Implementation and Comparative Study of Image Fusion Methods in Frequency Domain

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Abstract Complementary multi-focus and/or multi-model data from two or more different images are combined into one new image is called Image fusion. The main objective is to decrease vagueness and minimizes redundancy in the output while enhancing correlate information specific to a task. Medical images coming from different resources may often give different data. So, it is challenging task to merge two or more medical images. The fused images are very useful in medical diagnosis. In this paper, image fusion has been performed in discrete wavelet transform (DWT) and Contourlet transform (CNT). As a fusion rule, spatial techniques like Averaging, Maximum Selection and PCA is used. Experiments are performed on CT and MRI medical images. For evaluation and comparative analysis of methods, a set of standard performance measures are used. This paper's results show that, the Contourlet method gives a good performance in medical image fusion, because it provides parabolic scaling and vanishing moments.

Keywords Image fusion · Spatial domain · DWT (discrete wavelet transform) · Contourlet transform

1 Introduction

The process of combining multiple images into a one image that contains a more useful data than provided by any of the resource images known as image fusion. Image fusion is more appropriate for the purpose of human visual perception [1]. The research work of image fusion can be classified into the following three stages:

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- Primitive methods
- Discrete Wavelet Transform
- Contourlet Transform

Primitive methods include all spatial domain methods like averaging, PCA and Max. Selection, but the disadvantage of it is, it will not provide the directional singularity [2]. So frequency domain can be used with image fusion, which provides directional singularity. Discrete Wavelet Transform provides directionality but it is limited. It will provide only horizontal, vertical and diagonal directionality. To enhance the directionality Contourlet transform is helpful. Contourlet transform provides C^2 directional singularity which gives good result along with curves [3]. Though work has been carried out in DWT and CNT, in these paper basic methods are implemented in combination with Averaging, Maximum Selection and PCA methods to do comparative study and analysis of methods.

2 Image Fusion in Spatial Domain

The primitive fusion schemes do the fusion on the resource images. Operations like averaging, addition etc. are to be fused in primitive fusion, which gives some disadvantages also like reducing contras etc. but, it also having advantage that it works better for input images which have an overall high brightness and high contrast [4]. The primitive fusion methods are:

- Averaging [5, 6]
- Select Maximum [4, 6]
- PCA [4–6]

3 Image Fusion in Frequency Transform

Transform domain techniques are based on updating the Fourier transform of image. Every pyramid transform has three parts—Decomposition, Formation and Recomposition [5].

The Discrete Wavelet Transform (DWT) is spatial frequency decomposition. DWT gives a flexible multi-resolution analysis of an image [7]. DWT having disadvantages which degrades some image processing applications. The disadvantages are Shift sensitive, Absence of phase information, Produces sub bands in three directions 0° (Horizontal), 90° (vertical) and 45° (diagonal) only [2, 8].

A new multiscale, rich directional selectivity transform is introduced called Contourlet Transform (CT). It bases on an efficient 2D non-separable filter banks

and gives an elastic multi-resolution, local and directional approach for image processing [3, 9]. The properties of it is Multiresolution, Localization, Critical sampling, Directionality and Anisotropy [10]. CT is better than DWT in dealing with the singularity in higher dimensions, it provides a rich directional selectivity and can stand for different directional smooth contours in natural images [3, 11].

CT is also called Pyramidal Direction Filter Bank (PDFB), which combines Laplacian Pyramid (LP) and Directional Filter Bank (DFB) into a double filter bank construction. Here images are decomposed by LP into one low frequency sub-band and different high frequency sub-bands, and then high frequency sub-bands are nourished into DFB and segmented into multiple directional sub-bands [12].

Majority of Contourlet coefficients are close to zero that's why it is a sparse. It also gives detailed information in any arbitrary direction, as the number of directional sub-bands in each scale is usually 2^n, which is fairly elastic when different n is selected [12].

4 Frequency Domain Methods

Following combination of methods has been implemented in frequency domain:

1. Averaging, Maximum selection and PCA in Discrete Wavelet Transform
2. Various combination of methods like

- Averaging and Maximum selection fusion rule
- Averaging and PCA fusion rule
- Maximum selection and Averaging fusion rule
- Maximum selection and PCA fusion rule
- PCA and Averaging fusion rule
- PCA and Maximum selection fusion rule

have been applied in Contourlet transform. Here first method has been applied on Low coefficients and second method has been applied on high coefficients.

5 Experimental Results and Discussion

Image fusion methods have been applied on multimodality medical image data to derive useful information. Here Computer Tomography (CT) and Magnetic Resonance Imaging (MRI) images are used as shown in Fig. 1a, b.

Figure 2 shows the resultant fused images. Here we have implemented Averaging, Maximum selection and PCA fusion rule in DWT.

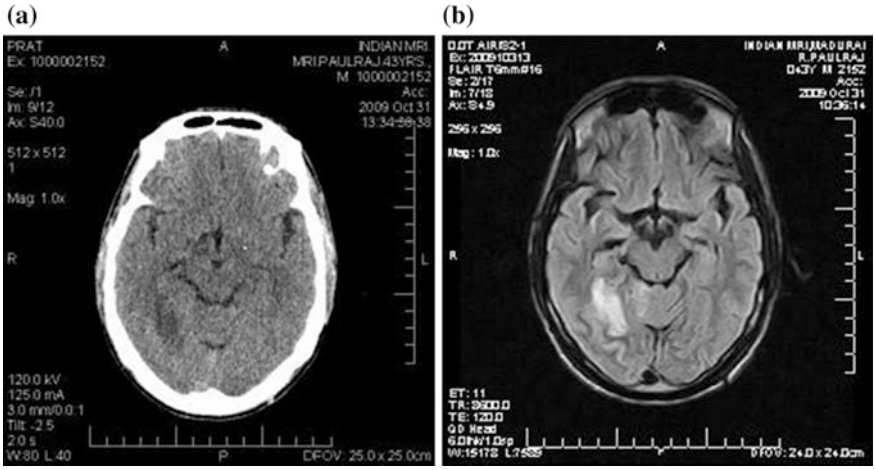
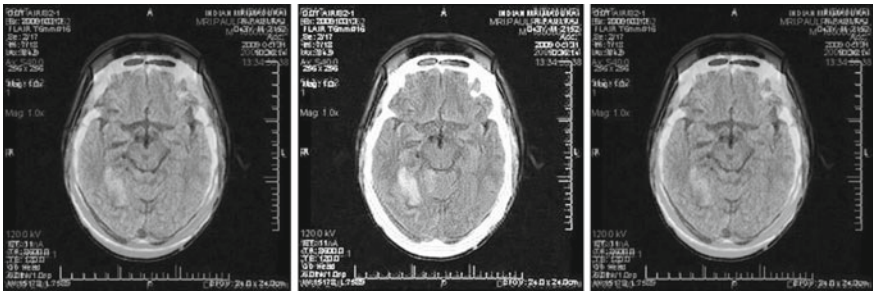


Fig. 1 **a** CT image (*input image 1*). **b** MRI image (*input image 2*) [15]



R1 R2 R3

Fig. 2 Medical image fusion in DWT. **R1** Averaging in discrete wavelet transform. **R2** Maximum selection in DWT. **R3** PCA in DWT

Figure 3 shows the resultant fused images. We have implemented Averaging and Max selection, Averaging and PCA, Max selection and PCA, Max selection and Averaging, PCA and Averaging and PCA and Max selection fusion rule in Contourlet transform. Here Qualitative analysis has been done. It shows that Averaging and Max. selection gives good fusion information.

Performance of image fusion methods have been measured using five standard metrics RMSE [13], PSNR [4, 6], NCC [4, 6], Standard deviation (SD) [3, 13] and Degree of Distortion (DD) [14]. All fusion methods are implemented in MATLAB 9.

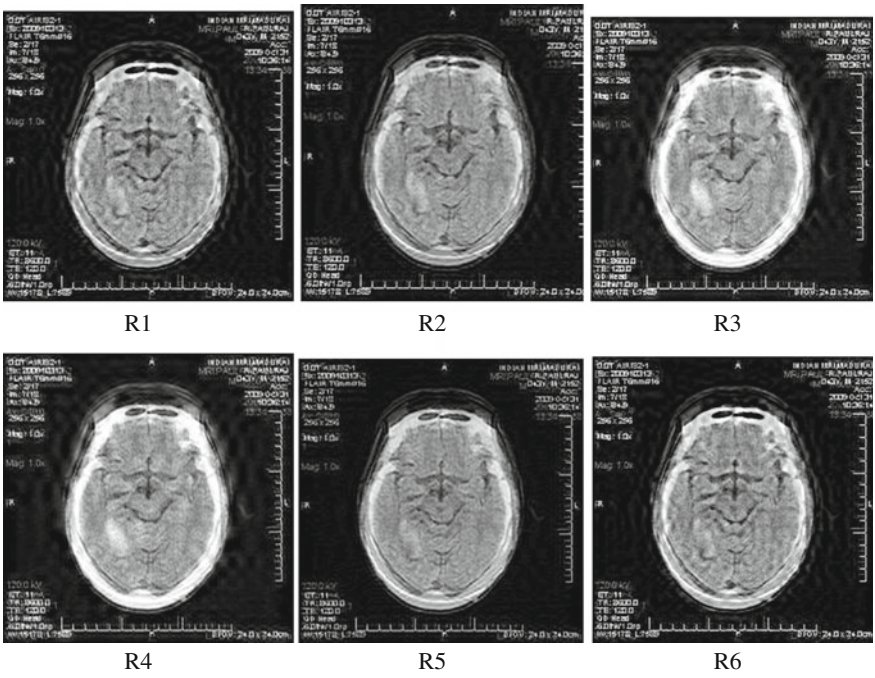


Fig. 3 Medical image fusion in Contourlet transform. **R1** Averaging and maximum selection in Contourlet transform. **R2** Averaging and PCA in Contourlet transform. **R3** Maximum selection and PCA in Contourlet transform. **R4** Maximum selection and averaging in Contourlet transform. **R5** PCA and averaging in Contourlet transform. **R6** PCA and maximum selection in Contourlet transform

Table 1 shows that in Maximum selection good contras is achieved in all the dataset. While less degree of distortion (DD), High NCC and high PSNR are obtained in averaging method.

Table 2 shows that in Maximum selection with combination of Averaging and PCA good contras is obtained in all the dataset. While less degree of distortion (DD), High NCC and high PSNR are obtained in PCA method.

Table 1 Comparative result of different fusion rule on CT and MRI images in DWT

Evaluation parameters	DataSet 1			DataSet 2			DataSet 3		
	Averaging	Max. selection	PCA	Averaging	Max. selection	PCA	Averaging	Max. selection	PCA
RMSE	34.69	54.22	38.09	38.79	59.54	44.85	43.78	70.93	56.1
PSNR	32.72	30.78	32.32	32.24	30.38	31.61	31.71	29.62	30.6
NCC	0.90	0.86	0.88	0.86	0.84	0.82	0.84	0.83	0.77
SD	59.95	80.03	60.81	58.24	83.16	60.15	64.79	93.71	70.8
DD	19.97	23.27	21.93	22.90	26.01	26.49	27.25	34.64	34.9

Table 2 Comparative result of different fusion rule on CT and MRI images in CNT

Fusion rule	RMSE	PSNR	NCC	SD	DD
Dataset 1					
Averaging and max. selection	9.4916	38.3574	0.9992	45.8996	3.8724
Averaging and PCA	11.5710	37.4971	0.9988	45.2420	4.3222
Max. selection and PCA	15.3848	36.2599	0.9978	41.3981	4.9753
Max. selection and averaging	15.0246	36.3628	0.9979	40.7901	4.7984
PCA and averaging	10.9969	37.7181	0.9989	44.7545	4.0664
PCA and max. selection	9.3771	38.4101	0.9992	45.9643	3.8259
Dataset 2					
Averaging and max. selection	43.9206	31.7041	0.8549	70.0413	27.9190
Averaging and PCA	39.5431	32.1601	0.8763	66.0551	24.5120
Max. selection and PCA	57.1955	30.5572	0.8444	83.3786	29.9443
Max. selection and averaging	58.5684	30.4542	0.8219	79.8799	31.2198
PCA and averaging	48.9377	31.2344	0.8141	67.6949	30.1354
PCA and max. selection	51.0299	31.0526	0.8185	75.4910	32.4004
Dataset 3					
Averaging and max. selection	50.5641	31.0924	0.8362	77.6684	33.1135
Averaging and PCA	49.5516	31.1802	0.8321	73.8123	31.7824
Max. selection and PCA	71.6050	29.5814	0.8098	94.3906	41.9669
Max. selection and averaging	69.3595	29.7197	0.8068	89.9417	40.3021
PCA and averaging	57.7873	30.5125	0.7894	78.3785	37.3587
PCA and max. selection	61.3323	30.2539	0.7948	86.9000	40.2977

6 Conclusion

Various combinations of methods like Averaging, Max selection and PCA have been developed in multi model image fusion using Contourlet transform. In DWT Averaging, Max selection and PCA have been implemented in multi model image fusion. For evaluation and comparative analysis of the methods RMSE, PSNR, NCC, SD and DD measuring parameters have been used. In DWT highest PSNR 32.7278 is obtained with Averaging method while in Contourlet transform, the highest PSNR 38.3574 is obtained in Averaging and Maximum Selection. Good contras are also achieved with Maximum Selection because it chooses one highest intensity value of pixel from both the image. Here results shows that, Contourlet transform is, better than discrete wavelet transform when it deals with the higher dimensions singularity, such as line, curve, edge and etc. Contourlet transform also provides rich directional selectivity.

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