

A NOVEL IMAGE REGISTRATION ALGORITHM FOR SAR AND OPTICAL IMAGES BASED ON VIRTUAL POINTS

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ABSTRACT:

Optical image is rich in spectral information, while SAR instrument can work in both day and night and obtain images through fog and clouds. Combination of these two types of complementary images shows the great advantages of better image interpretation. Image registration is an inevitable and critical problem for the applications of multi-source remote sensing images, such as image fusion, pattern recognition and change detection. However, the different characteristics between SAR and optical images, which are due to the difference in imaging mechanism and the speckle noises in SAR image, bring great challenges to the multi-source image registration. Therefore, a novel image registration algorithm based on the virtual points, derived from the corresponding region features, is proposed in this paper. Firstly, image classification methods are adopted to extract closed regions from SAR and optical images respectively. Secondly, corresponding region features are matched by constructing cost function with rotate invariant region descriptors such as area, perimeter, and the length of major and minor axes. Thirdly, virtual points derived from corresponding region features, such as the centroids, endpoints and cross points of major and minor axes, are used to calculate initial registration parameters. Finally, the parameters are corrected by an iterative calculation, which will be terminated when the overlap of corresponding region features reaches its maximum. In the experiment, WordView-2 and Radasat-2 with 0.5m and 4.7m spatial resolution respectively, obtained in August 2010 in Suzhou, are used to test the registration method. It is shown that the multi-source image registration algorithm presented above is effective, and the accuracy of registration is up to pixel level.

1. INTRODUCTION

With the enormous increase in availability and quality of remote sensing data products, remote sensing imagery and techniques have found applications in diverse areas like traffic studies, treaty and border monitoring, agricultural studies, generation of 3-D models and topographic maps, early-warning systems, urban growth monitoring, damage assessment, and specifically, disaster mitigation [5]. In general, images acquired both by the passive optical sensors and active synthetic aperture radar sensors (alone and in combination) are major sources for crisis information management. Optical image is rich in spectral information, while SAR instrument can work in both day and night and obtain images through fog and clouds. Combination of these two types of complementary images shows the great advantages of better image interpretation. Image registration refers to the task of aligning two or more images of the same scene taken under different imaging conditions, such as at different times, by different sensors, from different viewpoints, etc. It is a crucial step in combination of this two types of complementary images.

Automatic registration falls into two categories: intensity-based method and feature-based method. The intensity-based method finds the geometric transformation between optical and SAR images by optimizing a similarity measure between the two images[2]. Widely used measures include mutual information, cluster reward algorithm, and cross-cumulative residual entropy. The intensity-based methods work directly on image intensities, are very sensitive to image noise, and will become unreliable when they exist significant grey level difference and images distortion between the both images[7]. Thus, these methods are not suitable for multi-sensor images registration, not to mention for optical and SAR images. The feature-based method usually estimates the geometric transformation between images by establishing reliable feature matches. SAR image mainly reflects microwave backscatter coefficient of the targets, while optical image primary record solar radiation. Feature-based method tend to achieve better result compared with intensity-based method because of the difference in imaging mechanism and the speckle noises in SAR image.

For these features, point features and line features are usually huge in number and easy to locate, but difficult to match, especially when they are from different sensors. The number of closed regions is usually small, but they are relatively reliable and easy to match. For SAR and optical images, a novel image registration algorithm based on the virtual points, derived from the corresponding region features, is proposed in this paper.

2. METHODS

Feature-based methods basically consist of four steps: feature extraction, feature matching, transform model estimation and image transformation.

2.1 Feature extraction

Many closed regions extracting methods have successfully developed in the past decades, such as Chan-Vese model, GAC model, morphological segmentation algorithm, dynamic threshold technique, region increase method, the mean-shift algorithm etc. However, the speckle noise strongly destroying contours and boundaries of the objects in SAR images, the above methods are not only time consuming but cannot obtain a very good effect.

Among variety of objects, water is the most easily recognizable and could extract reliable regions in common. In this paper, the

main closed regions are coming from the classification of water. Firstly, Lee filter is used to eliminate the speckle noise of SAR images. Then unsupervised classification IsoDate algorithm and supervised classification algorithm are adopted to extract closed regions from SAR and optical images simultaneously. After closed region extracting, there are still many small regions and noise. So morphological operations and threshold method are used to avoid this kind of noise and improve the connectedness of the objects.

2.2 Feature matching

For the extracted closed regions, reasonable description and comparison of its characteristics are used to identify matching relations. Reasonable shape description parameters contain area, perimeter, the length of major and minor axes. The feature matching achieved by the cost function is defined as (1).

$$C_{ij} = \left| \frac{s_i - s_j}{s_i + s_j} \right|^{\frac{1}{2}} + \left| \frac{p_i - p_j}{p_i + p_j} \right| + \left| \frac{r_i - r_j}{r_i + r_j} \right| + \left| \frac{c_i - c_j}{c_i + c_j} \right| \quad (1)$$

Where S_i is the area of region i , p_i is the perimeter length, r_i is the length of the bounding rectangle, and c_i is the width of the bounding rectangle.

Only when two conditions to be satisfied, feature S comes from SAR image and feature O comes from optical image are determined to be matched:

(1) $C_{so} = \min (C_{so1}, C_{so2}, \dots, C_{son})$ where O_1, O_2, \dots, O_n are the possible matched features to feature S , n is the number of closed regions in the optical image.

(2) $C_{so} \leq T$, which T is threshold value. If the cost function is

less than the threshold value, the corresponding features will be eliminated.

2.3 Transform model estimation

Affine transformation is widely used in image registration and supports modeling of translation, rotation, stretching, and shearing [6]. The goal is to seek an appropriate transformation which correctly maps a position (x', y') on the optical image to a position (x, y) in the SAR image. As satellite images are very far from the camera sensor, the projective transformation can be approximated by the affine transformation involving six parameters.

$$x' = m_1x + m_2y + m_3 \quad (2)$$

$$y' = m_4x + m_5y + m_6 \quad (3)$$

Virtual points derived from corresponding region features C_s, o_j got in the above step, such as the centroids, endpoints and cross points of major and minor axes, are used to calculate initial registration parameters. Then, the parameters are corrected by an iterative calculation, which will be terminated when the overlapping of corresponding region features reaches its maximum.

2.4 Image transformation and resampling

The result of last three processing steps is the optimal six transformation parameters. Affine transformation in Eq. (2)(3) are used based on those parameters. After transformation, chose bi-cubic convolution interpolation method to resample the sense image.

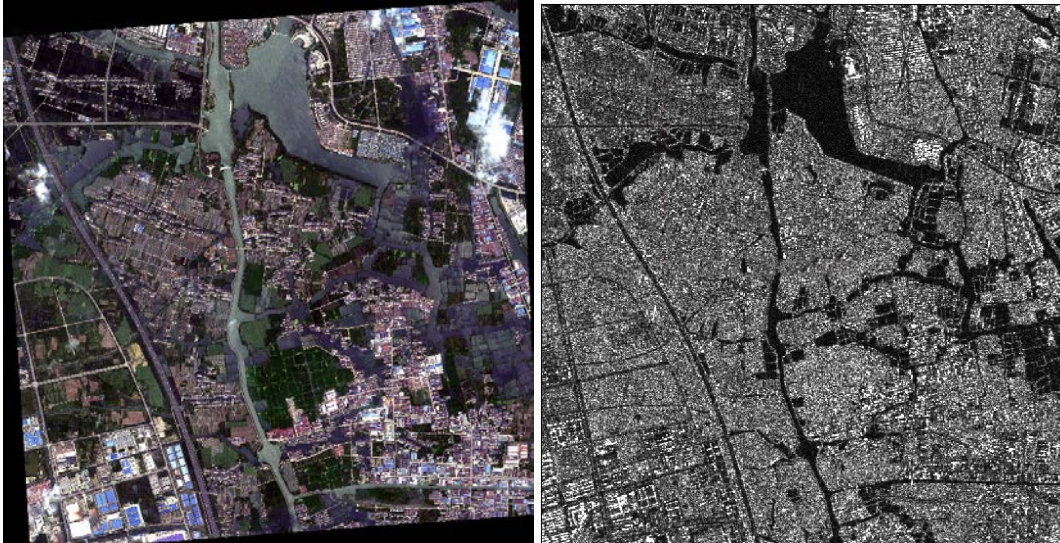


Figure 1. The original optical and SAR images



Figure 2. Closed regions extraction results

3. EXPERIMENTS

In our experiments, the optical image 10591×10804 (0.5m) was taken from WordView-2 and the SAR image 1116×1138 (4.7m) was taken from Radasat-2. They were all obtained in August 2010 in Suzhou. The original optical and SAR images are shown in Fig.1.

The Fig.2 shows the closed regions extraction of optical and SAR images.

To estimate the accuracy of the registration results using the proposed method, all the valid CPs are taken into evaluation. Root Mean Square Error (RMSE) involving all the CPs is 0.972 pixels in the X direction and 0.854 pixels in the Y direction.

4. CONCLUSIONS

In this paper, we have presented a novel virtual points based approach to register optical image and SAR image. The virtual points derived from corresponding region features is used in affine transform model to obtain the initial parameters. Fine registration is carried out by maximizing the overlapping of the closed regions coming from the two images. And the

experimental results shows that the virtual points based image registration algorithm presented above is effective, and the accuracy of registration is up to pixel level.

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