High-speed and Precise Geometric Correction for GMS S-VISSR Data

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***Abstract*—In this paper, high-speed and precise geometric correction for GMS S-VISSR data is described. Bi-linear interpolation is used for speeding up the geometric correction. The precise correction is carried out by using the ground control points. Moreover, the geometric correction considering the elevation is applied in land area. In the case of the correction on infrared channels, visible and infrared channels are used. As a result, the maximum of errors in the proposed method is 0.01 degree in the both direction of latitude and longitude.**

Keywords-geometric correction; residual errors; ground control points; bi-linear interpolation; elevation

I. INTRODUCTION

Since GMS (Geostationary Meteorological Satellite) [1] observes the earth very widely and frequently, GMS S-VISSR (Stretched VISSR, VISSR; Visible and Infrared Spin Scan Radiometer) 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, it takes long processing time for generating geometrically corrected images because the transformation is complex processing. Since the errors are included in orbit information, misregistration with GCPs after geometric correction is very large.

In order to calculate the correspondence between coordinates easily and improve the processing time of the geometric correction, bi-linear interpolation is used. Moreover, the accuracy of the geometric correction by using GCPs is improved. 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 in the high elevation areas. Then, the geometric correction method that considers the elevation was developed. In the case of the correction on infrared channels, the information of the geometric correction on visible channel is also used.

II. GMS S-VISSR DATA

GMS is located on the geostationary orbit on the equator of 140E. The S-VISSR data is the digital image data of VISSR which is stretched on time bases at the ground station during the VISSR observation. VISSR has one visible channel (VIS) (resolution; 1.25km at nadir) and three infrared channels (IR1, IR2 and IR3) (resolution; 5km at nadir). The image size is 9160 lines * 9164 pixels (VIS) and 2290 lines * 2291 pixels (IR) [1].

The geometric correction is applied to S-VISSR data, and geometrically corrected image on map coordinate is generated. As the map coordinate, there are the projections such as Mercator and polar-stereo. But, equi-latitude and equi-longitude projection is adopted as map coordinate, because it is flexible and easy to transform into other projection.

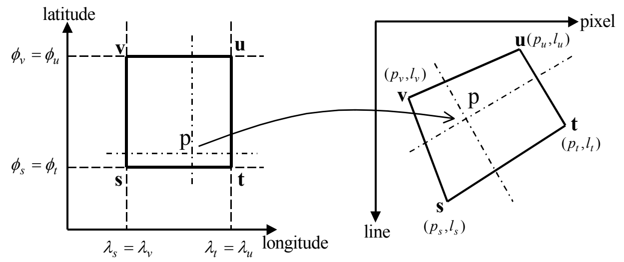
The range on equi-latitude and equi-longitude projection is from 80N to 80S and 60E to 140W. In the outside of the GMS observation area, geometrically corrected image is masked. Considering the resolution of the VISSR that is 1.25km (VIS) and 5km (IR) at nadir, the resolution of map coordinate is 0.01 deg (VIS) and 0.04 deg (IR) in order to overlap S-VISSR data, NOAA AVHRR and Terra/Aqua MODIS.

III. HIGH-SPEED AND PRECISE GEOMETRIC CORRECTION

The systematic geometric correction using orbit and attitude information can resample S-VISSR data into map coordinate by using the methods which are published by Meteorological Satellite Center [2]. But, because the errors are included in orbit information, misregistration with GCPs after the geometric correction is very large. It takes long processing time for generating geometrically corrected images because the transformation is complex processing. Then, we improved the processing time and the accuracy of the geometric correction by the following techniques.

A. Geometric Correction Using Bi-linear Interpolation

In order to solve the problem about the above processing time of the geometric correction, a method that the correspondence of latitude-longitude and line-pixel is calculated by bi-linear interpolation was developed [3]. This method has been proposed as a high-speed geometric correction method for NOAA AVHRR [4].



(a) Map coordinate (b) Image coordinate

Figure 1. Bi-linear interpolation for speeding up the geometric correction.

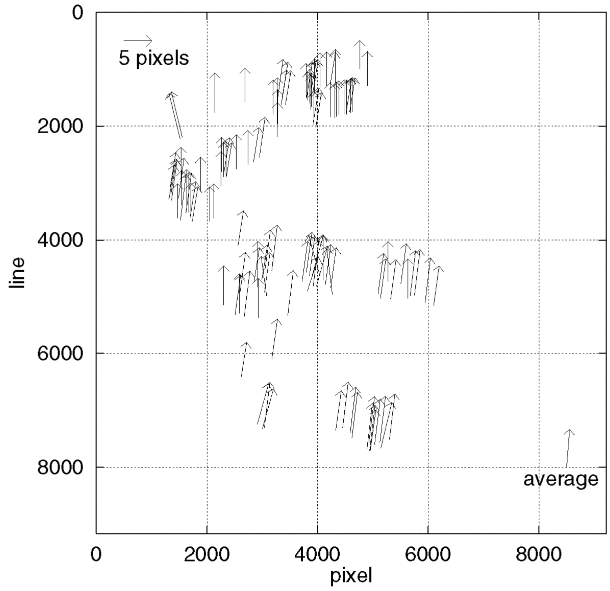
In Fig. 1(a), the output image on map coordinate is divided into blocks. For the four corners of the block, the latitude-longitude on map coordinate (s, t, u and v in Fig. 1(a)) is converted into the line-pixel on image coordinate (s, t, u and v in Fig. 1(b)) by the transformation using orbit information[2]. In the case of internal points such as p excluding four corners in the block, each correspondence of line-pixel and latitude-longitude is calculated by bi-linear interpolation using correspondences of the four corners, and each pixel in the output image on map coordinate is embedded.

In order to keep the accuracy of the geometric correction, it is necessary to adopt the block size that the maximum of the interpolation errors is less than 0.5 pixels. Also, it is necessary to choose the block size that the processing time of the geometric correction is short for speeding up the geometric correction. From the examination, the optimum block size is 100*100 pixels (VIS) and 50*50 pixels (IR).

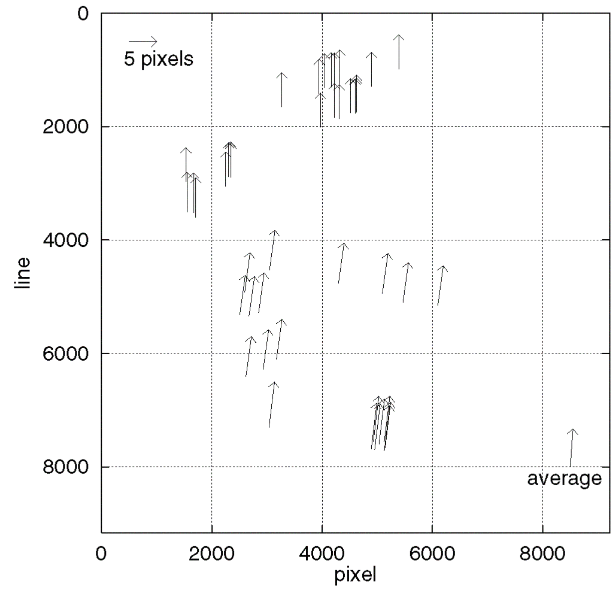
B. Geometric Correction Using Ground Control Points

In order to solve the problem about the accuracy of the geometric correction, a method of the precise correction using GCPs (Ground Control Points) was developed [3].

The geometric correction using GCPs means the following: (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 (Fig. 2(a)) [5]. (2) The errors are approximated with affine transformation by least-squares method. Only reliable residual errors with small approximation error of the affine transformation are selected (Fig. 2(b)). The affine coefficient is calculated using the reliable errors again. (3) The output image on map coordinate is divided into the blocks. For the four corners of the block, each correspondence between latitude-longitude on map coordinate and line-pixel on image coordinate is calculated using the orbit information. (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 bi-linear interpolation using correspondences of the four corners. (6) Finally, GMS image is resampled on map coordinate using the correspondences.



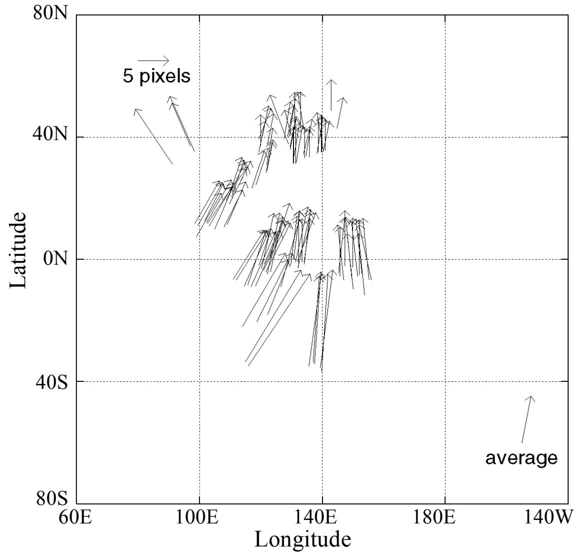
(a) Before the selection



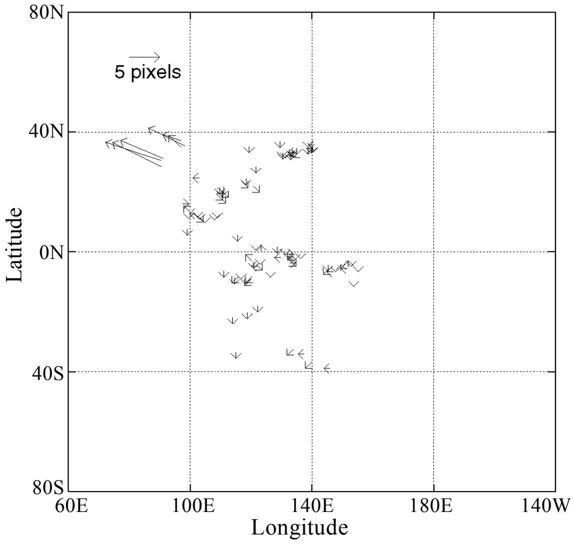
(b) After the selection

Figure 2. Selection of the residual errors (VIS of '99 12/23 3:00).

Fig. 3 shows the distribution map of residual errors on map coordinate. Each arrow means the vector of the residual error. S-VISSR data of visible channel at UT 3:00 on Dec. 23 1999 is used. Fig. 3(a) is systematic geometric correction. All residual error is very large. Fig. 3(b) is the proposed method. Most residual errors are equal to 0.01 deg or less than 0.01 deg. But, it has large errors around Himalaya (90E and 30N). This cause is that the elevation is not considered on the geometric correction using GCPs. Therefore, this method is useful for sea area. The processing time of the proposed method is about 6 minutes. The used computer is Sun Enterprise 5500 (CPU: Ultra Sparc 336MHz, Memory: 6GB).



(a) Systematic geometric correction



(b) Geometric correction using GCPs

Figure 3. Residual errors of the geometric correction using GCPs (VIS of '99 12/23 3:00).

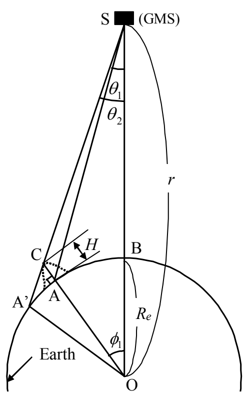


Figure 4. Relationship between the scan angle and the earth.

C. Geometric Correction Considering the Elevation

In order to solve the problem about the accuracy on high elevation area such as Himalaya, a method of the geometric correction considering the elevation was developed.

Although the earth is close to a sphere, it actually has unevenness like a dotted line of Fig. 4. In case that the elevation is not considered, the observation point corresponding the latitude-longitude is A, and the scanning angle is θ_1. But, considering the elevation, the observation point corresponding the latitude-longitude is C, the scanning angle should be θ_2. At this time, AA' is the elevation error on the earth surface of the geometric correction without elevation data, and θ_2- θ_1 is the elevation error on image coordinate. Although the elevation error for NOAA AVHRR, Terra/Aqua MODIS and Landsat occurs only in scanning (pixel) direction [6], that for GMS occurs also in stepping (line) direction because GMS is geostationary satellite. Then, each elevation error in line and pixel directions is calculated for GMS [7].

Then, the geometric correction considering the elevation means the following: (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. Residual errors are corrected using errors of the systematic geometric correction by the elevation. (2) The errors are approximated with affine transformation by least-squares method. Only reliable residual errors with small approximation error of the affine transformation are selected. The affine coefficient is calculated using the reliable errors again. (3) The output image on map coordinate is divided into the blocks. For the four corners of the block, each correspondence between latitude-longitude on map coordinate and line-pixel on image coordinate is calculated using the orbit information. (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 bi-linear 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 map coordinate using the correspondences.

Fig. 5 shows the distribution map of residual errors on map coordinate after the proposed method. Each arrow means the vector of the residual error. S-VISSR data of visible channel at UT 3:00 on Dec. 23 1999 is used. It is confirmed that the residual errors in high elevation area such as Himalaya are improved. Through the experiment using many scenes, the each maximum of errors in the proposed method is 0.01 deg in the both direction of latitude and longitude. Therefore, this method is useful for land area.

The processing time of the proposed method is about 8 minutes. The used computer is Sun Enterprise 5500 (CPU: Ultra Sparc 336MHz, Memory: 6GB).

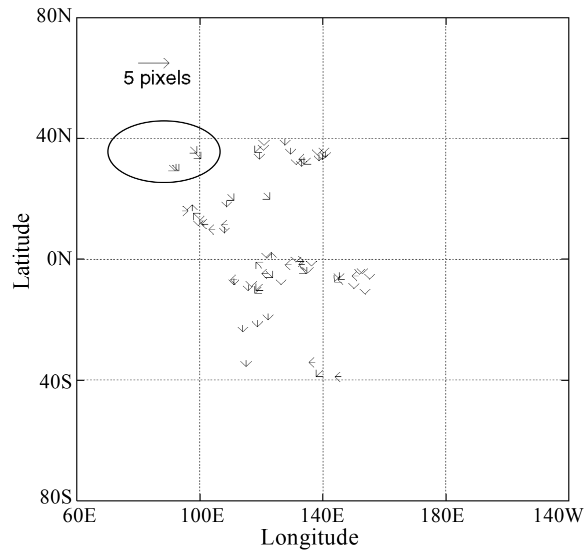
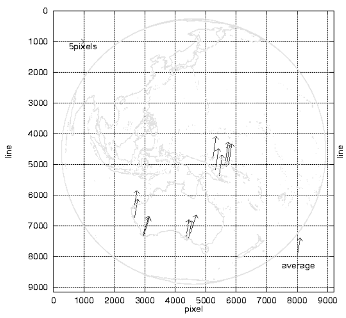
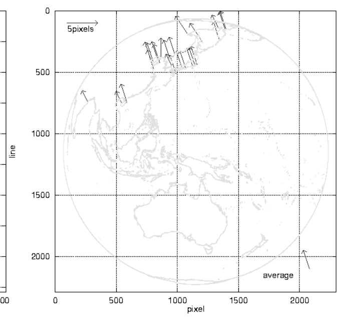


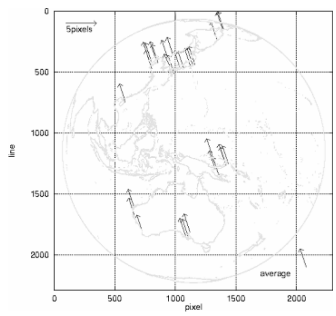
Figure 5. Residual errors of the geometric correction considering the elevation (VIS of '99 12/23 3:00).



(a) Visible channel (VIS)



(b) Infrared channel (IR1)



(c) Combined residual errors

Figure 6. Combination of residual errors ('99 12/23 1:00).

D. Geometric Correction on the Infrared Channels

Because infrared channels of VISSR observe the brightness temperature, the residual errors by using GCPs are not obtained when land temperature and sea temperature are same. In this case, the accuracy of the geometric correction using GCPs might decrease. Then, the acquisition technique of residual errors on the geometric correction using GCPs (above flow (1)) was improved.

At first, the residual errors of VIS and IR1 channels are acquired respectively (Fig. 6(a) and (b)) [5]. Since it has the difference of the resolution between channels, the residual errors of VIS channel are converted into the resolution of IR1 channel. Since the misregistration between channels is included, the residual errors of VIS channel are corrected. Finally, the residual errors of VIS and IR1 channels are combined (Fig. 6(c)).

Through the experiment using many scenes, the each maximum of errors in the proposed method is 0.01 deg in the both direction of latitude and longitude. Therefore, this method is useful for the infrared channels.

IV. CONCLUSION

In order to generate geometrically corrected image with high accuracy of the time series, high-speed and precise geometric correction method is described in this paper. Bi-linear interpolation is used for speeding up the geometric correction. The precise correction is carried out by using GCPs. Moreover, the geometric correction considering the elevation is developed and useful for land area. In the case of the correction on infrared channels, visible and infrared channels are used. As a result, the maximum of errors in the proposed method is 0.01 deg in the both direction of latitude and longitude. Precise geometric corrected images are archived and open for public use through the Internet (http://satellitedb.homelinux.com:8080/satelliteimage/index.jsp).

It is future plan to improve the quality of GCP data and to investigate the optimum distribution of GCP for calculating the coefficient of affine transformation.

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