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Enhancing Brain Tumor Diagnosis through MRI-CT Image Fusion: A Comparative Study of DWT and SWT Techniques Using Wavelet Families

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Abstract:
Integration of supplemental data from several imaging methods depends critically on medical image fusion. Particularly aimed at brain tumor detection across four datasets, this study assesses and contrasts two wavelet based fusion techniques applied to fuse Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans: Discrete Wavelet Transform (DWT) and Stationary Wavelet Transform (SWT). Additionally examined in the study is how different wavelet families affect fusion performance. Based on PSNR, RMSE, and entropy measures, experimental results show that SWT based fusion consistently outperforms DWT based fusion, with the bior2.2 wavelet family providing the best performance.
Keywords
Medical Image Fusion, Stationary Wavelet Transform (SWT), Discrete Wavelet Transform (DWT).

1. Introduction

The brain tumors are serious medical problems. Determining the most successful treatment and improving patient outcomes depends on an accurate diagnosis, which also helps to raise survival rates ultimately.

Medical image fusion uses data from several imaging methods, including Magnetic Resonance Imaging (MRI) and Computed Tomography (CT), to offer a more thorough and accurate knowledge of medical problems. This mix uses the benefits of every technique to improve diagnostic accuracy and treatment planning in medicine [1][2].

Previous research has explored various image fusion techniques. For instance, a study introduced a novel algorithm utilizing SWT attributes to enhance image quality, showing that SWT-based fusion with higher decomposition levels consistently delivered better results than DWT-based approaches [3]. In [4], they compared two medical image fusion techniques were using DWT with fast filtering, and the other using SWT with fast filtering. The DWT method demonstrated better performance. Another study [5] applied multiple fusion methods both DWT and SWT-based, varied results depending on image type. For brain images, the Haar-max method was most effective using DWT, while Haar fusion performed best with SWT. In [6], a fusion technique combining between a sharpening Wiener filter and DWT was proposed, showing superior results in reducing blurring and enhancing clinical diagnostic quality.

This paper compares the two wavelet-based fusion methods effectiveness SWT and DWT for fusing MRI and CT brain images. These Images are decomposed into sub-bands and fused using either maximum selection or averaging methods. Various wavelet families (Haar, Coiflets, Symlets, Daubechies, Biorthogonal, and Reverse Biorthogonal) are evaluated to identify the better choice in terms of minimal information loss and high-quality fusion. While the paper is structured as follows: Section 2 describes the proposed fusion method; Section 3 presents the evaluation metrics; Section 4 discusses the fusion results; and Section 5 concludes the study.

2. Method

This study used MRI and CT brain images of patients while diagnosed with brain tumors, collected from the Misurata National Institute for Oncology. Four image sets, representing different age groups a 35-year-old woman, a 40-year-old man, a 60-year-old woman, and a 70-year-old man. The proposed method includes several steps as : data collection, pre-processing, image decomposition, fusion using selected wavelet techniques, and evaluation. The entire process is illustrated in Figure 1.

3. Evaluation Metrics:

the DWT and SWT fusion techniques performance was evaluated using the following metrics:

3.1. Root Mean Square Error :

The RMSE value Explains the value pixel discrepancies between fused and reference images, the lower values indicating more accurate fusion and minimal distortion/errors[9]. RMSE is given by[7]:

$$\mathrm{RMSE} = \frac{1}{MN}\sum_{n=1}^{N}\sum_{m=1}^{M}(x_R(n,m) = x_F(n,m)^2)^{1/2} \qquad (1)$$

where $x_R(n,m)$ the pixel intensity at position (n, m) in the original image, $x_F(n,m)$ the pixel intensity at position (n, m) in the reconstructed image. M the number of rows in the image, N the number of columns in the image.

3.2. Peak Signal to Noise Ratio :

PSNR is a measure that quantifies the level of noise or distortion in fused images compared to the original images using a numerical value[10]. with higher values indicating more better fusion. PSNR measure is given by[8]:

$$\mathrm{PSNR} = 10\log_{10}(\mathrm{MAX}^2/\mathrm{MSE}) \qquad (2)$$

where MSE means Squared Error between the original and reconstructed images, MAX maximum possible pixel value in the image.

3.3. Entropy :

Entropy is a measure of preserved information in a resulted image, an increase in entropy indicates improved fusion performance [9]. it is given by[11]:

$$E = \sum_{i=0}^{L-1} P(i)\log_2 P(i) \qquad (3)$$

where L is the number of grey level, pi is the ratio of number of pixels having grey level i to the total number of pixels.

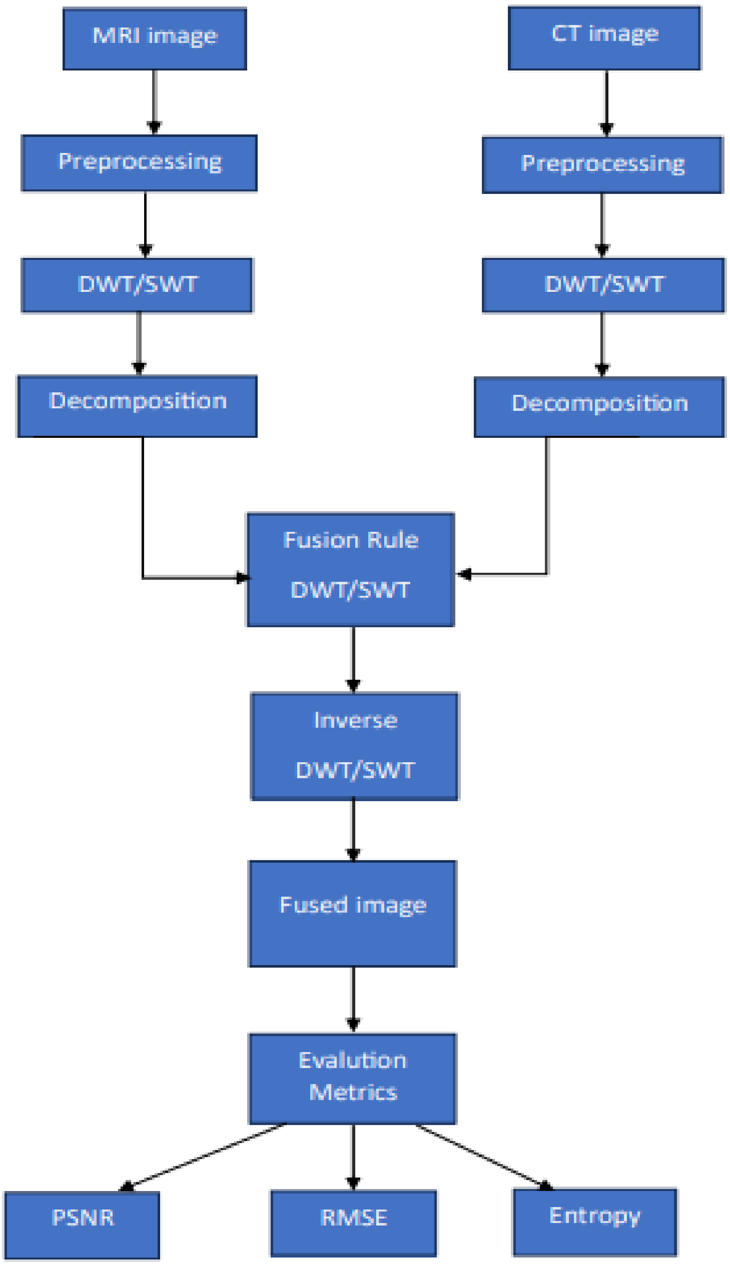

Fig1. Flow chart of DWT/SWT

4. Results and Discussion

A fusion technique was applied in this study, to four sets of CT and MRI images. Metrics like Peak Signal-to- Noise Ratio (PSNR), Root Mean Square Error (RMSE), and Entropy were used to assess the quality of the merged images. For Discrete Wavelet Transform (DWT) and Stationary Wavelet Transform (SWT), several wavelet families including Haar, db2, coif2, sym2, rbio2.2, and bior2.2 were investigated.

Figure 2 illustrate the fusion results of MRI and CT images using DWT and SWT, respectively.

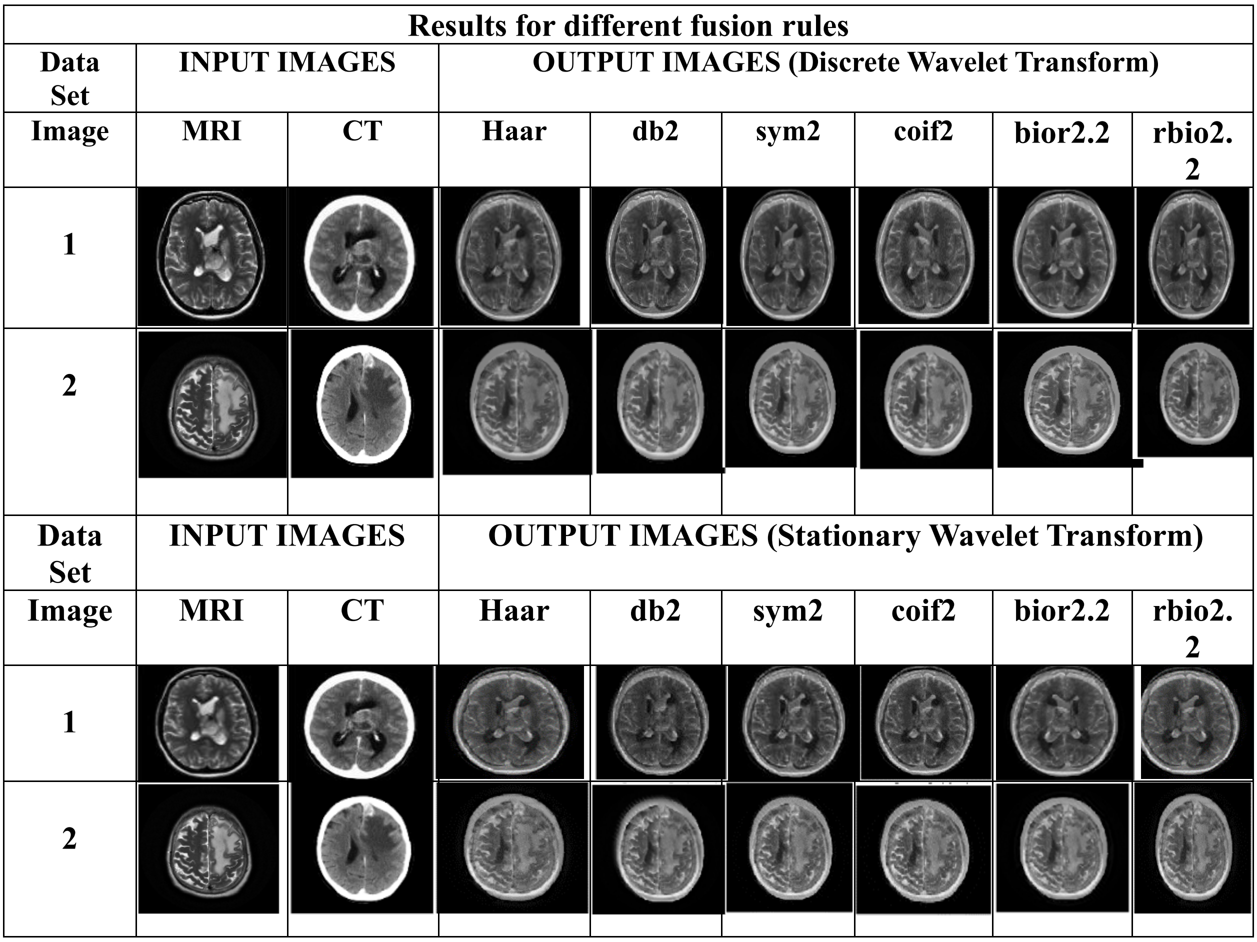

Figure 2. Fusion of MRI and CT Images

Table 1 shows of the several wavelet families performance using DWT. With the values of smallest RMSE (31.42 to 43.29), the Haar wavelet attained constantly the best PSNR values (15.37 to 18.19), this is mean better image quality and reduced distortion. Entropy values from 5.10 to 6.48; bior2.2 exhibited the highest entropy, therefore implying more information content in the fused images.

Table 2 shows the corresponding performance metrics for SWT. The bior2.2 wavelet family resulted the highest PSNR values (15.80 to 18.39) and the lowest RMSE values (30.71 to 41.34), while enhanced fusion performance. The highest entropy was with bior2.2 (up to 6.80), this confirming improved information preservation in the fusion process.

The results showed the quality of the fusion depends on the wavelet family selected. Where DWT-based fusion, the Haar wavelet always gave the highest PSNR values and lowest RMSE values, therefore suggesting improved preservation of image details and less disturbance. This may be explained by the basic structure of the Haar wavelet and its ability to detect sharp edges. bior2.2 wavelet of SWT based fusion, consistently outperformed others over every performance indicators.

It reached the highest PSNR and the lowest RMSE, which shows structural repair with little distortion. and, it produced the highest entropy levels, indicating better information retention and greater contrast in the merged images. These findings show that bior2.2 provides a wellbalanced fusion performance, hence it would be a good choice for medical image fusion projects needing accurate diagnostic as well as visual clarity.

Preservation of key characteristics and resolution increase in combined images enable clinicians to gain more accurate understanding of brain tumor borders and patterns. This help to early detection, treatment plan, and patient outcomes. In addition beneficial in medical imaging methods, these fusion methods help minimize distortion and noise, therefore lowering diagnostic errors.

(Discrete Wavelet Transform)						
Images	**Peak Signal to Noise Ratio**					
	Haar	**db2**	**sym2**	**coif2**	**bior2.2**	**rbio2.2**
1	**15.3704**	**14.4631**	**14.4631**	**13.9802**	**13.7962**	**15.3255**
2	**18.1856**	**17.824**	**17.824**	**17.6289**	**17.4917**	**18.0252**
3	**17.0152**	**16.4824**	**16.4824**	**16.4447**	**16.4029**	**16.7781**
4	**15.4035**	**15.0615**	**15.0615**	**15.121**	**15.1349**	**15.2687**
Images	**Root Mean Square Error**					
	Haar	**db2**	**sym2**	**coif2**	**bior2.2**	**rbio2.2**
1	**40.5564**	**45.0215**	**45.0215**	**47.5954**	**48.6145**	**40.7662**
2	**31.424**	**32.7598**	**32.7598**	**33.504**	**34.0374**	**32.0096**
3	**36.9517**	**38.2313**	**38.2313**	**38.3977**	**38.5827**	**35.9569**
4	**43.2876**	**45.0263**	**45.0263**	**44.719**	**44.647**	**43.9648**
Images	**Entropy**					
	Haar	**db2**	**sym2**	**coif2**	**bior2.2**	**rbio2.2**
1	**5.1027**	**5.2502**	**5.2502**	**5.3643**	**5.422**	**5.2574**
2	**5.4106**	**5.569**	**5.569**	**5.5912**	**5.6278**	**5.5218**
3	**6.3401**	**6.472**	**6.472**	**6.4775**	**6.4786**	**6.4032**
4	**5.8763**	**6.1492**	**6.1492**	**6.155**	**6.161**	**6.1533**

Table 1. Performance Measures of MRI and CT Images by DWT

(Stationary Wavelet Transform)						
Images	**Peak Signal to Noise Ratio**					
	Haar	**db2**	**sym2**	**coif2**	**bior2.2**	**rbio2.2**
1	**15.0853**	**13.8294**	**13.8294**	**14.42**	**16.2148**	**13.9341**
2	**17.7434**	**17.9357**	**17.9357**	**17.9685**	**18.3852**	**17.7364**
3	**16.6233**	**16.4637**	**16.4637**	**16.3462**	**17.2442**	**15.965**
4	**14.927**	**14.242**	**14.242**	**14.7626**	**15.8036**	**14.6433**
Images	**Root Mean Square Error**					
	Haar	**db2**	**sym2**	**coif2**	**bior2.2**	**rbio2.2**
1	**41.9096**	**48.429**	**48.429**	**45.2458**	**36.799**	**47.8487**
2	**33.0652**	**32.3411**	**32.3411**	**32.2191**	**30.7102**	**33.0917**
3	**37.6163**	**38.3138**	**38.3138**	**38.8355**	**35.021**	**40.5778**
4	**45.729**	**49.4814**	**49.4814**	**46.6026**	**41.3388**	**47.2473**
Images	**Entropy**					

	Haar	db2	sym2	coif2	bior2.2	rbio2.2
1	5.5094	5.5618	5.5618	5.7709	6.2306	5.6491
2	5.8039	5.7485	5.7485	5.7341	5.9649	5.6418
3	6.6644	6.6404	6.6404	6.6523	6.797	6.4745
4	6.424	6.5062	6.5062	6.4526	6.5348	6.1795

Table 2. Performance Measures of MRI and CT Images by SWT

5. Conclusion

This study contrasted and assessed the efficacy of Discrete Wavelet Transform (DWT) and Stationary Wavelet Transform (SWT), in the fusion of MRI and CT brain tumor images, quantitative evaluation of the fusion quality was done using performance criteria including PSNR, RMSE, and entropy. Wavelet family bior2.2 producing the best results in terms of detail preservation, information retention, and noise reduction, the results showed that SWT usually excels over DWT. These results demonstrate effectiveness of SWT based fusion techniques might improve medical imaging, which is important in correct diagnosis and successful treatment planning.

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