Automatic Matching Method of Control Points for AVHRR Remote Sensing Image

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Abstract. Remote sensing image automatic registration technology is one of the image processing technologies that have been developed rapidly in recent years, and automatic matching of control points is the core work of the automatic registration. Considering the influence of the cloud points and the phenomenon of uneven distribution of control points in AVHRR images, an automatic matching method of control points is proposed in this paper. In this method, the cloud points are detected first, and then feature points are extracted in the overlapping region of the two images. Finally, matching is performed based on image blocks method and the results of cloud point detection. Experimental result shows that this method not only can obtain even distributed control point pairs and avoid the interference of cloud points, but also can improve the accuracy of registration of AVHRR remote sensing images.

Keywords: AVHRR images; cloud point detection; even distribution; automatic matching

1 Introduction

NOAA AVHRR remote sensing image data has been widely used in many environmental research fields, such as detection of vegetation ecosystem, land use and detection of permafrost and grassland [1]. At present, Level-1 AVHRR data can be downloaded for free, and registration processing is necessary for more effectively usage.

There are two kinds of remote sensing image registration methods, manual and automatic. The manual method chooses control point pairs in referenced image and original image with visual observation to perform registration. Manual registration method is not only time-consuming but also difficult to ensure accuracy as a result of low spatial resolution of AVHRR images. However, accessing control point pairs with automatic method is completely depends on the images themselves instead of manual intervention. An automatic registration is divided into two main methods. One is based on region and another is based on feature [2]. The method based on feature is widely used, because it only uses parts of the image information and has certain robustness for occlusion and distortion in the image.
At present, the commonly used feature extraction methods include Moravec algorithm, Harris corner detection method, SIFT feature extraction method, etc. Li [3] et al., adopted SIFT feature extraction method to realize automatic remote sensing images registration. Lu [4] et al., utilized Harris feature corner to implement remote sensing images registration. There are many researches about remote sensing image automatic registration based on feature, but most of them did not consider the impact of cloud point in the remote sensing images. In fact, some pixels on the edge of cloud region in AVHRR images can easily be mistaken for control points, and it may bring adverse influence on the registration accuracy. Meanwhile, the obtained control point pairs using by feature extraction methods are easily distributed in regions that have clear texture and edge information using Harris feature points and are very few in those regions with low information. The phenomenon of uneven distribution will affect the accuracy of registration subsequently.

This paper proposes an effective automatic matching method of control points for AVHRR images to solve the interference of cloud point in AVHRR images and the uneven distributed control point pairs.

2 The Basic Process and Key Improvements

The proposed automatic registration method of control points for AVHRR remote sensing images in this paper is divided into five steps, All the steps are shown in Fig 1. Cloud points detection and correlation-coefficient coarse matching method base on image blocking and marks of cloud points are main research content in this paper.

2.1 Cloud Points Detection based on OSTU Method

In 1979, Otsu proposed minimum within-class variance criteria method to select the best threshold [5]. Experiments show that this method is applicable to the images which have obvious bimodal histogram. AVHRR images generally have obvious contrast between cloud region and underlying surface region and bimodal gray-level histogram. Thus we choose OSTU method to extract segmentation threshold of cloud region, and then we use the obtained threshold to mark those cloud points. The basic calculation formula of OSTU method can be expressed as follows

\[ \sigma^2 = \omega_1 \omega_2 (\mu_1 - \mu_2)^2 \]  

(1)
Where,

\[ \omega_1 = \sum_{i=0}^{t} p_i \]  

\[ \omega_2 = \sum_{i=t+1}^{M} p_i \]  

\[ \mu_1 = \sum_{i=0}^{t} i p_i / \omega_1 \]  

\[ \mu_2 = \sum_{i=t+1}^{M} i p_i / \omega_2 \]  

Here: \( \sigma^2 \)—the between-cluster variance; \( \omega_1 \)—the appearance probability of gray levels whose value is smaller than or equal to the threshold; \( \omega_2 \)—the appearance probability of gray levels whose value is larger than the threshold; \( \mu_1 \)—the average of gray levels whose value is smaller than or equal to the threshold; \( \mu_2 \)—the average of gray levels whose value is larger than or equal to the threshold; \( p_i \)—the appearance probability of each gray level in one image; \( N \)—the total number of pixels in one image; \( M \)—the gray levels of one image; \( t \)—the optimal threshold to be calculated.

The \( t \) is computed starting from 0 to \( M-1 \), accordingly, the between-cluster variance is calculated for each new threshold. The bigger the between-cluster variance, the greater difference of contrast between background and objectives in the images is. Finally, the \( t \) that has the maximum between-cluster variance is elected to be the final threshold.

In this paper, a between-cluster variance represents the degree of difference between the cloud regions and underlying surface regions in AVHRR images. The \( t \) is considered as the segmentation threshold of cloud region. We judge the segmentation threshold commonly varies from 300 to 550 with a large number of experiments and compress its range from 0-1024 to 300-550. This improvement can not only greatly reduce the amount of calculation, but also ensure the accuracy of the threshold. Finally, we regard the pixel whose value is greater than \( t \) as a cloud point, and then we mark these cloud points.

### 2.2 Extraction Strategy of Control Point Pairs based on Image Blocks and Cloud Point Detection Method

The proposed extraction strategy of control point pairs in this paper has two steps. In the first step, we divide \( X \) (reference image) and \( Y \) (original image) into sub-blocks by using image blocks method at first. Theoretically, the more sub-blocks, the easier to extract even distributed control point pairs. Then, we divide the overlapping region into \( m \times n \) sub-blocks. For the region containing \( M \) rows and \( N \) columns, the row
length is $M/m$ and the column length is $N/n$ in a sub-block. But the length should not be too small. And then we should mark $X_i$ (a sub-block in referenced image) and $Y_i$ (a sub-block have the same geographical position with $X_i$ in original image, $1 \leq i \leq m \times n$), and consider them as a sub-block pair.

In the second step, we firstly select $X_i$ and $Y_i$ to perform match with the maximum of correlation-coefficient method. This method need to compute the correlation-coefficient between a template to be matched in original image and the small window in referenced image and can find the position of maximum correlation-coefficient by moving the small window in the referenced image. The template to be matched is the region whose geographical position is close and size is same with the small window. Then, with the results of cloud detection, we present an inequality to rule out the interference of cloud point for the matching. This inequality is described as follows

$$\theta > (m \times n) \times 10\%$$

Here, the $\theta$ represents the number of cloud points in a template to be matched. If the $\theta$ over 10% of the template size, it means there exist lots of cloud points. Therefore, this calculation of correlation-coefficient can be abandoned to avoid the cloud point interference. On the contrary, it is necessary to calculate the correlation-coefficient for those templates that do not meet the inequality (6). We select $\mu_i$ (the maximum correlation-coefficient) in a sub-block pair and treat the corresponding feature point pair as a candidate control point pair. Then, we set a global threshold $\mu_g$ that varies from 0.55 to 0.75. The value is adjusted based on the quality of AVHRR images. If $\mu_i \geq \mu_g$, then the corresponding candidate control point pair can be selected as final control point pair, if not, the corresponding candidate control point pair should be eliminated.

### 3 Experiment and Analysis

In this paper, we firstly perform the automatic matching experiment of control points based on cloud point detection method. Finally, we complete the automatic registration experiment for one AVHRR image combined with multiple methods mentioned above. All the experimental data are derived from the website of Chinese national satellite meteorological center. The original image is an AVHRR remote sensing image in 2004 and the referenced image is a MODIS remote sensing image of China.

Experiment 1 performs an automatic matching with cloud detection method, and compares with an automatic matching without dealing with the cloud points. The results of the two experiments are shown in Fig. 2 and Fig. 3.

It can be found that there are more control points in Fig. 3 than them in Fig. 2 at the edge of cloud region. But these extra points are not real control points and we call them as pseudo control points. The accuracy of automatic registration will be reduced with lots of pseudo control points. But the Fig. 3 shows that these pseudo control points around the edge of cloud region can be effectively eliminated with ruling out the interference of cloud points.
Experiment 2 performs two geometric precision correction, one is based on the result of proposed automatic matching method which contains cloud detection, and image blocking and another uses traditional processing method. Precision analysis method for the two experiments is as follows. Firstly, we select twenty even distributed pixels which have obvious feature in referenced image. Secondly, we find the corresponding twenty pixels which have the same location with the selected pixels in referenced image from the two corrected images obtained by the experiments above. Finally, we calculate mean error and root-mean-square error of the X-direction, Y-direction and distance and analyze them.

Table 1. Statistical analysis of errors with twenty selected points in the two corrected images, one image is the result of traditional method and another is the result of the method proposed in this paper. In this table, trad means traditional method and paper means the method presented in this paper.

<table>
<thead>
<tr>
<th>Error type</th>
<th>X-trad</th>
<th>Y-trad</th>
<th>Distance-trad</th>
<th>X-paper</th>
<th>Y-paper</th>
<th>Distance-paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN error</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>MAX error</td>
<td>3.0</td>
<td>2.0</td>
<td>3.0</td>
<td>2.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Mean error</td>
<td>0.80</td>
<td>1.0</td>
<td>1.49</td>
<td>0.45</td>
<td>0.70</td>
<td>1.04</td>
</tr>
<tr>
<td>RMS error</td>
<td>0.77</td>
<td>0.65</td>
<td>0.60</td>
<td>0.60</td>
<td>0.47</td>
<td>0.35</td>
</tr>
</tbody>
</table>

As it is shown in Table 1, both the mean error and RMS error obtained by the proposed method are less. The experimental results show that using the proposed method can improve the accuracy of automatic registration for AVHRR images.
4 Conclusion

This paper researches automatic matching method of control points for AVHRR images. OSTU method is adopted to calculate the threshold of cloud region. And then the cloud points can be marked with this threshold. The correlation coefficient coarse matching based on image blocks and the marks of cloud points is also performed. Even distribution control point pairs can be obtained after the matching with blocking method so that the phenomenon of uneven distribution can be effectively solved. Meanwhile, the interference of cloud points can be eliminated with the marks of cloud points. The experiment of automatic registration shows that the accuracy of automatic registration for AVHRR images can be improved.

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