SAR AND SPOT IMAGE REGISTRATION BASED ON MUTUAL INFORMATION WITH CONTRAST MEASURE

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ABSTRACT

In this study, we propose a novel robust mutual information (MI) based method to register SAR and SPOT images. Traditional MI based method can register SAR and SPOT images well. However, its robustness is not satisfying for local spatial information is absent. In our approach, first, local contrast of 5*5 windows centered at each point in both images is calculated, then the contrast value is assigned to each pixel and two contrast images are obtained. Finally, the SAR and SPOT images are registered by maximizing the MI between their contrast images. Experimental results show that compared with traditional MI, our approach is much more robust and acquires comparable or even higher accuracy. Meanwhile, compared with the MI with orientation information based registration (MIOI), another robust MI based method, our algorithm works much faster and more accurately.

Index Terms— Image registration, mutual information, contrast measure

1. INTRODUCTION

Image registration is the process of establishing point-by-point correspondence between two or more images obtained from a same scene. SAR and SPOT images are two kinds of satellite data extensively used in remote sensing. Their registration helps to fuse their complementary information and get more complex and detailed scene representation.

Over the years, many image registration methods have been proposed [1]. However, due to the abundant speckle noise existing in SAR images as well as the very different imaging condition between SAR and SPOT images, most of those methods can not work well for SAR and SPOT image registration. Mutual information, which is a similarity criterion widely used in medical imaging [2, 3, 9, 10], has been found to be suitable for SAR and SPOT image registration [4, 5].

Nevertheless, absence of local spatial information in MI weakened the robustness of MI based registration, and local maxima or artifacts in the MI registration function occasionally result in mis-registration [6]. Improvements have been suggested, such as combining mutual information with image gradient [7, 8] or orientation information [5]. However, due to the abundant speckle noise, gradient is not an effective representation for SAR images. Therefore, the approaches presented in [7, 8], in which image gradient provides spatial information for mutual information, is not suitable for SAR and SPOT image registration. In [5], MI is calculated on the corresponding filtered image pairs at four orientations. The robustness of MI based SAR and SPOT image registration is successfully improved, however, the improvement is at the expense of four times the time-consuming of the traditional MI based method. Moreover, as the global feature, orientation ignores the local spatial information

In this study, instead of intensity, local contrast of 5*5 windows centered at each point in the SAR and SPOT images is used for MI calculation. Because local spatial information is contained in the contrast measure, the ill-definition of MI is overcome. Experimental results show that compared to traditional MI, our approach is much more robust and acquires comparable or even higher accuracy. Meanwhile, compared with the MI with orientation information based method (MIOI) [5], our algorithm works much faster and more accurately.

2. SAR AND SPOT IMAGE REGISTRATION BASED ON MI WITH CONTRAST MEASURE

2.1. Mutual information based image registration

MI is a measurement for the statistical dependency between two images. Given image M_1 and image M_2, MI is able to predict information of image M_1 from that of image M_2. Their mutual information can be calculated using [9]

$$I(M_1,M_2) = H(M_1) + H(M_2) - H(M_1,M_2) \qquad (1)$$

where H(M_1) and H(M_2) are the entropies of M_1 and M_2, and H(M_1, M_2) denotes their joint entropy. Considering the sensitivity of MI measure to the amount of overlap between the images, normalized MI measure [10] is chosen in our approach.

For MI based method, image M_1 and image M_2 are registered when $I(M_1,T(M_2))$ is maximal. Here T represents

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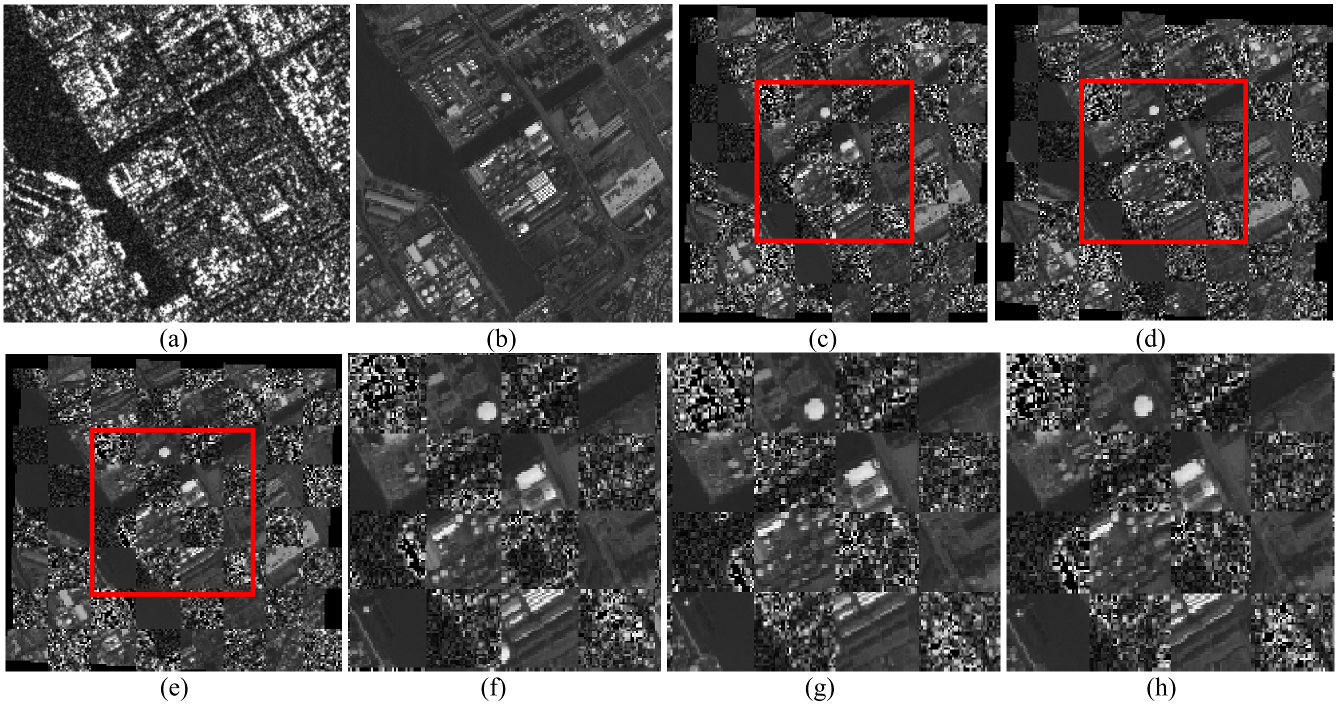
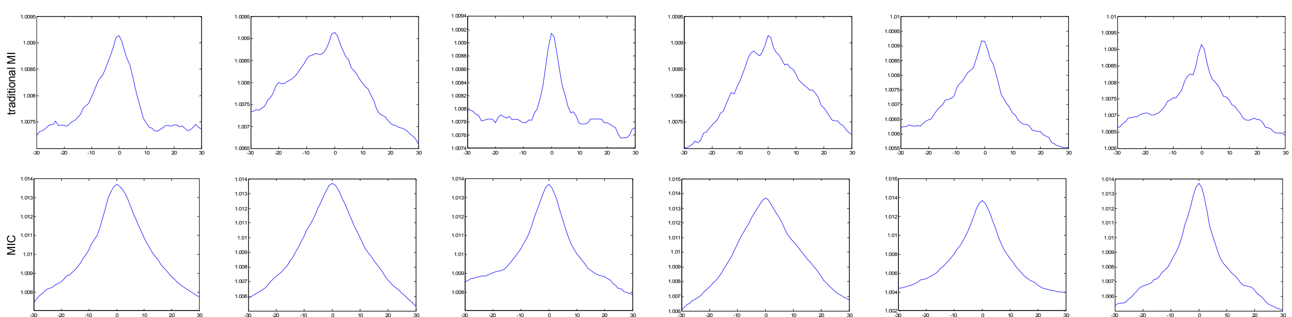


Figure 1. (a) SAR image 1; (b) SPOT image 1; (c) chessboard overlay of image pair 1 after coarse manual registration; (d) chessboard overlay of image pair 1 after the traditional MI based fine registration; (e) chessboard overlay of image pair 1after MIC based fine registration; (f) close-up of the boxed region of (c), (g) close-up of the boxed region of (d), (h) close-up of the boxed region of (e).



a_{00}=1+0.002*x a_{01}=0.002*x a_{01}= 0.002*x a_{11}=1+0.002*x t_x=x ty=x

Figure2. MI curves of traditional MI and MIC on image pair 1 shown in Figure 1. The first row and the second row correspond to traditional MI and MIC respectively. They are obtained by changing one of the corresponding parameter around the correct registration position while the other parameters are kept unchanged.

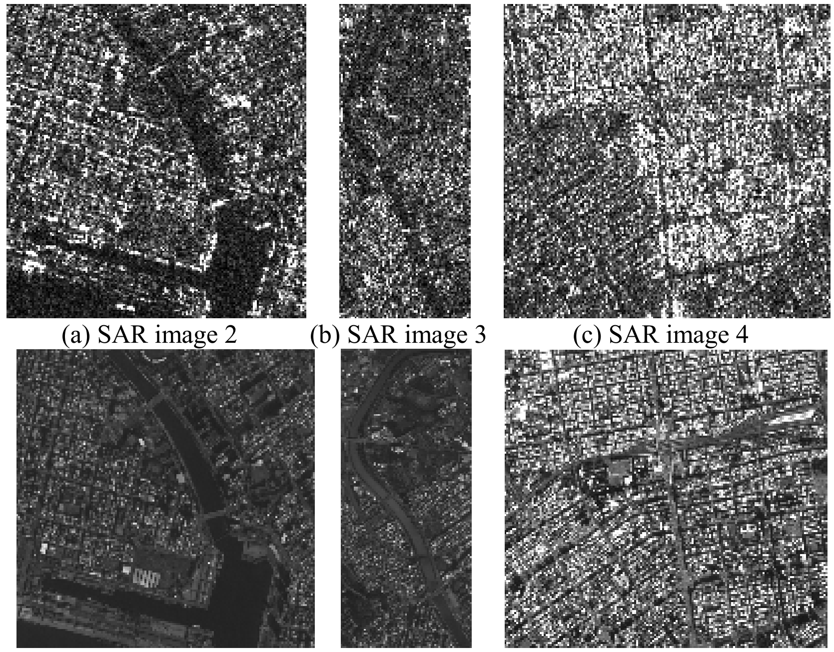
a transform. In this paper, affine transform is used:

$$\begin{cases} x' = a_{00}x + a_{01}y + t_x \\ y' = a_{10}x + a_{11}y + t_y \end{cases} \qquad (2)$$

2.2. Mutual information with contrast measure (MIC)

According to the definition of MI, we can note MI is calculated on the global intensity statistical information, and no image local spatial information is used. Consequently, MI registration function always contains many local maximum or artifacts (except the influence of interpolation), especially for SAR and SPOT images, which image under very different condition and have abundant speckle noise. To overcome this problem, in our approach, intensity of each point in the SAR and SPOT images is substituted with the local contrast of the n*n window centered at it, and we get two contrast images. MI between them is then calculated. Because local contrast measure contains the spatial information in the n*n window, the MI of the two contrast images can be used as the improved MI measure for registration.

In this study, we estimate the contrast of local image texture



(a) SAR image 2 (b) SAR image 3 (c) SAR image 4

(d) SPOT image 2 (e) SPOT image 3 (f) SPOT image 4

Figure3. Three pairs of SAR and SPOT images

with a rotation invariant measure of local variance [11]:

$$C=\frac{1}{N}\sum_{p=1}^{N}(g_p-u)^2 \qquad (3)$$

Where g_p denotes a point in the n*n windows, $u=\frac{1}{N}\sum_{p=1}^{N}g_p$, and N=n*n. The size of the widow influences registration results. Experiments demonstrate that larger the window, smoother the registration function. Whereas when n reaches 11, the MI maximum will deviate from the correct transform. With window enlarging, deviation continues increasing. Therefore, considering the balance between accuracy and robustness, 5*5 and 7*7 are the better choice. In this paper, 5*5 is chosen.

3. EXPERIMENTAL RESULTS

As indicated in [12], maximizing MI may not necessarily produce an optimal solution when the deformable transform is too flexible. Therefore in our application, we apply coarse-to-fine method. Based on the manually chosen tie-points, the transform parameters between the two images are first estimated using the linear least-square technique. Then by using this coarse registration result as the initial point for optimization and MIC as the fine registration function, the SAR and SPOT images are finely registered.

3.1 Experiment 1: comparison of MIC and traditional MI based method

Result of experiment 1 shows the robustness of our method (MIC). In Figure 1, image (a) is a 259*237 Radarsat SAR

	Coarse (pixels)	MI (pixels)	MIC (pixels)	MIOI (pixels)
Pair 1	8.1314	6.1101	1.8659	4.0031
Pair 2	8.4914	3.3391	3.4912	3.9850
Pair 3	5.4287	--	2.2793	2.5650
Pair 4	6.7356	--	3.0291	3.6543

Table 1: comparison of registration accuracy (RMSE)

	MI (s)	MIC(s)	MIOI(s)
Pair 1	1422.9	2431.7	6720.7
Pair 2	1820.4	1891.2	7493.5
Pair 3	--	2433.5	6625.6
Pair 4	--	1452.6	5842.2

Table 2: comparison of registration speed

sub-image acquired on Nov.2, 2000, and (b) is a 595*601 SPOT-5 sub-image acquired on Dec.31, 2002. We call them image pair 1. By visual comparison shown in Figure 1 as well as numerical comparison of accuracy shown in Table 1, we can note that our approach registers image pair 1 much more accurately than traditional MI based method does.

Three other pairs of SAR and SPOT images are exhibited in Figure 3. Radarsat SAR sub-images (a)(b)(c) are acquired at the same time as SAR image 1, and their size are 259*291, 153*348, 468*397, respectively. SPOT-5 sub-images (d)(e)(f) are acquired at the same time as SPOT image 1, and their size are 688*651, 375*879, 500*454. Image (a) and (d), (b) and (e), (c) and (f) are respectively called image pair 2, image pair 3, and image pair 4. Each pair of images is registered by both traditional MI and MIC. From the results displayed in Table 1, we can see that traditional MI and MIC get the approximate accuracy when image pair 2 is registered, however, as to pair 3 and pair 4, traditional MI fails while MIC yields satisfying results.

The cause can be inferred from the MI curves of traditional MI and MIC shown in Figure 2. Considering the limitation of pages, only MI curves of image pair 1 are exhibited. The figure shows that many artifacts exit in the traditional MI registration functions. Consequently, it tends to be trapped in local maximum if the initial point is not near the registration result. However, the inclusion of local contrast information attenuates the influence of speckle noise and thus remarkably reduces the artifacts. MIC registration function is smooth, which makes optimization easier to find out correct result even if the initial point is a little far away. That is the reason why the traditional MI based method gets unsatisfying result or even fails while MIC based method works well. So compared to the traditional MI based method, our method is less sensitive to initial point for optimization, and can obtain larger capture range. Thus, the proposed method is much more robust.

3.2 Experiment 2: comparison of MIC and MIOI (MI with orientation information based method)

In this experiment, the four image pairs are also registered by MIOI, a robust MI based method combing MI with orientation information [5]. Registration results of MIC and MIOI are compared. They are shown in Table 1 and Table 2. For the four image pairs, MIC works much fast than MIOI, and obtains better accuracy as well. The reason lies in their definitions. As to MIOI, though MI is measured on the filtered SAR and SPOT images at four directions, and orientation information is contained in the improved MI measure, local information as well as the spatial information except the four orientation information is still ignored. However, as to MIC, local contrast in the 5*5 windows is considered. The local spatial information in the 5*5 window centered at each point, rather than just four global directions information, is included in MIC. That is why MIC registers SAR and SPOT images more accurately than MIOI does. Moreover, MIOI is the average of MI of four filtered image pairs at four directions, whereas MIC is directly calculated on the two contrast images, the computational load of MIOI is obviously much greater than that of MIC, therefore MIC works much faster.

4. CONCLUSION

Traditional MI is ill-defined for local spatial information is absent, thus the MI based registration is not robust for SAR and SPOT images. To overcome this drawback, in this paper, a novel MI base method is proposed. In our approach, contrast of the 5*5 window centered at each point in both images is calculated, and similarity between the two contrast images is evaluated by MI. This MI with contrast is then used as the improved MI measure for registration. Experiments validate that compared with traditional MI based method, our approach is much more robust, and compared with another robust method (MIOI), it work much faster and gain better registration accuracy.

5. ACKNOWLEDGMENTS

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