Fusion of The Multimodal Medical Images To Enhance The Quality Using Discrete Wavelet Transform

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Abstract. The operation of medical image fusion is to merge various images from different imaging modalities in to one image fused. The quality of image fused is improved especially by extracting the useful information of multiple images in one image. To rise the diagnosis and estimate of many medical problems by using clinical application of medical images and improving the accuracy medical imaging clinical is the most important goal of multi-modal image fusion algorithms. There are many types of modality used as a reference in medical image fusion like X-ray, Ultrasound , Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET) and Computed Tomography (CT). In this work, a multi solution images are used and coming from (CT) and (MRI) by Discrete Wavelet Transform (DWT) techniques to get a high quality image fusion. It can be proved the improvement in performance of image quality after fusion techniques by using some popular parameters of image metrics to test the image as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Structural Similarity Index Measure (SSIM) . The quality improve of the fused image by tested and analyzed as low MSE of 0.02632, higher PSNR of 15.7955 and higher SSIM of 0.75434.

Keywords - Image processing, DWT, Image Fusion, Multimodal medical image fusion, SSIM ,PSNR, MSE.

1. Introduction

Nowadays the image fusion processing is the best accomplishment role in the medical image for treatment and diagnosis of diseases. Researchers for medical image fusion had proposed abundant methods so many of them are sensitive by distortion of fusion and noise. Computed Tomography scans (CT) using an array of X-ray sensors to create images that provides high resolution information about hard tissue like bone structure ,while MRI scans uses a magnetic field and radio waves to create images that provides detailed information about soft tissue like bones and blood vessels [1], [2]. The medical experts chosen the quality of spectral and spatial data image for many uses like the diseases diagnosed precise and monitoring. The patient is treated according to the exact diagnosis of the disease by the medical expert [3]. The image fusion processing is the technique of combining and registering more than one image taking by different modality to get a new image that has all the specifications and task information for the sources images and combines them in one image with minimizing redundancy [4]. Experiments show that the technique can extract beneficial information from source images to fused images so that obtained the clear and best images. There are four main classes of image fusion depending on the nature of the source images are: Multi_view fusion, Multimodal fusion, Multi_temporal fusion and Multi_focus fusion [5].

1.1. Multi_view fusion: The modality of the fused images must be similar at same time but the conditions had taken is various. The improvement in quality and high resolution for the output image fused is shown in Figure1.

![Figure 1. Multi-view fusion.](image-url)
1.2. Multi-modal fusion: The various modalities for same scene source image to be fused contained the best information from images, it used mostly in medical images applications, as shown in Figure 2.

![Figure 2. Multi-modal fusion.](image)

1.3. Multi-temporal fusion
It’s used as a detected image changes over time. The modality of fused images is similar, though they had taken at various times as shown in Figure 3 [6].

![Figure 3. Multi-Temporal fusion [6]](image)

1.4. Multi-focus fusion
The modality is the same as that for scene, but the focus in various parts of the image is shown in Figure 4.

![Figure 4. Multi-focus fusion [7]](image)

2. Related Works
This section presents related works of the experimental efforts and theoretic and researches those are directly related to the main objective of this research for enhancing the quality of the medical images, using the most convenient methods as below.

Cui and et al. [5]: in 2009 proposed, firstly, they decomposed the images by Wavelet Transform (WT), secondly, they used independent component analysis (ICA) to analyze the wavelet coefficients at distinct
levels for autonomous component acquisition. So WT-ICA method fusion on CT images can be found in this work that they used Entropy, SNR and RMSE as Metrics.

K Sharmila, S Rajkumar, and V. Vijayarajan [6]: in 2013 they suggested that a proposal of new fusion technique namely; “Discrete Wavelet Transform-Averaging-Entropy-Principle Component Analysis method [DWT-A-EN-PCA]” with dataset of brain images CT-MRI. Comparison of the outcomes of the suggested method with other current fusion methods using quantitative metrics such as, Entropy EN, SNR, Fusion Symmetric.

Mirajkar Pradnya P. and Ruikar Sachin D. [7]: in 2013 suggested to prove the geometric resolution of the images by using Stationary Wavelet Transform (SWT) for two levels comparing to other method, and used MSE, PSNR and SNR to surport the performance evaluation.

Nayera Nahvi and Deep Mittal [8]: in 2014, they proposed a different type of DWT techniques, the dataset are of brain images CT-MRI, that tested by metrics to improve the quality with PSNR, MSE and Elapsed Time.

Bhavana. V, Krishnappa. H.K [3]: in 2015, they suggested that, the DWT transform used for MRI and Positron Emission Tomography (PET) images, the measures and performance indicators used are Average Gradient (AG) and Spectral Discrepancy (SD).

Saranya G and S. Nirmala Devi [9]: in 2016, they proposed two basic fusion domains with this work, using the measurement of sensitivity, specificity and accuracy to validate the evaluated results of the fused image.

3. Proposed Method

The proposed method is a Multi-modal fusion used specially for medical images, this process aims to get better clinical applicability of the medical images in assessment and diagnosis medical problems by decreasing the redundancy to make the quality had been improving [8]. The algorithm of fusion depends on input, so the fusion algorithms are divided into three sides: type of image modality, organs that be imaged, and the fusion algorithm is implemented as appears in Figure 5.

![Multi-modal fusion steps for medical Image](image)

**Figure 5.** The three steps in Multi-modal fusion for medical image.

3.1 Flowchart for The Proposed Image Fusion Method

There is a problem must be solved before getting into the processing of images and how to get the best match between the pictures of the proposed methods. Because the images are taken from the patient contain a different number of sections and sizes. To choose the optimal match between images is very difficult by eyes only therefore, we need before applying a proposed method to find this match. The following flow chart of the algorithm is suggested as shown in figure 6.
As shown in Figure 6 above, it is started the process with reading the images information from the two sources and find the sizes, if not match the operation stopped, and if match in size the operation will be continued. After that, finding the difference between each tested images cause to find the difference between the two images, then find the best two images match. Next step, apply DWT for decompose the two images into four coefficients with specified level and fusion technique for each level coefficient. The final fused images are found by applying inverse discrete wavelet transform (IDWT) as reconstruction of image fusion.

3.2 Proposed Algorithm for Image Fusion

The proposed method algorithm could be defined by steps as follows:
Step 1: Read image input data.
Step 2: Find the best matching images.
Step 3: Apply discrete wavelets transform (DWT).
Step 4: Apply the fusion selection rule to the images.
Step 5: Take the inverse discrete wavelets transform (IDWT).
Step 6: Get a fused image of the output.
4. Wavelet transform technique for image fusion

Wavelet transform is a useful tool to analysis non stationary signal that contained in both time and frequency. The wavelet analysis is using window technique in regions sized variable, as high resolution for small object and low resolution for large object. So the main concept of wavelet transform is the multi-resolution decomposition of image or signal to generate approximation component using a low-pass filter (scaling) and detail components using high pass filters (wavelet functions) [10]. The Discrete Wavelet Transform (DWT) type Haar, this technique has advantageous because it is the frequently transform method used in image fusion implementation with low spatial distortion and it is used to improve the characteristics of brightness, distribution or contrast of image gray levels. To perform a successfully fused image, it must go through the next three steps [11] and [12]: At the First step, the sources images decomposition. Through the DWT divides each input image to four several frequency bands which characterize the detail coefficients, and approximation coefficients of the image analyzed. After that, a sub-sampling process applies to make the size of the out fused image equal half size of the reference image and so on in each level [13]. The low-frequency components LL of an image gives the approximation, while others give the details are the three high-frequency components are LH, HL, HH and then repeat decomposition steps until S times level as shown in Figure 7.

![Wavelet decomposition](image-url)

**Figure 7.** The sources images decomposition for 3 levels

The second step is the multiscale fused image for each level image, we fused the coefficients end up by one of different fusion way maximum, minimum or average for each image. The final step is image reconstruction of the fused image, to get the final fused image by using IDWT on the output value by level times to get the starting level as shown in Figure 8.

![Fusion process](image-url)

**Figure 8.** Fusion process of DWT using Haar.

5. Metrics for Measurement

There are many performance measurement metrics to estimate image fusion, Mean Square Error (MSE), Peak Signal to Noise ratio (PSNR), Structure Similarity Index Measure (SSIM) are used in this paper. Below are given characterization of these metrics.
\( \mathbf{I}_r \) is the reference image and \( \mathbf{I}_f \) is the fused image to be measured. \( m \) and \( n \) are sizes of the images, \( i, j \) are the row number and the column number of the pixels.

5.1 Mean Square Error (MSE)
MSE is a frequently used between the fused image and the reference image to compare squared error. the MSE equation is given by equation (1):

\[
MSE = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} [r(i,j) - f(i,j)]^2
\]  

The non negative lower value Close to Zero for best fusion.

5.2 Peak Signal-to-Noise ratio (PSNR)
Commonly is used in image processing which is the ratio of maximum pixel intensity to the strength of the corrupting noise, the PSNR equation is given by (2) [14]:

\[
PSNR = 10 \log_{10} \left( \frac{R^2}{MSE} \right)
\]

The Higher value for Best Fusion ,where \( R \) is the value of maximum pixel (255).

5.3 Structure_Similarity Index Measure (SSIM)
SSIM:measures the match of the fused and reference image by comparing pixel strengths [15]. The SSIM equation is given by (3):

\[
SSIM = \frac{(2\mu_r \mu_f + C_1)(2\sigma_{rf} + C_2)}{\mu_r^2 + \mu_f^2 + \sigma_{rf}^2 + C_1}(2\sigma_{rf} + C_2)
\]

The Higher value closer to positive 1 for best fusion where:
\( \mu_r \) is the average of the reference image
\( \mu_f \) the mean of fused image.
\( \sigma_r \) and \( \sigma_f \) are the standard deviation of reference and fused images respectively. \( \sigma_{rf} \) are the covariance of \( I_r \) and \( I_f \). \( C_1 \) and \( C_2 \) are constants for control division.

6. Experimental Analysis and Results
The proposed method was implemented through the MATLAB R2018b program and the medical registered images contained the brain axial. The images contain the same patient and the same organ with the presence of brain tumor axial (MRI-T1) and CT. After getting the fused image must be tested according to the measurement quality metrics as suggestion, MSE, PSNR and SSIM. The results are shown in Table 2.

| Fusion Algorithm Type | No. | Fusion techniques | MSE   | PSNR   | SSIM  |
|-----------------------|-----|-------------------|-------|--------|-------|
| DWT                   | 1   | Mean, Mean        | 0.02632 | 15.7955 | 0.75434 |
|                       | 2   | Mean, Max         | 0.03479 | 14.6055 | 0.67414 |
|                       | 3   | Mean, Min         | 0.03479 | 14.6056 | 0.61131 |
|                       | 4   | Min, Min          | 0.05265 | 13.5647 | 0.61504 |
|                       | 5   | Min, Max          | 0.05265 | 13.5647 | 0.61504 |
|                       | 6   | Max, Min          | 0.05265 | 13.5645 | 0.58513 |
|                       | 7   | Max, Max          | 0.05265 | 13.5645 | 0.58513 |
|                       | 8   | Min, Mean         | 0.04419 | 15.2122 | 0.70673 |
|                       | 9   | Min, Mean         | 0.04419 | 15.2122 | 0.65096 |
It is seen clearly by the Table 2 that the proposed method (Mean, Mean ) achieves better than all other methods by increasing the values of PSNR and SSIM and decreasing the value of MSE on the value of other techniques . Less error and it holds more information. 
To note that the method (Max, Min) equal result to the method (Max, Max) and the method (Min, Max) equal to the method (Min, Min).

![PSNR Chart](image)

Figure 9. Chart of PSNR for all Fusion techniques by DWT

Figure 9 shows a comparison of all methods results that reveal in standings of PSNR. It is clear from the chart that there is an increase in PSNR value of the fused image by using the method we proposed on the other methods. This increasing indicates an improvement in image quality.

![SSIM Chart](image)

Figure 10. Chart of SSIM for all fusion techniques by DWT

Figure 10 shows a comparison of all methods results reveals in standings of SSIM. It is clear from the chart that the higher value of SSIM and closer to a positive one by using the proposed method on the other methods.
Figure 11. Chart of MSE for all fusion techniques by DWT

Figure 11 shows a comparison of all methods results that reveal in standings of MSE. It is clear from the chart that there is a decrease in MSE value of the fused image using the proposed method on the other methods. This decrease is giving better image quality with less error.

The graphical results of the proposed algorithm are discussed for both referenced images and the fused image with different techniques in (DWT) as shown in Figure12 and Figure13.

![Graph of MSE for all fusion techniques by DWT](image)

Figure 12. (A) Reference image (CT) and (B) Reference image (MRI)
Figure 13. Proposed fused image (mean, mean) with all fused images with different techniques

The best graphic result is method (mean, mean) as seen in the performance analysis of various fusion techniques are recorded in the Table 2, unlike the other methods that are shown distortion in the output image.

7. Conclusion

The proposed article in this work is the image fusion with discrete wavelet transform type (Haar) with average rule (mean, mean) as powerful method and without distortion or blurry. It clearly shows that when applied to image fusion, the wavelet decomposed images increase the information quality in an image. The quality improved of the fused image by tested and analyzed by using metrics as low as this of MSE 0.02632 , higher PSNR of 15.7955 and higher SSIM of 0.75434 as results. From the previous positive results, the improvement is clear by using the proposed method that is easy to process and the least complex for future work which leads to better diagnosis by special doctor for clinical medical images.

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Acknowledgment

Our heartfelt gratitude to the “Dr.Mohamed Muyaser Naif Specialist in radiology and diagnostic imaging M.B.Ch.B., C.A.B.M.S. (rad.) – Samark and Diagnostic Center-Mosul” and to the “Dr.Shaiban Abdulsalam Al-Mukhtar Specialist in Oncology & Nuclear Hematology-Mosul”, for obtained medical images of cases and for to evaluate the results of the fused image of the output.