

Automatic Selection of Control Points for Remote Sensing Image Registration Based on Multi-Scale SIFT

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Abstract. In this paper, we present an automated image registration algorithm, which combines the multi-scale wavelet transform (WT) with Scale Invariant Feature Transform (SIFT). The control points are selected using three levels WT. First, the image is decomposed into multi-scale levels using WT, then low frequency (approximation) images are input to SIFT algorithm for automatically obtaining control points. Experimental results show the efficiency and the accuracy of the proposed technique for selecting enough and correct control points.

Keywords: Image registration, SIFT, Wavelet Transform, correspondence points.

1. Introduction

Image registration is an important preprocessing step needed for many image processing applications such as remote sensing, medical imaging and computer vision. Its purpose is to overlay two or more images of the same scene taken at different times from different viewpoints and/or by different sensors [1, 2]. Image registration methods can be categorized into different ways according to different perspectives, and according to the information used for registration; in general they can be classified into the area-based and the feature-based methods [2].

In the area-based method, a small window of points in the first image is statistically compared with the same size window in the second image. On the other hand, feature-based method utilizes extracted features and matches the common structures from two images [1]. There are two important steps in feature-based techniques. The first one is feature extraction and the second is finding feature correspondence. The final steps in automatic image registration are transform modeling and resampling image. In the transform modeling the parameters of the mapping function are computed by means of the established feature correspondence, while the image resampling sensed image is registered by means of the mapping function. Feature correspondence is one of the most important steps in automatic image registration. This step can be achieved either by selecting features in the reference image and searching for them in the sensed image or by selecting features in both images independently and then determining the correspondence between them. Features from the sensed and reference images with most similar invariant descriptions are paired as the corresponding ones.

Many authors proposed different descriptors to find the corresponding matching between points such as complex filter [3], moment invariant, chain code [4], spin image [5] and shape context [6]. Dai and Khorran [4] combine an invariant moment descriptor with improved chain-code matching to establish corresponding between the potentially matched regions detected from the two images. The spin image representation comprises a set of descriptive images associated with the oriented points on the surface of an object. The complex filters are orthogonal, and the Euclidean distance between complex filters provides a lower bound on the Squared Sum Differences between corresponding image patches. The shape matrices were used for registration of rotated and scaled satellite images [7]. David.G and Lowe[8] proposed a scale invariant feature transform (SIFT) detector and descriptor, which detects a set of local feature vectors through scale space extremes and describe this feature using 3D histogram of gradient and orientation. Belongie et al. [6] proposed shape context descriptor that is invariant to scale and rotation. This based on a histogram of edge points with respect to a reference point under the log-polar coordinate. Mikojclyk and Schmid [9] evaluated the performance by comparative study on the various local invariant feature descriptors, and showed the SIFT given the excellent performances with respect to other descriptors. Chen and Tain [10] proposed technique to use SIFT method as preregistration step in registration algorithm to multi-modality medical image.

The paper is organized as follows. Section II describes the method for image registration. Experimental results are obtained and analyzed in Section III. Finally, section IV concludes the paper.

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2. Method Description

Although the performance of the SIFT algorithm as a local descriptor outperform many descriptors [7] due to its resistance to many image deformations, accuracy of the keypoints correspondences between two images in image registration needs to be improved. Furthermore, in remote sensing images, the number of keypoints obtained by the SIFT is usually large which elevate the problems of complexity and selection of correct control points for the registration algorithm. In order to solve these problems an algorithm for automatic selection of control points to image registration that combines the wavelet transform and the SIFT is proposed in this paper. The proposed algorithm comprises a number of distinct steps Fig.1:

- (1) Input the reference and sensed images.
- (2) Apply the wavelet decomposition to each image separately.
- (3) Extract the feature points and then find correspondences between images (for each of the first three approximation wavelet levels) using SIFT algorithm.
- (4) Rectify matching points using the three matched levels, and then automatically obtain the strong control points for transformation parameters calculation.
- (5) Reconstruct the sensed image according to mapping function.

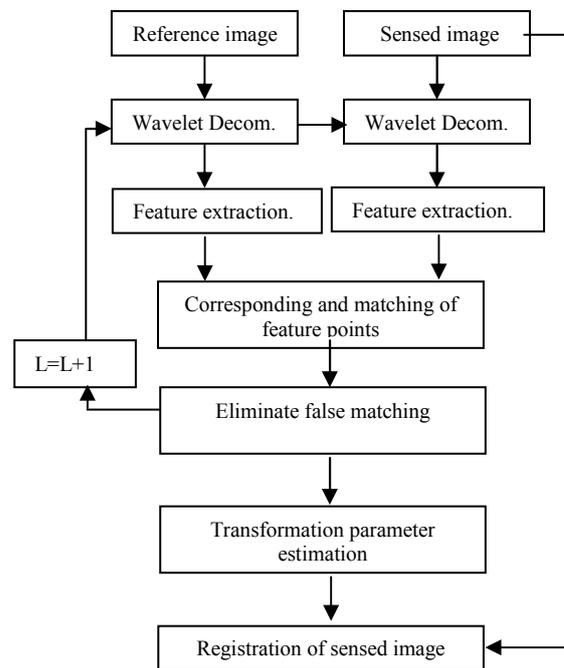


Fig.1 Framework of proposed algorithm.

In this paper, three undecimated wavelet levels are used with SIFT algorithm to remove false matching points which improves obtaining correct correspondences. The undecimated wavelet transform (SWT) is similar to a discrete wavelet transform (DWT), but the difference is that SWT does not perform down sampling between hierarchy levels. Because of this reason the subimages obtained after the decomposition process have the same size as the original images.

The voting steps of the three levels with the SIFT algorithm is illustrated by the following:

- The reference and sensed images are decomposed into their first approximation level which are fed to the SIFT algorithm for obtaining the corresponding points. Fig.2 shows the corresponding points result from first level decomposition.



Fig.2 Matching points results from first level SIFT.

- In the second step, the reference and sensed images are decomposed into next approximation level (second level) in order to find the corresponding points using SIFT algorithm. Using the results of the first two approximation levels, only repeated matched points are selected. Fig.3 shows the corresponding points result from the voting process between the first and the second decomposed approximation levels.

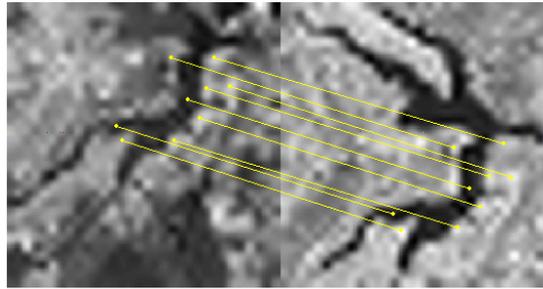


Fig.3 Matching points results from two levels SIFT.

- In the third step the two images are decomposed into next level to find the corresponding points at this level. Then the correspondences are compared with the result from the previous levels in order to find the repeated matched points. Experimentally, the three levels of multi-scale SIFT are enough to assign correct control points as shown in Fig.4. Fig.5 shows the number of correct and false matching between the sensed and the reference images using different wavelet approximation levels.

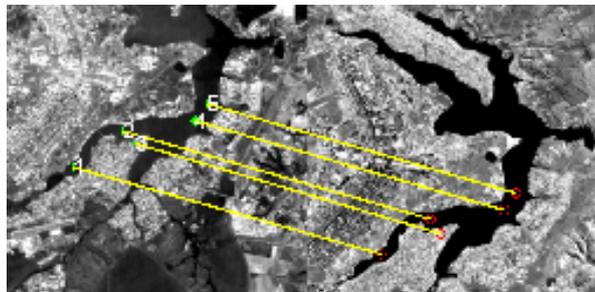


Fig.4 Control points result after eliminating false correspondences using three WT levels.

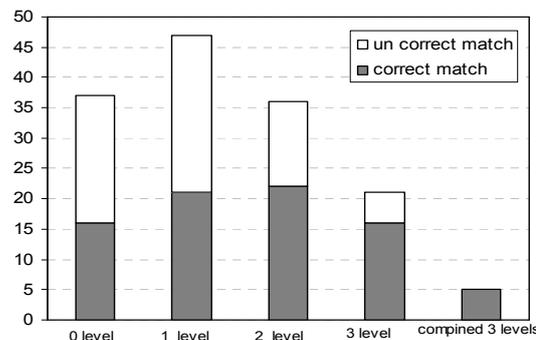


Fig.5 Matching points at different WT levels.

3. Image Registration Experiments

In order to evaluate the performance of the presented image registration algorithm, we tested the algorithm using images from the website [11]. The size of all tested images is set to 256x256 pixels. In the first experiment, the proposed algorithm is applied to images taken by different sensors (as seen in Fig. 6), which shows the registration of two images from two different sensor images (Urban SPOT band 3 (08/08/95) and TM band 4 (06/07/94)). Fig. 7 shows registration result of a pair of Landsat and Spot images with scale difference. Fig. 8 shows image registration result of SPOT, band 3, 08/08/95 (resampled to 30 m. pixel) and TM, band 4, 06/07/94 (TM94) images.

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Registration accuracy is measured by computing the root-mean-squared-error RMSE of the matched keypoints of each registration experiment. The RMSE is defined as:

$$RMSE = \sqrt{\frac{1}{K} \sum_{i=1}^K (P_{R(x,y)} - Q_{S(x,y)})^2} \quad (1)$$

Where

$K = \text{number of matching keypoints}$.

$P_{R(x,y)}$: Coordinates of matching points in reference image.

$Q_{S(x,y)}$: Coordinates of matching points in sensed image.

The results of the RMSE are compared to the algorithm in [11], as shown in table 1, which shows that the proposed algorithm has better localization performance than the algorithm of [11]. The results of table 1 and the visual inspection of Fig.s 6, 7 and 8 clearly illustrate the good performance of the presented algorithm compared to other algorithms.

Table 1 RMSE of transformed control points

| Experiments | RMSE of proposed method | RMSE of [11] |
|-------------|-------------------------|--------------|
| Ex1 | 1.0247 | 1.322876 |
| Ex2 | 0.5631 | 1.253566 |
| Ex3 | 0.5551 | 1.429503 |

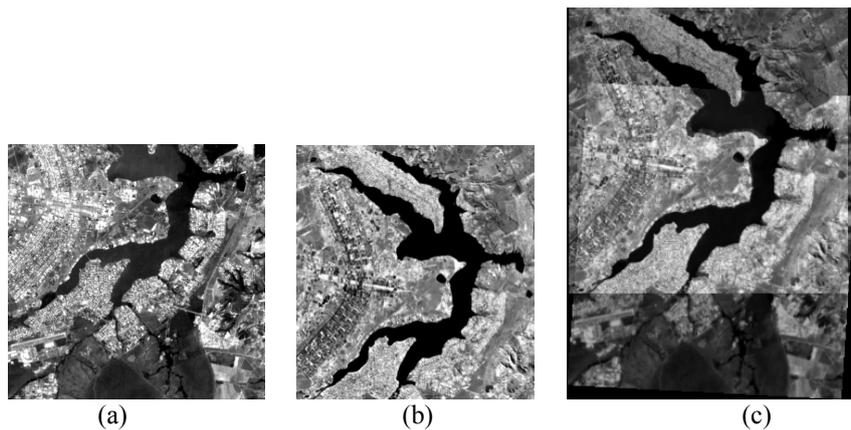


Fig. 6 Image registration of: (a) Reference image (Urban SPOT band 3 (08/08/95): (b) Sensed image TM band 4 (06/07/94): and (c) Registered image.

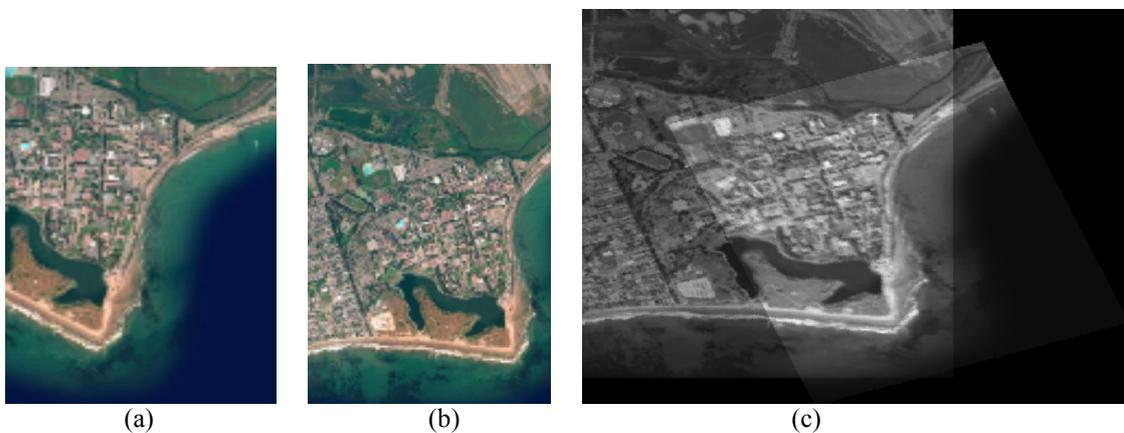


Fig .7 Image registration of highly distorted images with high rotation optical image: (a) Reference image: (b) Sensed image: and (c) Registered image.

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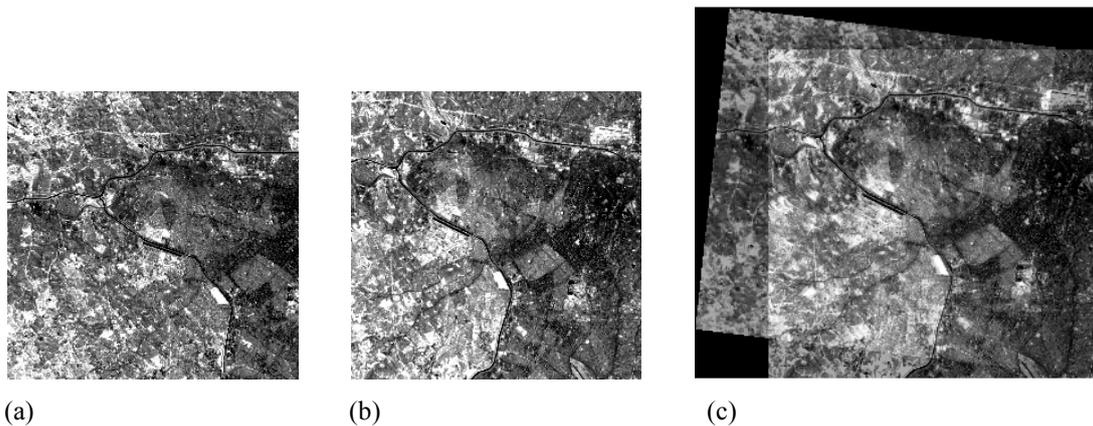


Fig .8 Image registration of: (a) Reference image (SPOT, band 3, 08/08/95 (resampled to 30 m. pixel)): (b) Sensed image (TM, band 4, 06/07/94 (TM94)): and (c) Registered image.

4. CONCLUSION

In this paper, we presented a new automatic Image registration technique based on combined undecimated wavelet transform with SIFT algorithm. The SIFT algorithm is applied to the approximation levels of the sensed and reference images in order to find strong control points that repeat on all levels consistently. The voting scheme rectifies control points and ensures correct correspondences between the sensed and the reference images. Experimental results show that the proposed algorithm provides enough and accurate matching control points to estimate the transformation parameters. Furthermore, the RMSE results show that the registration errors of the proposed algorithm are acceptable in remote sensing image registration.

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(Demo online (<http://vision.ece.ucsb.edu/registration>)).

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