefore, a little number of residual errors can be enough for the calculation of the affine coefficient. In order to speed up the above geometric correction, the selection method of residual errors for the GMS geometric correction is examined. In a word, it is the reexamination of the above processing no. (1).

The proposed method is as follows:

(1) Image coordinate (Visible: 9160 lines * 9164 pixels) is divided into blocks.

(2) The GCPs are classified on each block.

(3) The residual error acquisition is carried out for one GCP in the block.

(4) If the residual error acquisition is successful, the processing of the residual error acquisition is ended. If the acquisition is failure, the acquisition is carried out using next GCP. If the acquisition is failure for all GCPs, the processing in the block is ended as a failure of the residual error acquisition.

(5) For the next block, the processing no. (3) and (4) are repeated. When the residual error acquisition is finished for all blocks, the processing of proposed method is ended.

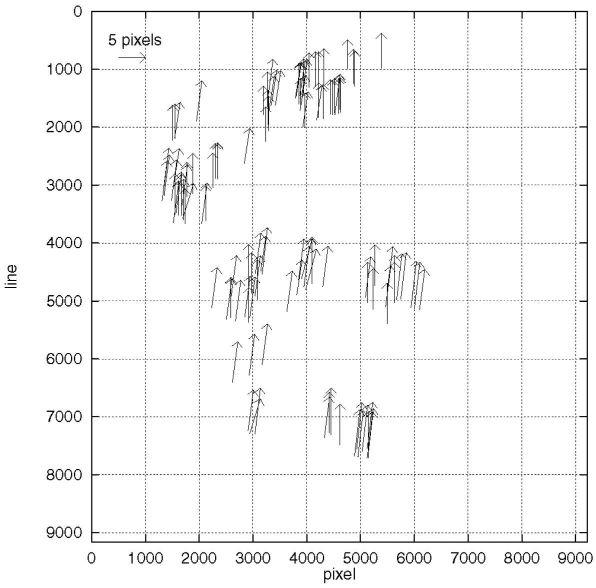
But, the problem in the proposed method is the block size. In next section, the relation between the block size, the accuracy of geometric correction and the processing time, is analyzed. Then, the optimum block size is determined.

3. Results

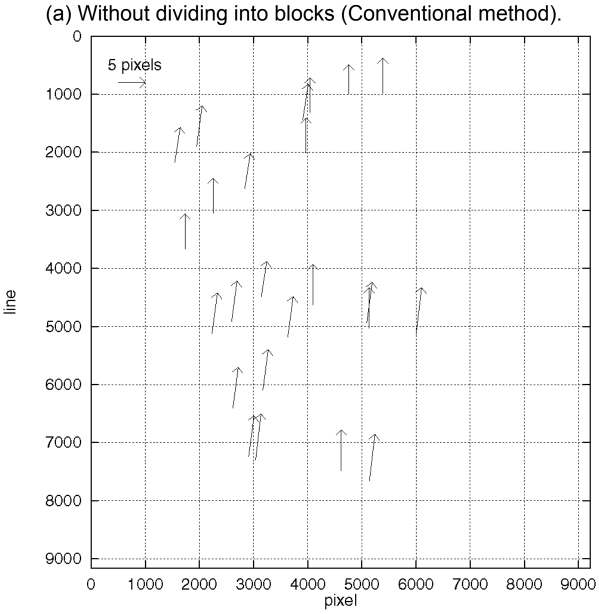
The geometric correction is applied to S-VISSR data, and geometrically corrected image on latitude-longitude coordinate is generated. The range on latitude-longitude coordinate is from 80N to 80S and 60E to 140W. The resolution of latitude-longitude coordinate is 0.01 deg (visible) and 0.04 deg (infrared). Then, the size of output image on latitude-longitude coordinate is 16000*16000 pixels (visible) or 4000*4000 pixels (infrared).

Fig. 1 shows the distribution map of residual errors on image coordinate. S-VISSR data of visible channel at UT 3:00 on Dec. 23 1999 is used. Fig. 1(a) is conventional method. The number of residual errors is 120, and any residual error is almost the same. Fig. 1(b) is the proposed method (block size; 1000 lines * 1000 pixels). The number of residual errors is 24, and the number of residual errors in each block is one or less. It is found that the tendency of residual errors is kept though the number of residual errors in (b) is less than that in (a).

Table 1 shows the average and maximum of absolute of residual errors after the geometric correction. S-VISSR data of visible channel at UT 6:00 on Feb. 14 1999, UT 4:00 on Sep. 8 1999, UT 3:00 on Dec. 23 1999, UT 3:00 on Dec. 7 2000 are used. The Unit is degree.



(a) Without dividing into blocks (Conventional method).



(b) Proposed method (Block size; 1000 lines * 1000 pixels).

Fig. 1. Residual error vectors on image coordinate ('99 12/ 23 UT 3:00).

From Table 1, it is found that the residual errors are also large in any scene when the block size is large. Because the maximum errors of the proposal method should be the same as those of the conventional method in consideration of use to the time series analysis, the block size should be 2000 lines * 2000 pixels or less.

Table 2 shows the processing time of the residual error acquisition. S-VISSR data of visible channel at UT 3:00 on Dec. 23 1999 is used. The used computer is Sun Enterprise 5500 (CPU: Ultra Sparc 336MHz, Memory: 6GB). From Table 2, it is found that the processing time is short when the block size is large. The proposal method is about 11 times as high-speed as the conventional method when the block size is 2000 lines * 2000 pixels.

Table 1. Residual errors after the geometric correction.

		'99/ 2/14 UT 6:00 (latitude, longitude)	'99/ 9/ 8 UT 4:00 (latitude, longitude)	'99/12/23 UT 3:00 (latitude, longitude)	'00/12/ 7 UT 3:00 (latitude, longitude)
Without dividing into blocks	Average	(0.003? , 0.003?	(0.004? , 0.004?	(0.005? , 0.005?	(0.007? , 0.007?
	Maximum	(0.010? , 0.020?	(0.010? , 0.020?	(0.020? , 0.010?	(0.020? , 0.020?
Block size: 1000 lines * 1000 pixels	Average	(0.006? , 0.006?	(0.004? , 0.004?	(0.005? , 0.005?	(0.007? , 0.007?
	Maximum	(0.010? , 0.020?	(0.010? , 0.020?	(0.020? , 0.010?	(0.020? , 0.020?
Block size: 2000 lines * 2000 pixels	Average	(0.006? , 0.007?	(0.007? , 0.005?	(0.005? , 0.005?	(0.007? , 0.011?
	Maximum	(0.010? , 0.020?	(0.020? , 0.020?	(0.020? , 0.020?	(0.020? , 0.020?
Block size: 3000 lines * 3000 pixels	Average	(0.007? , 0.007?	(0.007? , 0.005?	(0.005? , 0.006?	(0.007? , 0.009?
	Maximum	(0.010? , 0.020?	(0.020? , 0.020?	(0.020? , 0.020?	(0.030? , 0.020?
Block size: 4000 lines * 4000 pixels	Average	(0.007? , 0.006?	(0.008? , 0.005?	(0.007? , 0.011?	(0.008? , 0.012?
	Maximum	(0.010? , 0.020?	(0.020? , 0.030?	(0.030? , 0.020?	(0.030? , 0.040?

Table 2. Processing time of the residual error acquisition ('99 12/23 UT 3:00).

	Processing Time [sec]
Without dividing into blocks	91.52
Block size: 1000 lines * 1000 pixels	18.80
Block size: 2000 lines * 2000 pixels	8.47
Block size: 3000 lines * 3000 pixels	6.87
Block size: 4000 lines * 4000 pixels	2.88

Table 3. Processing time of the geometric correction ('99 12/23 UT 3:00).

	Without dividing into blocks	Block size: 2000 lines * 2000 pixels
GCP template generation	14.84[sec]	14.84[sec]
Acquisition of residual errors	91.52[sec]	8.47[sec]
Calculation of the affine coefficient	0.01[sec]	0.01[sec]
Resampling	312.76[sec]	312.76[sec]
Total	**419.13[sec]**	**336.08[sec]**

The condition of the block size for speeding up the geometric correction is that the maximum residual error of the geometric correction are kept in comparison with the conventional method, and the processing time of the residual error acquisition is short. Then, from Table 1 and Table 2, the optimum block size is 2000 lines * 2000 pixels.

Table 3 shows the processing time of each geometric correction. S-VISSR data at UT 3:00 on Dec. 23 1999 is used. The used computer is Sun Enterprise 5500 (CPU: Ultra Sparc 336MHz, Memory: 6GB). The total processing time of the proposed method using the optimum block size is about 5.6 minutes, and the proposed method is 1.4 minutes more high-speed than the conventional method. Namely, it was confirmed that the geometric correction was speeded up while keeping accuracy.

4. Conclusions

In order to speed up the GMS geometric correction using GCPs, the selection method of residual errors was developed in this paper. It is the technique for limiting the number of residual error acquisition with GCPs in each region. In the experiment, the optimum block size on the selection method of residual errors was calculated, and that value was 2000 lines * 2000 pixels. Then, it was confirmed that the GMS geometric correction using proposal selection method of residual errors is more high-speed than conventional method.

It is future problem to examine the algorithm that the block size is variable in each area on the selection of residual errors.

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