Indian Journal of Science and Technology, *Vol 9(22), DOI: 10.17485/ijst/2016/v9i22/95298, June 2016*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Comparative Analysis of Similarity Measure Performance for Multimodality Image Fusion using DTCWT and SOFM with Various Medical Image Fusion Techniques

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Abstract

Objectives: In this paper, the performance of similarity measures such as Edge Based Similarity Measure and Structural Similarity Index Measure is evaluated and also compared with the existing medical image fusion techniques. **Materials and Methods:** Multimodality Medical Image fusion is the process of fusing two Medical images obtained from two different sensors for better diagnosis. Medical image fusion combines and merges all relevant and complementary information from multiple source images into single composite image which facilitates more precise diagnosis and better treatment. The fused image should convey a better description of the scene than the individual images. The performance of the fused image is evaluated by various metrics such as Peak Signal to Noise Ratio (PSNR), Entropy, Standard deviation, Edge Based Similarity Measure (EBSM) and Structural Similarity Index Measure (SSIM). This paper proposes a method for fusion of Medical images using Dual Tree Complex Wavelet Transform (DTCWT) and Self Organizing Feature Map (SOFM). **Findings:** The performance of the proposed fusion algorithm is evaluated over pairs of CT and MR images obtained from patients in comparison with existing fusion techniques such as Discrete Wavelet Transform (DWT), Nonsubsampled Contourlet Transform (NSCT) and Fast Discrete Curvelet Transform (FDCT). In this paper, performance is evaluated by using the metric; Edge based Similarity Measure (EBSM), and Structural Similarity Index (SSIM). **Applications / Improvements:** Through the simulation result, as compared with the DWT, FDCT, NSCT and DTCWT fusion methods, it is concluded that the Multimodality image fusion using DTCWT with Robust Second Order First Moment (SOFM) gives better Edge based similarity measure and Structural similarity index measure.

Keywords: Dual Tree Complex Wavelet Transform, Edge Based Similarity Measure, Fuzzy Rules, Structural Similarity Index

1. Introduction

Image fusion combines two or more than two images into a single composite image. Obviously the composite image should give a better composition of the scene than the individual ones. A novel approach of multimodal medical image fusion using wavelet transforms is presented in[1]. An efficient image fusion method using wavelet combined transformation is implemented in[2] for multi sensor lunar image data. A new information theoretic fusion algorithm combined neural network and fuzzy theory is presented in[3-4]. Image fusion method based on non subsampled contour let transform can achieve better fusion performance[5]. This method is complex in fusion algorithm and also lack

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of multi resolution feature. An innovative multilevel image fusion algorithm using Fast Discrete Curvelet Transform gives the best fusion result in terms of enhanced visual quality in fused images[6]. But it suffers from multi directional decomposition.

The DWT is the good method for image fusion. DWT and spatial frequency based image fusion algorithm is discussed in[7]. A DWT based multimodal medical image fusion is presented in[8]. DWT has two disadvantages, lack of shift invariance and poor directional selectivity. Dual Tree Complex Wavelet transform overcome the disadvantages of DWT. DTCWT based multimodal medical image fusion is implemented in[9]. In this paper, an efficient approach for medical image fusion based on DTCWT and SOFM is proposed. The importance of Multimodal Medical image fusion is discussed in section 2. The proposed image fusion algorithm is explained in section 3. The experimental results obtained from the proposed fusion technique are discussed in section 4. In section 5, conclusion is made from the results obtained.

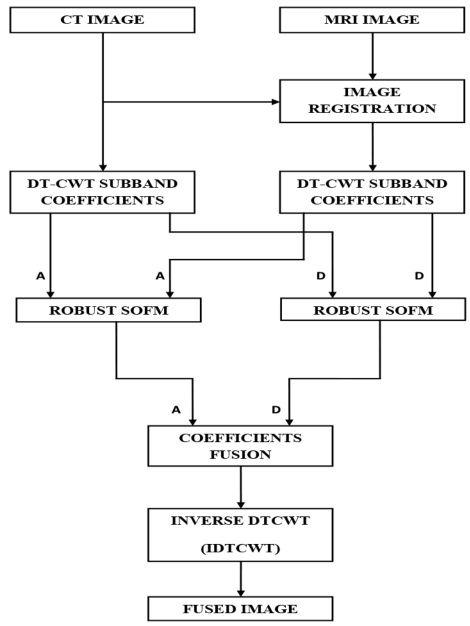

Figure 1. Blockdiagram of the Proposed Image Fusion.

2. Medical Image Fusion

Medical imaging has become an important factor in diagnosis, treatment and research. Medical image fusion combines and merges all relevant and complementary information from multiple source images into single composite image. In Medical image fusion, the fusion of images can often lead to additional clinical information not apparent in the separate images. The requirements of Medical image fusion are that the fused image should convey more information than the individual images and should not introduce any artifacts or distortions.

A review about various image fusion algorithms based on Discrete Wavelet Transform (DWT), **Principal Component Analysis** (PCA), morphological methods, knowledge based methods, neural network based methods and fuzzy logic method and their performances are compared in[10]. Fusion rule also plays a vital role in the image fusion. The rules like min rule, max rule, fuzzy rule[11] can be applied and are seen in the literature.

3. Multimodality Image Fusion using DTCWT and SOFM

The proposed multimodality image fusion technique is based on the DTCWT and SOFM. The fusion of Multimodal Medical images obtained from different sensors like ***Computed Tomography*** (CT) and ***Magnetic Resonance Imaging*** (MRI) has been considered in this work. Many techniques have been proposed in the literature has been studied and reviewed. Proposed method is demonstrated in Figure 1.

Image Registration is the process of establishing spatial correspondence between two or more images of the same scene taken at different times or from different viewpoints or by different sensors. In this work, the intensity based image registration done in MRI to position same coordination.

After image registration, the registered image and the image to be fused are decomposed by using DTCWT at predefined scale[14]. The robust SOFM neural network[12] is utilized to recognize and extract the features. This can be done by training and simulating the network for the resultant coefficients (approximation and detailed) of each level of MR and CT images. After decomposition, the proposed method is carried out on each sub band independently.

In order to identify the salient region in each subband, clustering[13] based image thresholding is applied. It assumes that the input image has bi-model histogram and calculates optimum threshold value based on their intra class variance[14]. Let us consider A, B are the registered image and the image to be fused respectively. AA and BB are their corresponding threshold image. Then, the fusion process after thresholding the images for all wavelet coefficients located at pixel position (i,j) :

Input : Registered image (A) and corresponding clustered image (AA), image to be fused (B) and corresponding clustered image (BB)
Output : Fused Image (F)
Rule1 : if AAi,j is true and Bbi,j is false then Fi,j = Ai,j
Rule2 : if Aai,j is false and Bbi,j is true then Fi,j = Bi,j
Rule3 : if Aai,j is true and Bbi,j is true then Fi,j = max(Ai,j, Bi,j)
Rule4 : if Aai,j is false and Bbi,j is false then Fi,j = min(Ai,j, Bi,j)

Then apply Inverse DTCWT to the fusion result to get the final fused image.

4. Results and Discussions

The performance of the proposed method is evaluated over pairs of CT and MR images obtained from patients in comparison with existing fusion techniques such as DWT, NSCT, FDCT. In this paper, performance is evaluated by using the metric; Edge Based Similarity Measure (EBSM), and Structural Similarity Index (SIM).

4.1 Edge Based Similarity Measure (EBSM)

The edge based similarity measure gives the similarity between the edges transferred in the fusion process.

Mathematically, is defined $Q^{AB/F}$ is defined as

$$Q^{AB/F} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left[Q_{i,j}^{AF}\, w_{i,j}^{x} + Q_{i,j}^{BF}\, w_{i,j}^{y}\right]}{\sum_{i=1}^{M}\sum_{j=1}^{N}\left[w_{i,j}^{x} + w_{i,j}^{y}\right]} \qquad (1)$$

Where *A*, *B* and *F* represent the input and fused images respectively.

The definition of Q^{AF} and Q^{BF} are same and given as

$$Q_{i,j}^{AF} = Q_{g,i,j}^{AF}\, Q_{\alpha,i,j}^{AF}, \quad Q_{i,j}^{BF} = Q_{g,i,j}^{BF}\, Q_{\alpha,i,j}^{BF} \qquad (2)$$

where Q_g^{*F} and Q_α^{*F} are the edge strength for images *A* and *B*.

It is observed from the Table 1 that the performance of the proposed method outperforms the existing methods based on DWT, FDCT, NSCT. The reason for better performance of the proposed fusion method is that the proposed fusion is the mixture of min rule and max rule and the application of these rules are based on the clustering based thresholding approach. Table 1 shows the Comparison on Edge Based Similarity Measure of different methods for Fused Image. Figure 2 shows the visual results of the proposed fusion method for five pairs of images in comparison with existing fusion methods and Figure 3 shows the Chart representation of Comparison on Edge Based Similarity Measure of different methods for Fused Image.

Table 1. EBSM Performance of the proposed method

Image Set	Edge based similarity measure				
	DWT	FDCT	NSCT	DTCWT	DTCWT-SOFM
1	0.2476	0.3643	0.4513	0.5677	0.8136
2	0.2564	0.407	0.5078	0.6151	0.8545
3	0.2599	0.3704	0.4703	0.5925	0.8241
4	0.2866	0.3653	0.4555	0.5589	0.8065
5	0.3271	0.3696	0.4405	0.5265	0.7823

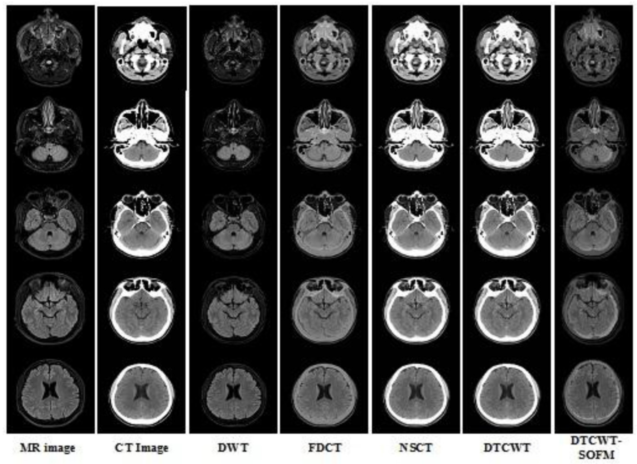

Figure 2. Visual results of the proposed DTCWT-SOFM for five pairs of MRI and CT images in comparison with existing fusion techniques.

4.2 Structural Similarity Index Measure (SSIM)

The structural similarity index is a method for measuring the similarity between two images using eqn. (3).

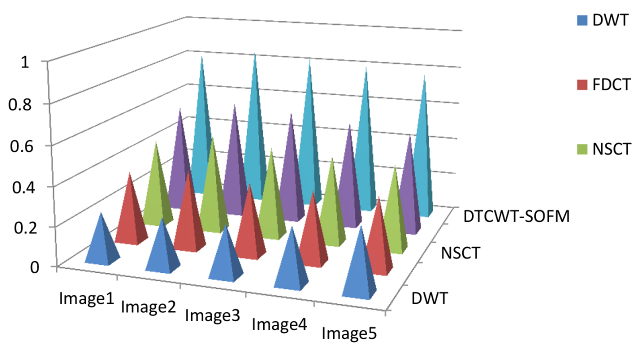

Figure 3. Comparison on Edge Based Similarity Measure (EBSM) of different techniques for Fused Image.

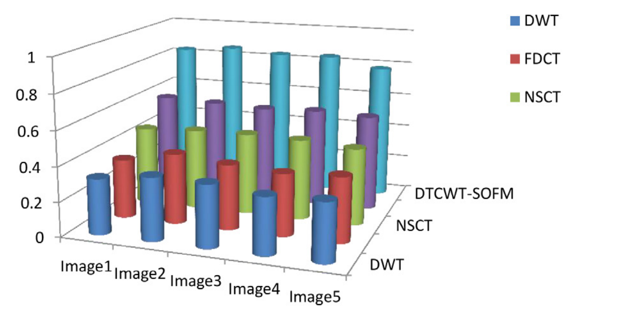

Figure 4. Comparison on Structural Similarity Index Measure (SSIM) of different techniques for Fused Image.

Table 2. Performance evaluation of SSIM using DTCWT-SOFM and Fuzzy rule based fusion method

Image Set	Structural Similarity Index Measure (SSIM)				
	DWT	FDCT	NSCT	DTCWT	DTCWT-SOFM
1	0.321	0.343	0.451	0.577	0.831
2	0.364	0.407	0.467	0.566	0.857
3	0.359	0.377	0.472	0.555	0.835
4	0.327	0.359	0.467	0.567	0.839
5	0.336	0.375	0.445	0.555	0.783

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (3)$$

with

μ_x the average of x; μ_y the average of y; σ_x^2 the variance of x; σ_y^2 the variance of y;

σ_{xy} the covariance of x and y ;

Table 2 shows the Comparison on Structural Similarity Index Measure of different methods for Fused Image. It is observed from the Table 2 that the performance of the proposed fusion algorithm outperforms the existing algorithms based on DWT, FDCT, NSCT and DTCWT. The reason for better performance of the proposed fusion method is that the proposed fusion is the mixture of min rule and max rule and the application of these rules are based on the clustering based thresholding approach. Table 2 shows the Comparison on Structural Similarity Index Measure of different methods for Fused Image. Figure 4 shows the Chart representation of Comparison on Structural Similarity Index Measure of different methods for Fused Image.

Table 3. Percentage of improvement on EBSM and SSIM for DWT *vs.* proposed method

Metrics	Image Set	DWT	Proposed DTCWT-SOFM	% of improvement
Edge based similarity measure	1	0.2476	0.8136	228.59
	2	0.2564	0.8545	233.27
	3	0.2599	0.8241	217.08
	4	0.2866	0.8065	181.40
	5	0.3271	0.7823	139.16
Structural Similarity Index Measure	1	0.321	0.831	158.88
	2	0.364	0.857	135.44
	3	0.359	0.835	132.59
	4	0.327	0.839	156.57
	5	0.336	0.783	133.04

4.3 Comparative Analysis

The proposed image fusion method using DTCWT with SOFM is quantitatively and qualitatively compared in terms of EBSM, SSIM and image quality with four other existing state of the art methods for image fusion. Table 3 – Table 6 shows the percentage of improvement for EBSM and SSIM between proposed multimodality image fusion using DTCWT with SOFM and existing state of the art methods; DWT, FDCT, NSCT and DTCWT.

Table 3 gives the percentage of improvement on EBSM and SSIM between proposed multimodality image fusion and DWT. From Table 3, the simulation results show that the proposed DTCWT and SOFM method has achieved maximum edge based similarity measure of 0.8545 and structural similarity index measure of 0.831 whereas the existing DWT method with maximum Edge

Table 4. Percentage of improvement on EBSM and SSIM for FDCT vs. Proposed Method

Metrics	Image Set	FDCT	Proposed DTCWT-SOFM	% of improvement
Edge based similarity measure	1	0.3643	0.8136	123.33
	2	0.407	0.8545	109.95
	3	0.3704	0.8241	122.49
	4	0.3653	0.8065	120.78
	5	0.3696	0.7823	111.66
Structural Similarity Index Measure	1	0.343	0.831	142.27
	2	0.407	0.857	110.57
	3	0.377	0.835	121.49
	4	0.359	0.839	133.70
	5	0.375	0.783	108.80

based similarity measure of 0.2564 and structural similarity index measure of 0.321. Thus there is an improvement of 233.27% in edge based similarity measure and 158.88% in structural similarity index measure.

Table 4 gives the percentage of improvement on EBSM and SSIM between proposed multimodality image fusion method and FDCT.

From Table 4, the simulation results show that the proposed DTCWT and SOFM method has achieved maximum edge based similarity measure of 0.8136 and structural similarity index measure of 0.831 whereas the existing FDCT method with maximum Edge based similarity measure of 0.3643 and structural similarity index measure of 0.343. Thus there is an improvement of 123.33 in edge based similarity measure and 142.27% in structural similarity index measure.

Table 5 gives the percentage of improvement on EBSM and SSIM between proposed technique and NSCT. From Table 5, the simulation results show that the proposed DTCWT and SOFM method has achieved maximum edge based similarity measure of 0.8136 and structural similarity index measure of 0.831 whereas the existing NSCT method with maximum Edge based similarity measure of 0.4513 and structural similarity index measure of 0.451. Thus there is an improvement of 80.28 in edge based similarity measure and 84.26% in structural similarity index measure.

Table 6 gives the percentage of improvement on EBSM and SSIM between proposed multimodality image fusion method and DTCWT. From Table 6, the simulation results show that the proposed DTCWT-SOFM method has achieved maximum edge based similarity measure of 0.7823 and structural similarity index measure of 0.857 whereas the existing DTCWT method with maximum Edge based similarity measure of 0.5265 and structural similarity index measure of 0.566. Thus there is an improvement of 48.58% in edge based similarity measure and 51.41% in structural similarity index measure.

Table 5. Percentage of improvement on EBSM and SSIM for NSCT *vs.* Proposed Method

Metrics	Image Set	NSCT	Proposed DTCWT-SOFM	% of improvement
Edge based similarity measure	1	0.4513	0.8136	80.28
	2	0.5078	0.8545	68.27
	3	0.4703	0.8241	75.23
	4	0.4555	0.8065	77.06
	5	0.4405	0.7823	77.59
Structural Similarity Index Measure	1	0.451	0.831	84.26
	2	0.467	0.857	83.51
	3	0.472	0.835	76.91
	4	0.467	0.839	79.66
	5	0.445	0.783	75.96

Table 6. Percentage of improvement on EBSM and SSIM for DTCWT vs. Proposed Method

Metrics	Image Set	DTCWT	Proposed DTCWT-SOFM	% of improvement
Edge based similarity measure	1	0.5677	0.8136	43.32
	2	0.6151	0.8545	38.92
	3	0.5925	0.8241	39.09
	4	0.5589	0.8065	44.30
	5	0.5265	0.7823	48.58
Structural Similarity Index Measure	1	0.577	0.831	44.02
	2	0.566	0.857	51.41
	3	0.555	0.835	50.45
	4	0.567	0.839	47.97
	5	0.555	0.783	41.08

5. Conclusion

In Medical image processing applications, specifically in MRI and CT images, the edge preserve is an important criterion in complementary details of input images.

This work investigates the proposed Neural Network based nonlinear medical image fusion algorithm based on DTCWT with Robust SOFM. This allows us to fuse two modalities, CT and MR images to visually assess the details on a single image. The steps involved in the proposed fusion algorithm are image registration, DTCWT decomposition, Robust SOFM, image fusion and reconstruction to obtain the fused image. The Similarity Measure performance is evaluated by using Edge Based Similarity Measure and Structural Similarity Index Measure. The simulation results show that the proposed method has achieved maximum Edge based similarity measure and Structural Similarity Index Measure values. Hence the fused image provides better diagnosis without artifacts. Through the simulation result, as compared with the DWT, FDCT, NSCT and DTCWT fusion methods, it is concluded that the Multimodality image fusion using DTCWT with Robust SOFM gives better Edge based similarity measure and Structural similarity index measure.

6. References

1. Soma Sekhar, Giri Prasad MN. A Novel Approach of Image Fusion on MR and CT Images Using Wavelet Transforms. IEEE 3rd International Conference on Electronics Computer Technology, 8-10 April 2011, p. 172–76.
2. Lavanya A, Vani K, Sanjeevi S, Suresh Kumar R. Image Fusion of the Multi sensor Lunar Image data using Wavelet Combined Transformation. IEEE International Conference on Recent Trends in Information Technology, 3-5 June 2011, p. 920–25.
3. De-gan Zhang, Yuan-yuan Wang, Wei-wei Liu, Xiao-li Zhang. A New Method for Image Fusion Based on Fuzzy Neural Network. IEEE International conference on Modelling Identification, 17-19 July 2010, p. 574–78.
4. Das S, Kundu M. A Neuro-Fuzzy Approach for Medical Image Fusion. IEEE Transactions on Biomedical Engineering. 2013; 60(12):3347–53.
5. Xing Su-xia, Lian Xiao-feng, Chen Tian-hua, Xiao Hongbing. Image Fusion Method Based on NSCT and Robustness Analysis. IEEE International Conference on Computer Distributed Control and Intelligent Environmental Monitoring. 19-20 Feb 2011, p. 346–49.
6. Roshna J. Sapkal, Sunita M. Kulkarni, Innovative Multileve Image Fusion Algorithm using combination of Transform domain and spatial domain methods with comparative analysis of wavelet and curvelet transform. International Journal of Computer Applications. March 2013; 66(21):41-37.
7. Zhongxian QU, Jingbo Zhang, Zijun Feng. Image Fusion Algorithm Based on Two-Dimensional Discrete Wavelet Transform and Spatial Frequency. IEEE Fifth International Conference on Frontier of Computer Science and Technology. 18-22 Aug. 2010, p. 537–40.
8. Singh R, Khare A. A Wavelet Based Multimodal Medical Image Fusion, in Proceedings of International Symposium on Medical Imaging: Perspectives on Perception and Diagnostics. 2010.
9. Rajiv Singh, Richa Srivastava, Om Praksh, Ashish Khare. DTCWT Based Multimodal Medical Image Fusion. Electronic Proceedings of the 13th British Machine Vision Conference University of Cardiff, January 2012, p. 1–4.
10. Sahu, DK, Parsai MP. Different Image Fusion Techniques–A Critical Review," International Journal of Modern Engineering Research (IJMER). 2012; 2(5): 4298–4301.
11. Heydar Jafarzadeh, Rouhollah Rahmati Torkashvand, Chamran Asgari, Amir Amiry. Provide a New Approach for Mining Fuzzy Association Rules using Apriori Algorithm. Indian Journal of Science and Technology. 2015 Apr; 8(supp 7), p. 127–34. Doi:10.17485/ijst/2015/v8i8/63627
12. Teuvo Kohonen. The self-organizing map. IEEE Proceedings. 1990; 78(9):1464–80.
13. Revathy S, Parvaathavarthini B, Rajathi S. Futuristic Validation Method for Rough Fuzzy Clustering. Indian Journal of Science and Technology. 2015 Jan; 8(2):120–27. Doi: 10.17485/ijst/2015/v8i2/58943
14. Karthikeyan C, Ramadoss B. Fusion of Medical Images using Mutual Information and Intensity based Image Registration Schemes. ARPN Journal of Engineering and Applied Sciences. May 2015; 10(8):3561–65.