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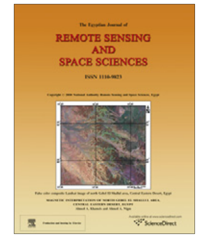

Comparative study for image registration techniques of remote sensing images

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PCNN;
Moment;
RMSE

Abstract Image registration determines the relative orientation between two images. As there are different techniques for image registration, it is important to compare these techniques to identify the advantages and disadvantages of each one. In this paper, a comparison between a fast Fourier transform (FFT)-based technique, a contour-based technique, a wavelet-based technique, a Harris–Pulse Coupled Neural Network (PCNN)-based technique and Harris–Moment-based technique is presented. The algorithms were tested on Landsat Thematic Mapper (TM) and SPOT remote sensing images and its performance were compared using the Root Mean Square Error (RMSE).

It has been concluded that the order of techniques with less RMSE is the PCNN, the moment, the contour, the wavelet and the FFT-based techniques, respectively. Whereas the order of techniques with the less running time is the contour, the wavelet, the moment, the FFT and the PCNN-based techniques, respectively. And finally the technique that detects the more control points in both images is the wavelet.

1. Introduction

The objective of image registration (Kang et al., 2000; Araiza et al., 2001) is to find a spatial transformation such that dissimilarity metric achieves its minimum between two images taken at different times, from different sensors, or from different viewpoints. So given a reference and a sensed images, the image registration process determines the amount of rotation and the amount of translation (in both the x and y axes), that the sensed image has with respect to the reference image. The source of the misalignment between images may be due to change in the sensor position, viewpoint and viewing characteristics or object movement and deformation.

The existing image registration techniques fall into two categories:

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(1) Area-based approaches (Anandan, 1993) which are divided into algorithms that use image pixel values directly, e.g., correlation methods (Bamea and Silverman, 1972), and algorithms that use the frequency domain, e.g., fast Fourier transform (FFT)-based methods (Zwicke and Kiss, 1983; De Castro and Morandi, 1987; Brown, 1992; Reddy and Chatterji, 1996).
(2) Feature-based techniques which are divided into algorithms that use low-level features such as edges and corners, e.g., feature-based methods (Li et al., 1995); and algorithms that use high-level features such as identified (parts of) objects, or relations between features, e.g., graph-theoretic methods (Zheng and Chellappa, 1983).

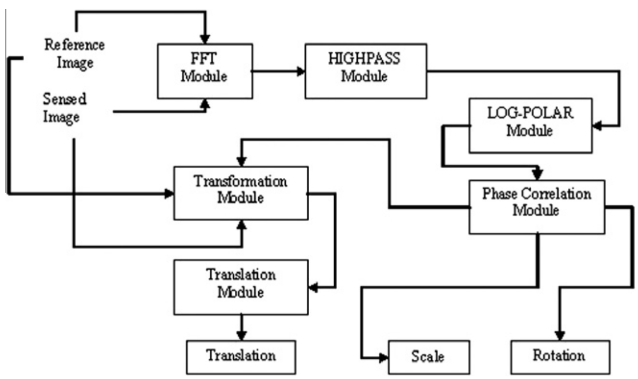

Figure 1 Flowchart of FFT-based technique.

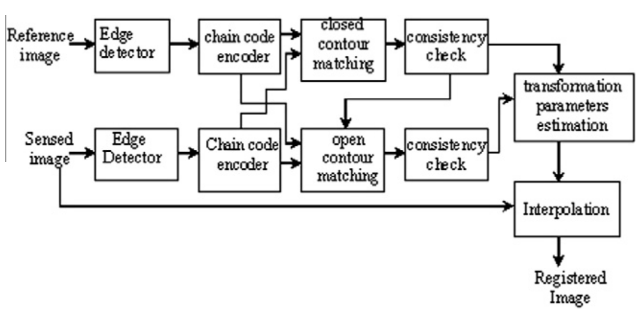

Figure 2 Flowchart of contour-based technique.

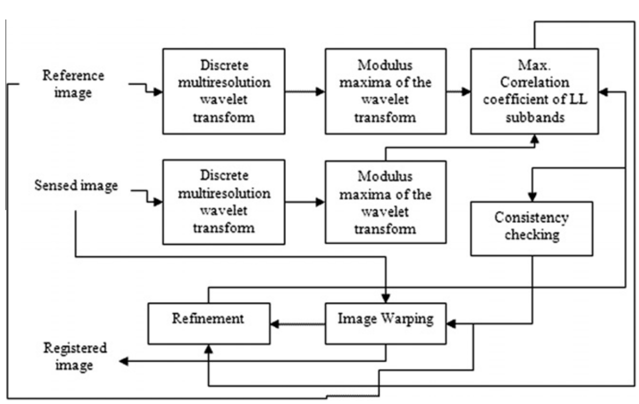

Figure 3 Flow diagram of wavelet-based technique.

In this paper five image registration techniques are compared and the registration results are presented, they are:

(1) FFT-based image registration technique (Reddy and Chatterji, 1996).
(2) Contour-based image registration technique (Li et al., 1995).
(3) Wavelet-based technique (Fonseca and Costa, 1997) (Fig. 3).
(4) Harris–PCNN-based approach (Ezzeldeen et al., 2008).

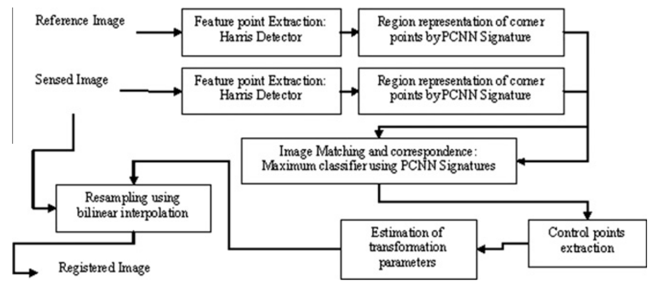

Figure 4 Flowchart of Harris–PCNN-based technique.

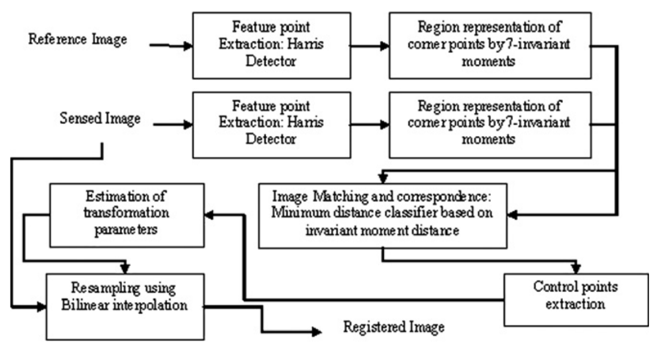

Figure 5 Flowchart of Harris–Moment-based technique.

Figure 6 TM01_1.

(5) Harris–Moment-based approach (Ezzeldeen et al., 2008).

The rest of the paper is organized as follows. In Section 2, the FFT, the contour, the wavelet, the Harris–PCNN and Harris–Moment-based image registration techniques are briefly described. In Section 3, the experimental results and discussion are presented for all algorithms. Finally in Section 4 the conclusions are given.

2. Registration techniques

2.1. FFT-based image registration

This method relies on the translation property of the Fourier transform (Reddy and Chatterji, 1996), which is referred to as the Fourier shift theorem. The shift theorem guarantees that the phase of the cross-power spectrum is equivalent to the phase difference between the images. By taking inverse Fourier transform of the representation in the frequency domain, there will be a function (an impulse) that is approximately zero everywhere except at the displacement that is needed to optimally register the two images. Fig. 1 shows the flowchart of the FFT-based technique.

2.2. Contour-based image registration

This method is based on contour matching (Li et al., 1995). This method works well for images in which the contour information is well preserved. It is computationally efficient. It uses region boundaries and other strong edges as matching primitives. Chain code correlation and other shape similarity criteria

Figure 7 TM01_3.

Figure 9 TM01_7.

Figure 8 TM01_5.

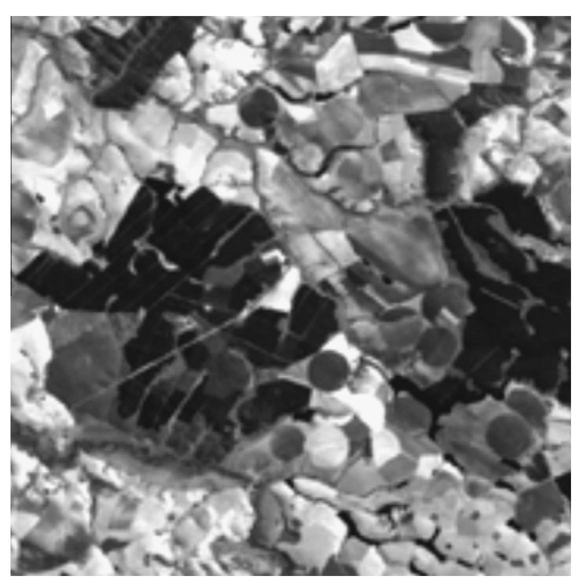

Figure 10 TM905A.

such as moments are used to match closed contours. For the open contours, salient segments such as corners are detected first and then used in the matching process. A consistency check is conducted in the transformation parameter space to eliminate some false matches occurred in the matching process. The drawback is that the method works satisfactorily only if there are objects with well-defined closed contours, which are detected by the gradient operator. Fig. 2 shows the flowchart of the basic contour matching scheme.

2.3. Wavelet-based image registration

This method is based on the wavelet transform (Fonseca and Costa, 1997). It usually extracts a large number of control points. The candidate control points are extracted using the local maxima of the wavelet coefficients. The initial control points are obtained in the lowest resolution of the wavelet decomposition and then are refined at progressively higher resolutions. The control point identification process uses the

Figure 11 SP953U.

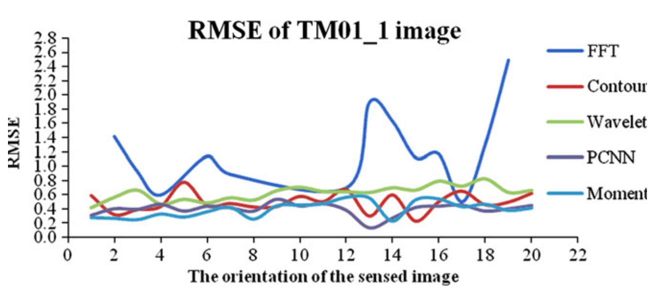

Figure 12 Results of TM01_1: RMSE results using FFT Algorithm; contour Algorithm; wavelet Algorithm; Harris–PCNN Algorithm; Harris–Moment Algorithm.

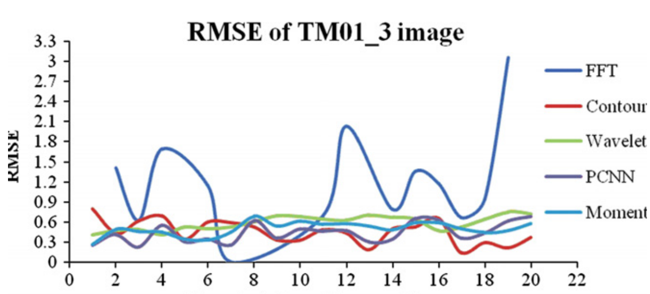

Figure 13 Results of TM01_3: RMSE results using FFT Algorithm; contour Algorithm; wavelet Algorithm; Harris–PCNN Algorithm; Harris–Moment Algorithm Network Analyst.

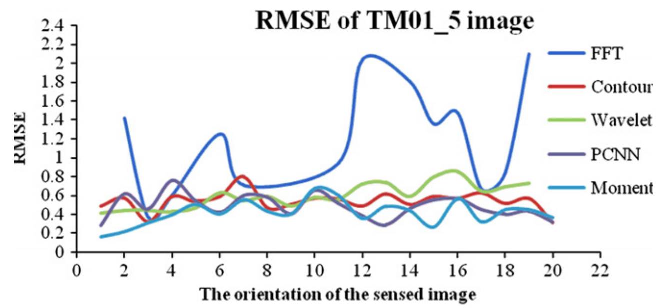

Figure 14 Results of TM01_5: RMSE results using FFT Algorithm; contour Algorithm; wavelet Algorithm; Harris–PCNN Algorithm; Harris–Moment Algorithm.

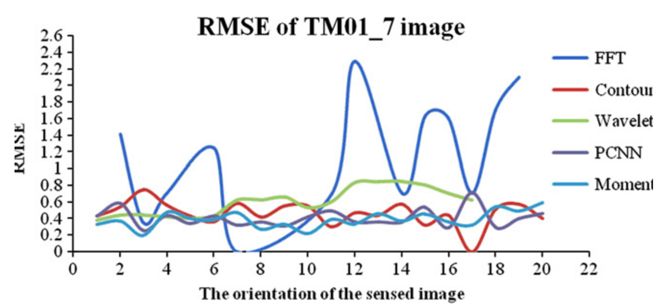

Figure 15 Results of TM01_7: RMSE results using FFT Algorithm; contour Algorithm; wavelet Algorithm; Harris–PCNN Algorithm; Harris–Moment Algorithm.

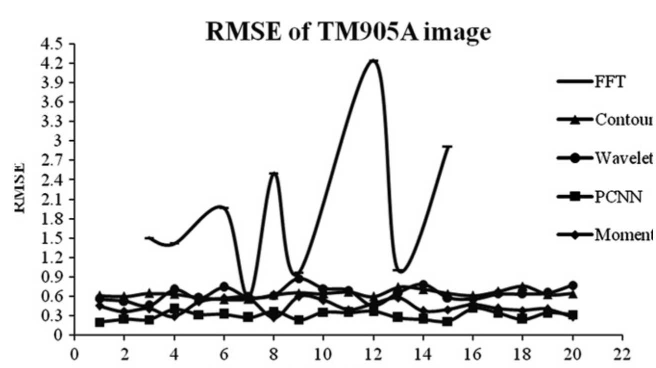

Figure 16 Results of TM905A: RMSE results using FFT Algorithm; contour Algorithm; wavelet Algorithm; Harris–PCNN Algorithm; Harris–Moment Algorithm.

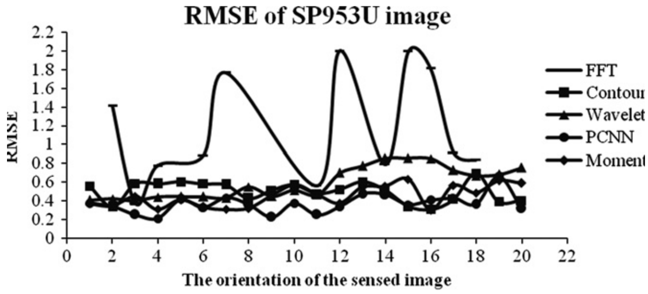

Figure 17 Results of SP953U: RMSE results using FFT Algorithm; contour Algorithm; wavelet Algorithm; Harris–PCNN Algorithm; Harris–Moment Algorithm.

correlation coefficient as a similarity measure and a consistency-checking procedure in order to eliminate incorrect control points and improve registration precision.

2.4. Harris–PCNN-based image registration

This method is a feature-based technique that apply Harris operator for both images to detect corner points, then uses PCNN signature as a similarity measure to establish a correspondence between detected points (Ezzeldeen et al., 2008). Fig. 4 shows the flowchart of Harris–PCNN-based technique.

The Pulse Coupled Neural Network (PCNN) is a biological model based on the mammalian visual cortex, proposed by Eckhorn et al. (1990). The model used for the network had been proposed by Lindblad and Kinser (1998).

2.5. Harris–Moment-based image registration

This method is a feature-based technique that uses Harris operator for both images to detect corner points, and then uses affine invariant moments as a similarity measure to establish a correspondence between detected points using minimum distance classifier (Ezzeldeen et al., 2008). Fig. 5 shows the flowchart of Harris–Moment-based technique.

3. Experimental results and discussion

In this section, the performance of the proposed registration techniques in remote sensing image sequences is evaluated experimentally. Images from Landsat TM and SPOT satellites have been used in the experiments.

Experimental results are depicted in Figs. 12–17, Figs. 6–11 display of the reference images that used for different techniques. The sensed images are created by rotating the reference images with angles from 1 to 20 in counter clock wise direction. These versions are considered as the test images to be registered using the mentioned techniques.

Each figure from 12–17 presents the effect of different orientations on the RMSE difference between the registered images and the reference images shown in Figs. 6–11 using FFT, contour, Wavelet, Harris–PCNN and Harris–Moment-based image registration techniques, respectively.

Figs. 6–9 (TM01_1, TM01_3, TM01_5 and TM01_7) show 256×256 images of Saudi Arabia taken by Landsat TM5 bands 4, 3, 2 in 11/02/2001, Fig. 10 (TM905A) shows 512×512-pixel image taken by Landsat TM5 band 5 in 09/09/90, it corresponds to an agricultural region near Itapeva, Sao Paulo, and finally Fig. 11 (SP953U) shows 256×256-pixel image taken by SPOT band 3 in 08/08/95, it corresponds to an urban area of Brasilia, Brazil.

Table 1 represents the Statistical parameters (maximum, minimum, and average) of RMSE for all mentioned techniques, where the first column indicates the image name and columns 3 through 7 represent the RMSE for all mentioned techniques. The timing results, running on Pentium IIII 1.70 GHz windows XP, for different registration methods are shown in Table 2. The average number of control points is shown in Table 3.

It is noted from Table 1 that the average RMSE for PCNN and moment-based techniques are less than the RMSE of contour, wavelet and FFT-based techniques (PCNN and Moment-based techniques have the lowest average RMSE where wavelet and FFT-based technique have the highest average RMSE), as it is seen that the average RMSE for PCNN

Table 1 The RMSE ranges of the five techniques.

		FFT	Contour	Wavelet	Harris–PCNN	Harris–Moment
TM01_1	Min	0.5	0.22272	0.41551	0.1314	0.22741
TM01_1	Max	2.4862	0.77852	0.82116	0.53278	0.56666
TM01_1	Average	1.21042	0.49360	0.62233	0.393371	0.397473
TM01_3	Min	0.0000	0.14151	0.40873	0.22517	0.26826
TM01_3	Max	3.0557	0.79963	0.75303	0.68563	0.68783
TM01_3	Average	1.198838	0.45241	0.58066	0.439426	0.497289
TM01_5	Min	0.3704	0.31483	0.41383	0.28001	0.16564
TM01_5	Max	2.0997	0.79849	0.85394	0.5127	0.67325
TM01_5	Average	1.197062	0.54090	0.59720	0.418553	0.41912
TM01_7	Min	0.0000	0.00000	0.38269	0.25667	0.20025
TM01_7	Max	2.2955	0.74853	0.85067	0.5869	0.59575
TM01_7	Average	1.166385	0.46129	0.58704	0.388349	0.389624
TM905A	Min	0.5872	0.54828	0.44975	0.19389	0.26624
TM905A	Max	4.2476	0.75626	0.87005	0.41145	0.59084
TM905A	Average	1.897033	0.63295	0.63342	0.298611	0.432436
SP953U	Min	0.3711	0.30965	0.40393	0.20985	0.30427
SP953U	Max	1.9994	0.69769	0.85634	0.66612	0.63337
SP953U	Average	1.17765	0.50061	0.59193	0.369701	0.452443

Table 2 Timing results in seconds for different methods.

Image size	FFT	Contour	Wavelet	PCNN	Moment
256×256	6.898	2.103	3.045	11.622	2.151
512×512	14.447	2.214	4.118	15.716	8.728

Table 3 Average number of control points.

	Contour	Wavelet	PCNN	Moment
Average number of CP	10	30	7	7

technique is the lowest one. Also it is noted that the FFT-based technique has the more stable RMSE profile independent of the image content but the largest one.

From Table 2 it can be seen that the running time of the mentioned techniques are sorted from the lowest to the highest to be contour technique, wavelet technique, moment technique, FFT technique and finally PCNN technique. From Table 3 it is noted that the wavelet technique has the largest number of control points detected in the reference and sensed images.

4. Conclusions

This paper has dealt with five automatic registration techniques of remotely sensed imagery, one is an area based technique (FFT technique) and the others are feature based which are contour, wavelet, Harris–PCNN and Harris–Moment based techniques. In this work, the performance of all the mentioned techniques had been evaluated using Landsat TM and SPOT images. In summary, it is concluded that the more stable technique is the FFT but have the largest RMSE where the least running time technique is the contour, the least RMSE technique is the PCNN, and the technique that detects the more control points in both images (the reference and the sensed) is the wavelet.

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