Remote Sensing Image Registration Algorithm Based on Multi-scale Corner and Haar Transformation

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Abstract. This paper proposed a new image registration algorithm based on multi-scale corner and Haar transformation, which its core idea is the combination of Haar operator and the Laplace image pyramid are used in down sampling the original images, and detect corner at the resulting images, Angle of the corner and most value point of scale response (scale precision positioning) will get, registrating images will obtained after rotation and translation. Theoretical analysis and simulation results shows the algorithm has higher registration accuracy and small amount of computation.

1. Introduction

Image registration is a basic problem in image analysis and processing, and it’s one of the key technologies in remote sensing image analysis, remote sensing image automatic mapping and three dimensional reconstruction. Image registration is the process of establishing the corresponding relationship between two images, determining the corresponding geometric transformation parameters, and making a geometric transformation of one picture by taking the other of the two images as a reference image. Mage registration methods can be roughly divided into two categories: region-based registration method and feature-based registration method. The region-based method is to compare the pixels in a small window on one image with the same size window on another image. The feature based method is to calculate registration parameters according to the geometric relationship of the same features of two images.

There have been many studies on feature-based registration methods. Zheng proposed a method based on computer vision to determine the transformation parameters between two images. That is to say, the estimation of camera initial attitude angle is estimated by the estimation of illumination direction. Then a small number of feature points are determined based on Gabor wavelet model which detects local curvature discontinuity. The initial parameters of scale and translation are estimated by obtaining matched feature points from two images. Finally, the exact values of the transformation parameters between the two images are obtained by using the hierarchical feature matching method. An edge-based image registration method was proposed by JianAn jun et al. They used edges as fixed features in images and used wavelet transform to detect edges. These algorithms are still vulnerable to noise interference and large computational load.

A registration method based on multi-scale corner features was proposed in this paper. Haar operator was combined with Laplace image pyramid, and the image was scaled at different scales and rotated at different angles. Multiresolution corner detection was used to compute the descriptors of these corners. Compared the corner points between the reference image and the image to be registered. Image
registration is performed according to the transformation relationship. Experiments proved that, this method can well register the objects in remote sensing images.

2. Haar and Laplace operators

Haar corner detection operator is a good and stable corner detection operator among many operators. It has good repeatability corresponding to the usual translation, rotation and small light changes. But it is easy to make mistakes in image registration with large scale changes. To overcome this shortcoming, in this paper, Haar operator and Laplace image pyramid are combined. Multi-scale corner detection and registration are realized. Let the image gray function be \( I(x, y) \). Then a second-order autocorrelation matrix based on different scales is constructed.

\[
C(x, \sigma_I, \sigma_D) = G(\sigma_I) \ast \begin{bmatrix} I^2_u(x, \sigma_D) & I_x I_v(x, \sigma_D) \\ I_x I_v(x, \sigma_D) & I^2_v(x, \sigma_D) \end{bmatrix}
\]  

\( (1) \)

Among them, \( I_u(x, \sigma_D) \), \( I_v(x, \sigma_D) \) is the first-order Gauss differential filtering of the image in two directions. The standard deviation of Gauss operator is scale \( \sigma_D \). So \( \sigma_D \) is called differential scale. \( G(\sigma_I) \) is a weighted Gauss low pass filter for differential images. Its variance \( \sigma_I \) is called integral scale. The corner of a multiscale Haar operator is defined as:

\[
cornerness = \det(C) - k \text{ trace}^2(C) > \text{thresh}
\]  

\( (2) \)

\( K \) is a custom parameter. Threshold is the detection threshold.

Corresponding to the translation, rotation and scaling of the image, its transformation matrix is:

\[
\begin{bmatrix}
\dot{x} \\
\dot{y} \\
1
\end{bmatrix} = \begin{bmatrix}
S \cos(\theta) & -S \sin(\theta) & x_0 \\
S \sin(\theta) & S \cos(\theta) & y_0 \\
0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
x \\
y \\
1
\end{bmatrix}
\]  

\( (3) \)

Shorthand for \( \dot{x} = hHx + x_0 \), among \( H = \begin{bmatrix}
S \cos(\theta) & -S \sin(\theta) \\
S \sin(\theta) & S \cos(\theta)
\end{bmatrix} \) is a rotation matrix. Bring the transformation matrix into formula (3), the relation of corner response function between different scales is obtained as follows.

\[
C'(\dot{x}, h\sigma_I, h\sigma_D) = \frac{1}{h^2} C(x, \sigma_I, \sigma_D)
\]  

\( (4) \)

Therefore, at different scales, there is a close relationship between corner response functions. Using the above relationship, multi-scale corner detection can be realized smoothly. Image registration between different scales is realized.

3. Algorithmic steps and simulation

3.1. Stability verification of Haar algorithm

Liu Ningbo proposed a corner and angle detection method to detect ships with sharp corners at the front [4]. Then determine the position of the ship. Zhou Peng proposed an image registration method based on corner detection [5]. The corner information is obtained by scanning along the arc curve, and then
the initial registration parameters are obtained according to the corresponding relations of these corners. By studying the registration algorithm, we can know that, Traditional image registration methods based on corner feature can be roughly divided into four steps: The first step is to extract corner points from the reference image and the image to be registered. The second step is to calculate the descriptors of these corners. The third step is to compare the corner descriptor between the reference image and the image to be registered. Find a number of corresponding corners. In the fourth step, the registration image is transformed and registered according to the transformation relation of the corresponding corner points.

Among many corner detection operators (including Moravec, SUSAN, Hannah, Dreschler, Forstner, etc.). Haar operator is much better than other operators in speed and performance [6]. It has good repeatability. But the inherent disadvantage of Harris operator is that it cannot adapt to the change of image scale. For this reason, Haar operator is combined with Laplace image pyramid. Multi-resolution corner detection is used. To overcome the problem of low corner repetition detection rate caused by scale change of Haar operator.

In order to verify the stability of multi-scale Haar operators. In this paper, the image is scaled at different scales and rotated at different angles. The results are as follows (Red Cross marks are corner points):

Step one: the original image is filtered smoothly. Reduce the impact of noise. Then corner detection is performed on the filtered image and the rotated and scaled image. As can be seen from the results of the detection, the multi-scale Haar operator can adapt to rotation and scale change better. Whether before or after transformation, the corner points detected are abundant and distributed evenly in the whole image. This is conducive to the subsequent registration work. This ensures that the false corners can be removed by further screening. There are still enough corners to complete the registration work.

Second two: A directed rectangular window is constructed around each corner. Divide the rectangular window into four small pieces. Simple features of uniform points are calculated in each block. The Haar wavelet response and are accumulated along the vertical and horizontal directions of the point in each small area as the first and second components of the describing operator. In order to consider the direction problem, and are added together as the third and fourth components of the describing operator, that is. So the corner description vector is. The following are flat areas. Descriptive operators in the changing and gradient regions along the X direction.

A matching is considered when the descriptor vector is nearest and larger than a threshold value. That is \( ||V_1 - V_2|| < t \). In order to speed up matching, comparisons are made only when the gray difference between two corners is less than a certain value. That is \( |I(x_1, y_1) - I(x_2, y_2)| < t \). The following is the matching result. Red forks represent corners. The number next to it indicates the ordinal number of the corner: (The same corner in the two pictures is marked with the same number).
Figure 3. Expand the original image twice and rotate 50 degrees

Figure 4. (Left): gray flat area; (middle): gray mutation in X direction; (right): gray gradient in X direction

Figure 5. Reference image (red "x" indicates the corner Position and the number next to it indicates the serial number of the corner)

Figure 6. Registration results (red "x" indicates the corner position, and the number next to it indicates the serial number of the corner)
3.2. Registration and transformation of collocated corners between different scales

(1) Each scale image in the image pyramid, choose a circular window \( w \) around each corner. The radius is \( kS \). \( S \) is the scale of the corner. Then the response vectors of Haar wavelet are computed along the X and Y directions on the current scale \( S \), which are denoted as \( Sdx, Sdy \). The center is weighted by the Gauss window at the corner (the standard deviation is the current scale \( S \)). The sum of sliding windows along \( u \) and \( V \) directions is calculated in this vector space. This sum forms a new vector. The vector with the longest modulus is the direction of the corner, that is, the angle of the corner is:

\[
\theta = \arctan\left(\frac{\max(\sum_{w} Sdx)}{\max(\sum_{w} Sdy)}\right)
\]

(5)

(2) Let the set of corner description vectors in two graphs be \( P \) and \( Q \) respectively. Using a distance measurement method. For example, European distance or Hausdorff distance, take

\[
\min_{p \in P, q \in Q} |p - q|
\]

as the best match. For a pair of matching points \( (p, q) \), centering on \( P \) and \( Q \) respectively, the Gaussian window with radius \( R_o \) and \( R \in (r_1, r_2) \) is weighted as the scale response of the corner point. Scale transformation size \( S_o \) between images is obtained by comparing scale responses.

Maximum Point Ratio of Scale Response:

\[
S_o = \frac{\arg(\max(S_o))}{\arg(\max(S_o))}
\]

(6)

That is the actual image size transformation (precise scale positioning).

After obtaining scale transformation information \( S_o \), the image to be registered is transformed. Make it at the same scale as the reference image. Then bring in the matching corner. The rotation and translation information can be obtained. Finally, the image is transformed by rotation and translation. Make two images registration.

4. Conclusion

In this paper, a fast registration method for remote sensing images based on rotation of arbitrary angle is proposed. It is a registration method that combines corner detection with Haar operator and Laplace image pyramid. The response vector of Haar wavelet is obtained for each scale image in the image pyramid. Weighting is done through the Gauss window at the point. Find the angle of the corner. Then, the maximum point ratio of scale response (scale precise positioning) is obtained by calculating. Then the registration image is transformed. At the same scale as the original image, rotation and translation are performed using rotation angle and translation information. Finally, the registration image is obtained.

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