SAR IMAGE AND OPTICAL IMAGE REGISTRATION BASED ON CONTOUR AND SIMILARITY MEASURES

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ABSTRACT:

Image registration is concerned with the establishment of correspondence between the images of the same scene. It is a challenge problem especially when multispectral/multisensor images are registered. In general, such images have different gray level characteristics and imaging model, and simple registration techniques based on area methods cannot be applied directly. A registration method between synthesize aperture radar (SAR) image and Optical image is presented in this paper. There are two steps to realize the registration process. Firstly, edge detector and some morphologic methods, such as dilate and thin, are used for the contour extraction in both images. Affine transform model is used to correct the global rigid deformation (rotation, translation, scale) between two images. Then, we will estimate the residual deformation between the two images with similarity measure based on possibilities. The local deformation will be reduced in this step. The proposed registration algorithm has been applied in the experimental area with airborne SAR image and Optical image. The experimental results demonstrate that the algorithm can solve some problems to some extent between the multisensor registrations and can receive high accuracy.

1. INTRODUCTION

The goal of image registration is to establish the correspondence between two images and determine the geometric transformation that aligns one image with the other. It is a prerequisite for accomplishing high level tasks such as sensor fusion, surface reconstruction, change detection, and object recognition, and is essential for a variety of applications in remote sensing, computer vision, pattern recognition and medicine.

Optical images are known to have excellent legibility, but they are affected easily by clouds, weather, and time condition. SAR image can be received in day and night, and it can look through cloud and fog, but they are difficult to understand and interpret. Therefore, the combination of these two kinds of information will be beneficial to many remote sensing applications, and registration of these two kinds of images is necessary for using them together. However, it is difficult to register SAR images and Optical images. The reasons are listed in the below. Firstly, the wavelength that SAR takes is from 1 centimetre to 75 centimetres, which is very different with the wavelength used by Optical remote sensing, which leads to the different gray level characteristics between SAR images and Optical images. Then, SAR image is kind of slant image, its resolution is defined by both the range and azimuth directions.Otherwise, there are serious interferometric phase noises in the SAR image. Thus, for this kind of images registration, some classical approaches based on area correlations cannot be used directly.

The existing registration methods on SAR and Optical images including: two contour-based methods which used region boundaries and other strong edges as matching primitives are proposed for multisensor image registration(Hi. Li et al., 1995). In this method, an elastic contour matching scheme based on the active contour model is applied for the registration of the optical images with SAR images. Non-Uniform Rational B-Splines (NURBS) was developed on multisource image registration (C.Pan and Z.Zhang, 2008). The experiments on both single-sensor and multisource data registration demonstrate the effectiveness and robustness of the method. A new approach of image registration(Paul Dare and Ian Dowman, 2001) based on multiple features extraction and matching techniques was introduced. It was used to solve the problem of the automatic registration on SAR and SPOT images. This approach improved the quality and quantity of the tie points compared with traditional feature based registration techniques which rely on single feature. But this method was complex and had low registration accuracy. An automatic registration system (Alexander Wong and David A.Clausi, 2007) was built, which is special to address the problem associated with the registration of remote sensing images obtained at different time or from different sensors. This system used control-point detection and matching processes based on a phase-congruency model. Maximum Distance Sample Consensus is introduced in this system to improve the accuracy of the transform model. However, this method has limitation in terms of robustness under rotation conditions. The problems of the automatic multisensor image registration were analyzed and similarity measures which can replace the correlation coefficient in a deformation map estimation scheme were introduced (Jordi Inglada and Alain Giros, 2004), and an example was showed that the deformation map between a radar image and an optical one was fully automatically estimated. But the method was based on orthorectified images, there were not a whole model for registration of SAR images and Optical images.

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In order to realize the registration between SAR and Optical images, in this paper, an registration algorithm based on contour and similarity measure is proposed. This method is based on contour feature and gray statistic probabilities of the both images. Firstly, there is a basic contour matching scheme for coarse registration of Optical-to-SAR image. There are different contour extraction methods applied in SAR image and Optical image. After contour matching, affine model is used for image transform to complete the primitive registration. After primitive registration, the images are aligned well globally, but local errors exist. The performance of similarity measure, Distance to Independence on registration of SAR and Optical images are tested. The experimental results prove that it has an absolute maximum for the zero case, which is sharp enough for a robust automatic detection. Therefore, the residual deformation between the two images is estimated with the Distance to Independence measure.

In this paper, SAR image and optical image are used for experiment. The result shows that the proposed algorithms are robust to register this two kind of images. The evaluation of the image registered accuracy proves the registration algorithm based on contour-feature and probability proposed in this paper work well in registration of SAR image and optical image.

2. REGISTRATION MODEL BASED ON CONTOUR AND SIMILARITY MEASURES

In this paper, the registration process is carried out in the following two steps:

1) The first step consists of contour extraction from both images. After contour matching, two sets of corresponding control points in reference image and sensed image are got. Affine transformation model are used for the primitive registration.

2) After primitive registration, the images are aligned well globally, but local errors exist because of the different geometric models between SAR image and Optical image. Similarity measure which using the probabilities is applied to estimate the residual deformation, and polynomial model is used for sensed image transforming.
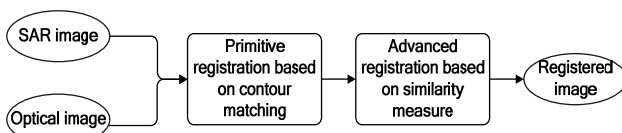

Figure 1. Summary of the proposed image registration model

2.1 Primitive Registration

2.1.1 Contour Extraction from SAR Image

It is well know that contour detection in SAR images is a very difficult task because of the severe speckle noise which disrupts contour lines. It is impossible for gradient based methods (Roberts, Prewitt, Canny, et al.) or region based method (split and merge, region growing, et al.) to obtain a precise and one-pixel wide contour in SAR image. Based on our SAR image characteristics, we propose a method that combine image segmentation and morphologic method (dilation and thin) to achieve one-pixel wide road contour in SAR image.

Because of the roads which we want to use as contour feature has lower backscatter in the SAR image, and they are darkness

in our image. Therefore, a threshold is taken to partition the SAR image. Most of the road part appeared in the segmentation map, which show in the Fig.2.
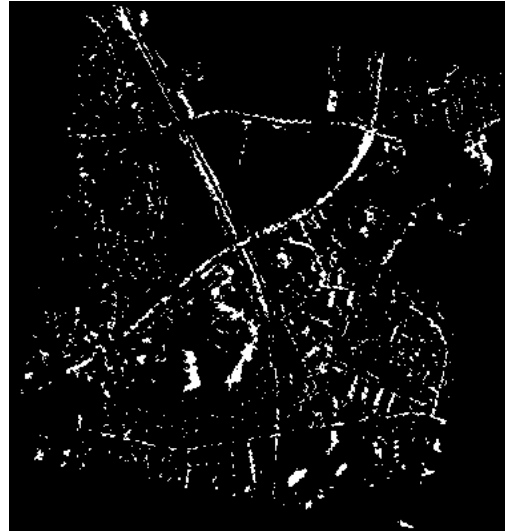

Figure 2. SAR image after segmentation

Then, dilation algorithm is operated in this segmentation image to "enlarge" object base on one construct element. In mathematics, dilation is defined as congregate operation. A is dilated by B, as $A \otimes B$, defined as:

$$A \otimes B = \{z \mid (\hat{B})_z \cap A \neq \varnothing\} \tag{1}$$

Where $\varnothing$ is empty set, B is construct element. In this paper, B is $\begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}$.

Through dilation, some closed segment in the road would link together.

Afterward, thin operator would reduce the object and shape of the dilation image into single pixel line, which show in Fig.3.

Figure 3. The SAR image after dilate and thin operation

2.1.2 Contour Extraction from Optical Image

Sobel edge detector is applied in contour extraction in optical image. According to compute the first-order derivative of the image, it sums up x derivative and y derivative.

$$g = [G_x^2 + G_y^2]^{1/2} = [\frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2}]^{1/2} \quad (2)$$

Thus, if $g \geq T$ in (x,y), (x,y) was an edge pixel. T is a given threshold. The contour extraction result in optical image show in Fig.4.

Figure 4. The contour map of optical image

2.1.3 Contour Matching

Since we mainly correct the translation, rotation and scale deformation between two images in the primitive registration, the matching procedure should be invariant with respect to these deformation styles. The simple combined invariants which were invariant to symmetric blur, scaling, translation and rotation (Flusser and Suk, 1998). These invariant operators are used in this paper, and given by the following equations:

$$\phi_1 = (v_{30} - 3v_{12})^2 + (3v_{21} - v_{03})^2.$$

$$\phi_2 = (v_{30} + v_{12})^2 + (v_{21} + v_{03})^2.$$

$$\phi_3 = (v_{30} - 3v_{12})(v_{30} + v_{12})((v_{30} + v_{12})^2 - 3(v_{21} + v_{03})^2) +$$
$$(3v_{21} - v_{03})(v_{21} + v_{03})(3(v_{30} + v_{12})^2 - (v_{21} + v_{03})^2). \quad (3)$$

$$\phi_4 = (3v_{21} - v_{03})(v_{30} + v_{12})((v_{30} + v_{12})^2 - 3(v_{21} + v_{03})^2) -$$
$$(v_{30} - 3v_{12})(v_{21} + v_{03})(3(v_{30} + v_{12})^2 - (v_{21} + v_{03})^2).$$

$$\phi_5 = [v_{50} - 10v_{32} + 5v_{14} - 10(v_{20}v_{30} - v_{30}v_{02} - 3v_{12}v_{20} +$$
$$3v_{12}v_{02} - 6v_{11}v_{21} + 2v_{12}v_{03})]^2 + [v_{05} - 10v_{23} + 5v_{41} -$$
$$10(v_{02}v_{03} - v_{03}v_{20} - 3v_{21}v_{02} + 3v_{21}v_{20} - 6v_{11}v_{12} + 2v_{21}v_{30})]^2$$

The correspondence of contours is established by the minimum distance rule with threshold in the Euclidean space of the invariants. The distance between two different windows is defined as

$$d_r(w_1, w_2) = \left\| \vec{C}(r)^{(w_1)} - \vec{C}(r)^{(w_2)} \right\| \quad (4)$$

Where, $\|\cdot\|$ is the Euclidean norm and $\vec{C}(r)$ is the combined invariants vector, which is defined as

$$\vec{C}(r) = (\phi_1, \phi_2, \phi_3, \phi_4, \phi_5) \quad (5)$$

The smaller the distance, the more similar two regions are. The matching contour defined as contours in the similarity region in two images. The intersection and endpoint of the corresponding contours are considered as control points, which can be used to estimate transform parameters.

2.1.4 Primitive Transform Model

2-D affine transform can be expressed as:

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} \quad (6)$$

(x, y) is the point in the reference image, and (X, Y) is the corresponding point in the sensed image. $(a_{11}, a_{12}, \Delta x, a_{21}, a_{22}, \Delta y)$ corresponding to the scale, rotation and translation parameters. Without considering the nonlinear distortion, this model is effective to the image deformation.

The root mean square error(RMSE) between the matched points provides a measure of registration accuracy and is defined as:

$$RMSE = \left(\sum_{i=1}^{m} \left[(ux_i + vy_i + \Delta x - X_i)^2 + (ux_i + vy_i + \Delta y - Y_i)^2 \right] \right)^{1/2} \quad (7)$$

Where, m is the number of matched points.

2.2 Advance registration

Feature extraction and affine transform are used in the primitive registration. Because the feature extraction can introduce localization errors, and affine transform can be effectively only to global deformation, the accuracy of registration is affected by these reasons. Thus, the advance registration base on similarity measure is introduced in this step to improve the whole registration accuracy.

2.2.1 Similarity Measures

In image registration of remote sensing, the most common used similarity measure is correlation coefficient (CC). CC estimates the similarity of two images by statistics of mean values and standard deviations, which is only restrict to images of the same modality. Therefore, Distance to Independence is introduced to calculate the relationship of SAR and Optical images. It does not directly use the radiometry of the pixels, but only use the joint possibility dense function (PDF) to estimate the similarity between two images. Distance to Independence is a normalized version of the χ^2 test, which can be expressed as:

$$\chi^2(I, J) = \sum_{i,j} \frac{(p_{ij} - p_i p_j)^2}{p_i p_j} \quad (8)$$

Where, p_{ij} is the value of the joint normalized histogram of the pair of the images.

In order to qualitatively characterize this similarity measure we propose the following experiment. We take two images of SAR and Optical images that are perfectly registered, and we extract a window of 101*101 from each of the images in this experiment. The window will be centred on coordinate (x_0, y_0) in the master image, and it will be centred on coordinate $(x_0 + \Delta x, y_0)$ in the moving image. Δx is range from -10 pixels to 10 pixels in our experiments. Through the

experiment, we will achieve a set of $\rho(I,J)$. It supposes to be maximum when $\Delta x = 0$. This experiment is applied in the same bands (B1) and different bands(B1 & B3) of the optical image, and B1 of SAR image to B1 of the optical image. The results show in Fig5.
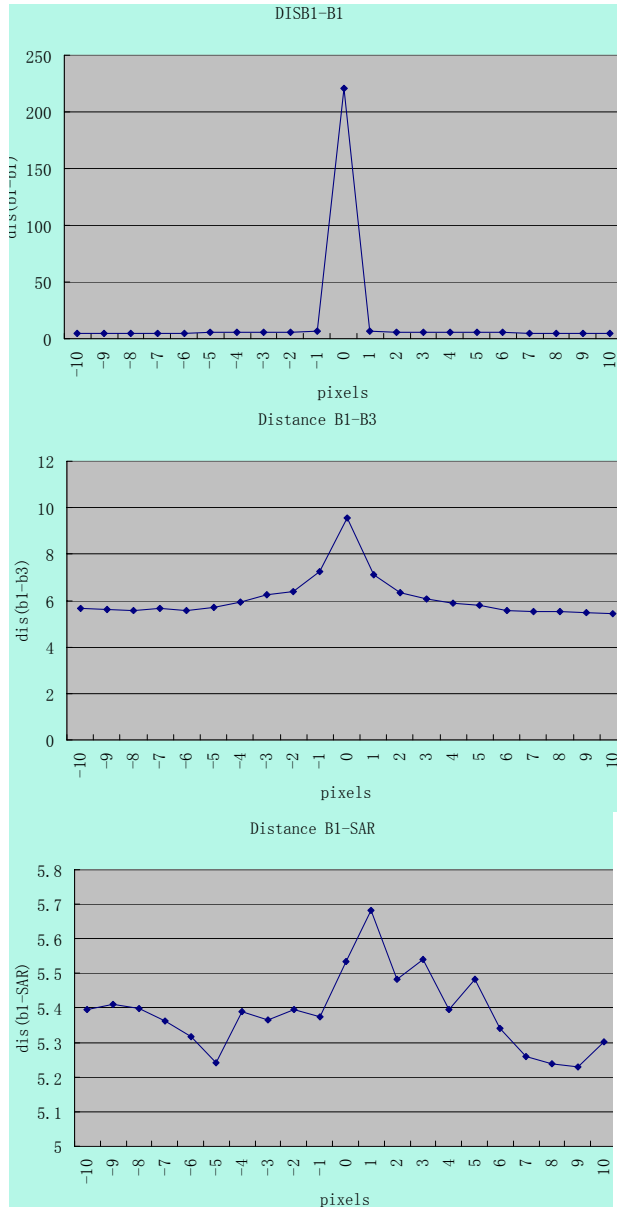

Figure 5. The similarity measure experimental result

The results show that we obtain an absolute maximum for the SAR and Optical images, which is sharp enough for a robust automatic detection.

3.   EXPERIMENT ON REGISTRATION MODEL

The experiment takes on the residential and industrial areas of Copenhagen, where the topography is flat and there are many roads in the image. The SAR image is gotten by EMISAR and its wavelength is C-Band, its resolution is 4 meters. The sizes of images of both SAR and Optical are 1077*729 pixels. We use part of them in our experiment.

In the primitive registration, the contours in SAR image are obtained by segmentation and morphologic methods (Fig.3) and contours in optical image are obtained by Sobel edge detector. The contours in these two images are matched by invariant moments. Six pairs of control points are gotten in the intersections and endpoints. Put these points on the affine transform model. The parameters can be computed as show in Table1.

Parameter	values
a_{11}	0.9712
a_{12}	-0.1650
a_{21}	0.1714
a_{22}	0.9712
Δx	40.6166
Δy	0.7927

Table1. Transform parameters

By the equation (7), the result of RMSE is 3.4025.

Then, in the advanced registration, independence to distance is used as similarity measure to estimate the residual deformation between the two images. According to the accuracy of primitive registration, the size of estimate window is set to 21*21 pixels.

Some points are picked in sensed image in the areas where are not align well with based image, Independence to Distance is applied to compute the corresponding points in other image(as shown in the Fig.6.). Ploynomial model is used to transform sensed image.
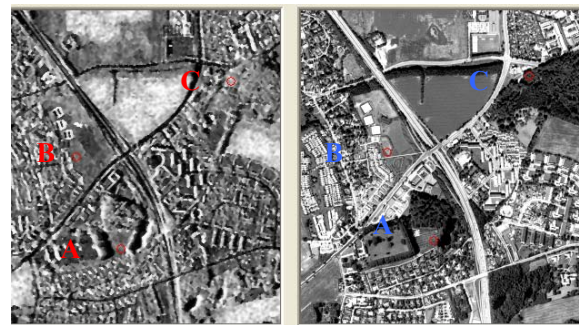

Figure 6. The alignment of SAR and Optical image

4.   CONCLUSION

In this paper, a registration model of SAR image and Optical image based on contour feature extraction and similarity measure is presented. Based on the characteristics of image (for example, there are many roads, forest in our image), the segmentation, dilate and thin operators are applied for the contours extraction in the SAR image and Sobel edge detector is used for the contour extraction in the Optical image. The contour feature is used for the primitive registration, which is mainly taking charge of the global rotation, scale and translation deformation. Then, the similarity measure is used for the advanced registration to reduce the local deformation of the image.

The experiment results between aerial SAR and Optical image prove the feasibility of this registration method. However, the registration of SAR and Optical image is a difficult task, there are still many problems not be resolved. The proposed method is no effective when used in the areas where have no distinct contour features, or have complicated topography areas. The advanced research should put effect on multi-scale matching and high accuracy registration methods.

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