AUTOMATIC PRECISION CORRECTION OF SATELLITE IMAGES

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ABSTRACT: Precision correction is the process of geometrically aligning images to a reference coordinate system using GCPs(Ground Control Points). Many applications of remote sensing data, such as change detection, mapping and environmental monitoring, rely on the accuracy of precision correction. However it is a very time consuming and laborious process. It requires GCP collection, the identification of image points and their corresponding reference coordinates. At typical satellite ground stations, GCP collection requires most of man-powers in processing satellite images. A method of automatic registration of satellite images is demanding. In this paper, we propose a new algorithm for automatic precision correction by GCP chips and RANSAC(Random Sample Consensus). The algorithm is divided into two major steps. The first one is the automated generation of ground control points. An automated stereo matching based on normalized cross correlation will be used. We have improved the accuracy of stereo matching by determining the size and shape of match windows according to incidence angle and scene orientation from ancillary data. The second one is the robust estimation of mapping function from control points. We used the RANSAC algorithm for this step and effectively removed the outliers of matching results. We carried out experiments with SPOT images over three test sites which were taken at different time and look-angle with each other. Left image was used to select GCP chipsets and right image to match against GCP chipsets and perform automatic registration. In result, we could show that our approach of automated matching and robust estimation worked well for automated registration.

***Key Words*: Precision Correction, GCPs, SPOT**

1. INTRODUCTION

Geometric correction is the transformation of a remotely sensed image so that it has the scale and projection properties of a map. A related technique, called image registration, is locating the coordinate system of one image to the reference coordinate system. Many applications of remote sensing data, such as data fusion, mosaic, classification and change detection, rely on image registration. For all these tasks, accurate image registration is the first step. If these steps failed and then other procedures cannot proceed. For precise registration control points must be distributed equally and generated accurately. In general GCP is collected manually, using digital map, rectified image, field survey and so on. However, it is a very enormous time consuming and laborious step. Automatic satellite image registration and precision correction will be an essential part of remote sensing.

For image registration, we used ground control points(GCPs), which are specific pixels in an image and the output map coordinates.

In the past, an operator has manually extracted the GCPs while viewing the collected image and the referenced map with naked eyes. Therefore, many researches on methods for automatically extracting the GCP have been recently conducted.

These include a method using wavelet scheme, multi-spectral analysis(Djamdji *et al.*, 1993; Zhang *et al.*, 2000; McGuire and Stone, 2000), generic algorithm(Jacp and Roux, 1995), and an automatic geometric correction techniques using a DTM(digital terrain model)(Rignot *et* *al.*, 1991).

However, these previous research of automatically extracting the GCP describes only a process of automatically extracting the control point from the image, but they did not suggest a process of finding out and overcoming the errors included in the extracted control points.

We believe that ground control points can be automatically extracted using stereo matching, but that there are the unavoidable errors included in the extracted control points.

In our experiments, we will use the RANSAC (Random Sample Consensus) algorithm (Fischler and Bolles, 1981) in order to effectively remove the outliers and will apply automatic precision correction. For three test sites, all outliers (or false matches) have been successfully identified. Correct mapping functions have been obtained, whose accuracy was close to the mapping function estimated with GCPs obtained by human operations.

2. STRETAGY AND METHODOLOGY OF AUTOMATIC PRECISION CORRECTION

The main process of this work can be composed of two steps. Firstly, ground control points are automatically extracted using stereo matching method. Secondly, mismatched control points are then effectively removed from the extracted control points so that image registration and precise image correction can be accurately performed. Here, we assume that there are a number of previously and probably manually registered images (reference images) and GCP chips

2.1 The generation of GCPs from the new image

In this procedure, GCPs from the new images(target images) is extracted using ancillary data and adaptive matching method. We also assume that new images have ancillary data, which describe information on imaging geometry (tilt angle, platform position, image orientation angle, etc.), image boundary coordinates and acquisition time. Such information is not very accurate but can be used as initial approximations.

First, if the target image and the ancillary data there of are inputted, coordinate information on four boundary corners of the new image is used as the ancillary data of the target image(Fig. 1).

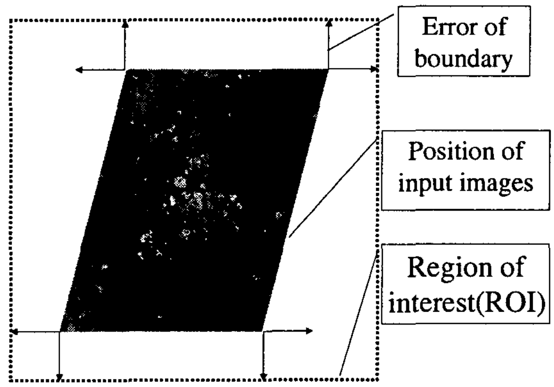

Fig. 1. Initial estimation of boundary position

Next, the GCP chips included in the region of the reference image are searched. In order to find out positions corresponding the GCP chips from the target image, a search region of target image is selected

We use normalized cross correlation as a measure to determine the correspondence. We define the size of the search window based on a scale factor S which is obtained by dividing a cosine value of the incidence image, as expressed in the following formula.

$$s = \frac{\cos(\text{incidence angle of target point})}{\cos(\text{incidence angle of reference point})}$$

We also rotate the search window by the difference in the image orientation angles between the reference and target images(Fig. 2).

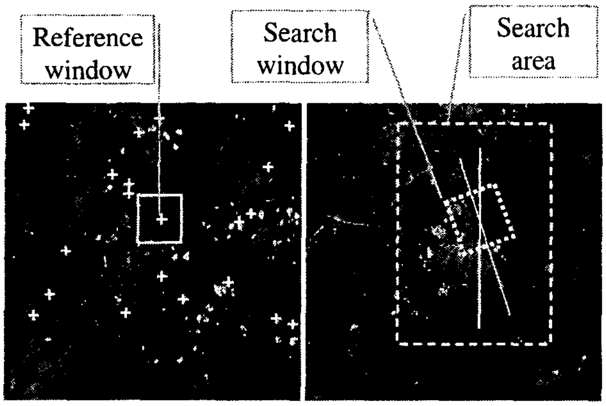

Fig 2. In stereo matching step we use adaptive search window using ancillary data.

2.2 The removal of outliers using RANSAC and estimation of mapping function

The second step of automatic image registration is the estimation of mapping functions using GCPs generated from the first step. GCPs from the first step will always contain false matches. These will act as outliers and hinder accurate estimation of mapping functions if naive estimation methods are used. We need robust estimation to overcome the effects of false matches and achieve correct mapping functions.

The Random Sample Consensus (RANSAC) proposed by Fischler and Bolles (1981) is a powerful and robust estimator in the presence of outliers. The RANSAC does not require prior assumption of the distribution of outliers. As long as we can postulate boundaries between inliers and outliers (Stewart, 1997) we can use the RANSAC to cope with outliers. It works by estimating a model with minimum required number of control points selected randomly and checking whether other control points support the model. It repeats these procedures for a certain number of times and chooses the best model that has the largest supports. After that, it re-estimates the model using those control points used for the best model and other supporting control points.

In computer vision applications, the RANSAC has been used in feature extractions (Cheng and Lee, 1995; Vincze, 2001).

The mapping function $\mathbf{M}_{target}$ will be estimated using correspondences between GCP chips and the target image. In this case, GCPs are generated by matching a new image against GCP chips. Each GCP will consist of target image coordinates and ground reference coordinates. The mapping function $\mathbf{M}_{target}$ is the transformation from 3D reference coordinates to 2D target image coordinates and can be expressed as below.

$$\begin{pmatrix} wC_{target} \\ R_{target} \\ w \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix}$$

The RANSAC will be used to identify outliers, i.e., false matches between GCP chips and the target image and to estimate $\mathbf{M}_{target}$ correctly.

3. RESULTS AND DISCUSSIONS

In order to verify the effectiveness of the present method, the SPOT image of three test area(Taejeon, Boryung, Junju) are utilized. For each test site, the left images were previously extracting GCP chips and storing manually. Then, the right images(target image) were used in automatic precision correction. GCPs were prepared by GPS survey. Table 1 summarizes the characteristics of stereo pairs and GCPs.

Table 1. Summary of test scenes and ground control points

Test Site	Taejon	Boryung	Junju
Scene Acquisition Date	L: Oct. 14, '97 R: Nov. 15, '97	L: March 1, '97 R: Nov. 15, '97	L: Oct. 14, '97 R: Nov. 15, '97
Tilt Angle	L: 25.8° R: 4.2°	L: -25.8° R: 0.6°	L: 25.8° R: 4.2°
No.of GCPs	21	20	16

For all three sites, the acquisition dates of the left and right image were not very close, unfortunately. For

Taejon and Junju, the difference of acquisition date was about one month, when season changes from the autumn to the winter. For Boryung, the left was taken in the spring and the right in the winter. Seasonal changes as well as different illumination conditions will make brightness patterns of stereo images appear very different. The aspect of the test datasets causes false matches unavoidably.

Firstly, automated registration was tested with GCP chips. We created GCP chips by defining small image windows from the left image for each test site. The right images were regarded as the image to be registered. The ancillary data of the right images can be used to define a ROI and to search for GCP chips within the ROI. In our experiments, the GPS surveyed GCPs prepared were within the stereo coverage of the left and right images and hence all lying within the ROI of the right image.

Secondly, automated matching was carried out between GCP chips and the target images. For each GCP chip, a point whose normalized cross correlation (NCC) value was highest was chosen as a correspondence. The search range was set as $\pm$ 2kms (or $\pm$ 200 pixels). Table 2 summarizes the result of automated stereo matching for the three test sites.

Match results were classified by their highest NCC values. Within each class the number of true matches versus the number of false matches are shown. If a match point did not deviate from the manually measured correspondence by more than three pixels, it was classified as a "true" match. For Taejon, automated matching created 14 true matches and 7 false matches in total. In this case, if the NCC value was higher than 0.8, there was no false matches. If the NCC value lied between 0.6 and 0.8, there were 7 false matches among 14 match points.

Table 2. Results of automated stereo matching. Each result shows the number of true matches versus the number of false matches.

Test site	Taejon	Boryung	Junju
NCC > 0.8	7:0	5:0	7:0
0.6 < NCC < 0.8	7:7	9:3	2:2
NCC < 0.6	N/A	2:1	0:5
Total	14:7	16:4	9:7

Table 3 shows results that the mismatching points are filtered out from the results of searching the matching points of the target image for the control points of the reference image using the RANSAC algorithm and the camera model is then established

Table 3. The estimation of M_{target} through the RANSAC

Test Area	Taejon	Boryung	Junju
Modeling with the RANSAC			
- No. of points used for modeling	14	16	9
- No. of outlier detected	7	4	7
- Modeling error (RMS, pixel)	0.70	0.79	0.90
Modeling with the true CPs			
- No. of points used for modeling	21	20	16
- Modeling error (RMS, pixel)	0.41	0.60	0.44

As can be seen from Table 3, if the RANSAC algorithm is used, the mismatching points can be accurately filtered out up to 100%. Further, it is understood that there is only a slight difference in accuracy between the actual camera model and the camera model by manual.

Fig 3 is a result of automatic precision correction for SPOT images covered Taejeon area.

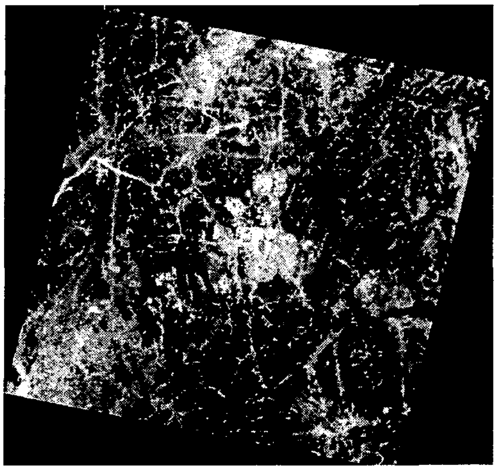

Fig 3. Automatic precision correction for Daejeon SPOT images

We could conclude that our approach of automated matching and robust estimation worked well for automated registration of new images with respect to map or datum using GCP chips.

4. CONCLUSION

From the test results given above, it is apparent that the proposed method was effectively used in automatic precision correction and showed a method to solve the problem of automated image registration.

To summarize, we addressed the important role of robust estimation in automated registration. We tested satellite images, which normally possess ancillary data. We devised a simple but intelligent stereo matching algorithm to produce control points automatically. We then used the RANSAC to estimate mapping functions in the presence of outliers. The experiments supported that our algorithm worked well.

This paper assumed that sufficient number of GCP chips were available beforehand. Our algorithm works only when the number of inliers is larger than the minimum required number for estimation, which is the current limitation.

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