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Medical Image Fusion Using Hybrid Wavelet Transform

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Abstract:

CT and MRI images are fused based an hybrid dual filter algorithm, Discrete Wavelet Transform (DWT) is used to obtain two approximation, six detailed coefficients of CT and MRI medical images, Laplace filter is used to de-noise the wavelet coefficients, by comparing the approximation as well as detailed coefficients two weight maps obtained and that are serves as an input image, the corresponding approximation coefficients are considered as guided image for Guided Filter (GF), weight maps are smoothed by guided filter, which are known as refined. New approximation and detailed coefficients are obtained by weighted fusion algorithm, the Principle Component Analysis (PCA) technique is applied before obtaining CT and MRI images. To get fused image Inverse Discrete Wavelet Transform (IDWT) is used. Proposed hybrid DWT-PCA technique provides better results compared to the existing algorithm qualitatively and quantitatively.

Keywords: *Registration, Weighted Fusion, DWT, PCA, Laplacian Filter, Guided Filter, Hybrid.*

1. Introduction

Combining multiple images generated from different sensors to form a single image is known as image fusion, the fused image contains accurate, detailed and reliable information compared to the source image, fusion process can be performed at different level as shown in figure 1 such as Pixel level, feature level and Decision level, among these three levels of fusion the simplest and the most commonly used method is Pixel level fusion.

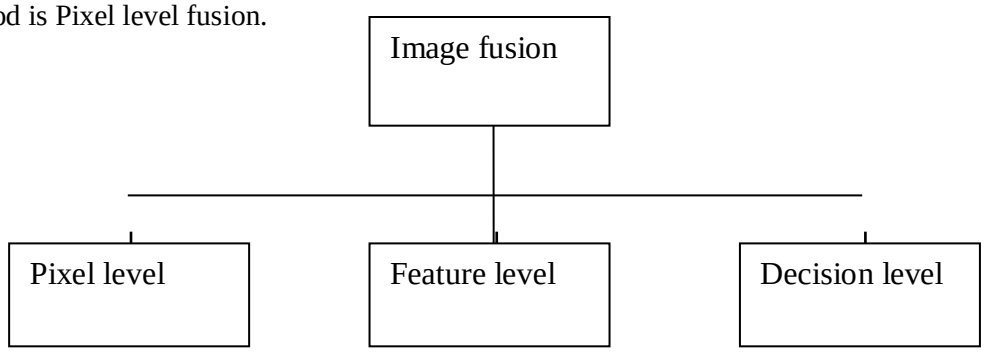

Figure-1: Various levels of image fusion

To fuse the images basically there are two methods used namely spatial domain image fusion and frequency domain image fusion, Discrete Wavelet Transform (DWT), Principal Component Analysis (PCA) and Stationary Wavelet Transform[8] (SWT) are most widely used image fusion techniques[9][10].

2. Related work

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Yan Na, et al [1] Medical images such as CT and MRI obtained by fusing them, by using GF algorithm, in order to determine position of the target volume, improves delineation efficiency of volume that helps in treatment process to avoid nearby health organs.

M.N. Narsaiah et al.,[2]fusion of CT and MRI images is performed with different wavelet transforms such as sym2, fk4, dmey, bior1.1, haar, db2, coif1 and rbio1.1 and concluded that the performances of proposed algorithm based the quantitative analysis in terms of standard deviation, edge strength and average gradient helps in selecting the suitable wavelet which provides better results.

Yagnik Trivedi1 [3] " Image Fusion Using Hybrid Wavelet Transform", the most commonly used method for image fusion is DWT, decomposition of images is little bit slower compared to the SWT, image data base is tested based on the proposed hybrid algorithm, performance of algorithm is measured in terms of performance evaluation metrics such as PSNR, MSE and Information Entropy and concluded Higher PSNR values and Information Entropy can be obtained using proposed algorithm.

Zhiming et al., [4] the main area of research in image processing is image fusion. That combines more than two images into a one image known as fused image, which will have detailed, and complimentary information of both the images.

Richa Gupta et al., [5] The pixel-level methodology works either in the spatial domain or frequency domain. Pixel level fusion works directly on the pixels acquired at imaging sensor outputs whereas feature level algorithms take care about extraction of features from the source images. The requirement for such feature level operation is that the images are acquired with the aid of homogeneous sensors, specified images reproduce comparable physically features of the image. Based on the properties of Feature level algorithms typically segment the images into contiguous regions and fuse the regions based on their characteristics.

Image fusion techniques: Multiple wavelets are used to fuse the medical images like Discrete Wavelet Transform (DWT), Principle Component Analysis (PCA) etc. ,

Discrete Wavelet Transform (DWT)

After input images registration, input images are applied to the DWT that decomposes the images into two sub bands such as Low sub bands and high sub bands. Different algorithms are used to fuse these low and high sub bands. At the end by applying inverse DWT on coefficients of input images fused image is obtained. The schematic of DWT is given by the following figure 2.

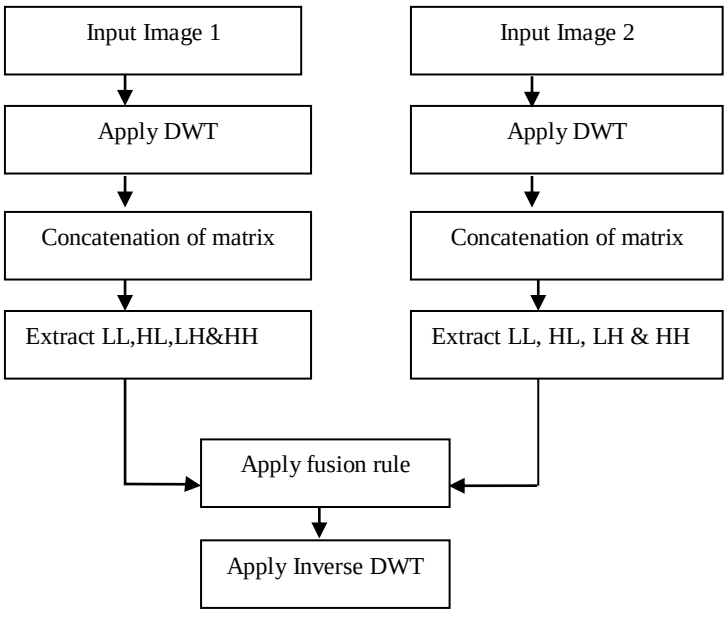

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Figure-2: DWT algorithm

Principle Component Analysis (PCA)

PCA [7] is one among the transformation methods which considers only statistical information, that converts the multimodality source images correlated data variable to fused images uncorrelated data variables, during this method images are fused by using the weighted averaging which is defined as

$$f = (P1 \times A) + (P2 \times B) \quad (1)$$

Here P1and P2 is the weights corresponding to the Eigen vectors with greatest Eigen values from PCA. Schematic of PCA is given by figure 3.

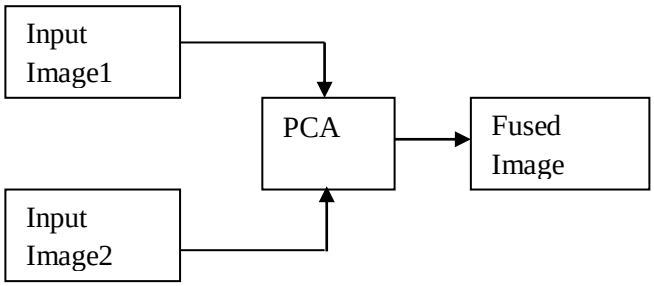

Figure-3: PCA algorithm

3. Proposed wok

To fuse medical images like CT and MRI dual filter algorithm [6] is used, proposed a hybrid wavelet DWT-PCA transform, the schematic of proposed algorithm given in figure 4.

Proposed algorithm:

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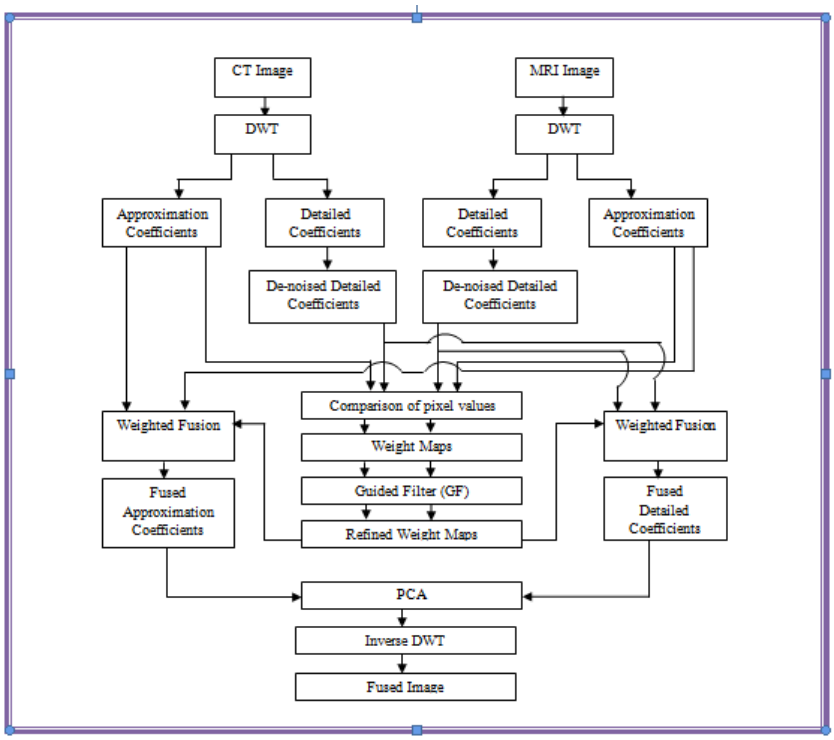

Figure-4: Schematic DWT-PCA proposed algorithm

Experimental Results

After the image registration, Discrete Wavelet Transform is applied to every source image, which Decomposes CT image into approximate coefficient A1 and three wavelet coefficients H1, V1, D1 similarly MRI image is Decomposed into approximate coefficient A2 and three wavelet coefficients H2, V2, D2. Laplacian filter is employed to de-noise the wavelet coefficients.

By comparing pixel values of approximation coefficients and wavelet coefficients weight maps W_1 and W_2 are obtained which are given by

$$W_1 = \begin{cases} 1, & \text{if } A1 > A2,\ H1 > H2,\ V1 > V2 \text{ and} D1 > D2 \\ 0, & \text{Otherwise} \end{cases}$$

$$W_2 = \begin{cases} 1, & \text{If } A2 > A1,\ H2 > H1,\ V2 > V1 \text{ and} D2 > D1 \\ 0, & \text{Otherwise} \end{cases}$$

In other way the weight maps W_1 and W_2 are selected from the maximum values of $A1,\ H1,\ V1$ and $D1$, similarly from $A2,\ H2,\ V2$ and $D2$ respectively.

$$W_1 = Max\ (A1,\ H1,\ V1, D1) \qquad (2)$$

$$W_2 = Max\ (A2,\ H2,\ V2, D2) \qquad (3)$$

Guided filter is used to smooth the weight maps W_1 and W_2 that are serves as input image, corresponding approximate coefficients (A_1,A_2). Weight maps are refined by the guided filter and generate new weight maps. Weight maps generated are called refined weight maps that are given by

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$$M1 = G_{r,\varepsilon}(W_1 A1) \quad (4)$$

$$M2 = G_{r,\varepsilon}(W_2 A2) \quad (5)$$

Parameters ε and r determine blur degree and filter size of the Guided Filter (GF) respectively. Fused approximation coefficients and detailed coefficients are obtained by applying weighted fusion algorithm. To determine fused approximation coefficient A, two approximation coefficients A1 and A2 are used. To compute three fused wavelet coefficients H, V and D, six wavelet coefficients are used H1, V1, D1, H2, V2 and D2.

$$\left.\begin{aligned} A &= A1 \times M1 + A2 \times M2 \\ H &= H1 \times M1 + H2 \times M2 \\ V &= V1 \times M1 + V2 \times M2 \\ D &= D1 \times M1 + D2 \times M2 \end{aligned}\right\} \quad (6)$$

Principle Component are selected from resultant approximation and detailed coefficient that are fused based on weighted averaging process. Finally, by the application of IDWT fused image is obtained.

4. Results and discussions

Quality Measure

The performance of proposed algorithm is measured by using the performance evaluation metrics like Average Gradient, Standard Deviation and Edge Strength, this section describes briefly about the evaluation parameters.

Standard Deviation (SD): The square root of variance is known as the Standard Deviation which is denoted by either SD or σ, standard deviation is used to measure the spread in data, higher the value of variance means high contrast of the image similarly lower the value of variance means low contrast of the image, the mathematical expression for the standard deviation is given below

$$\sigma = \sqrt{\frac{\sum_{i=0}^{A}\sum_{j=0}^{B}(If(i,j)-\mu)^2}{AB}} \quad (7)$$

Where A and B are the number of rows and columns, μis varianceIf is fused image or output image.

Average Gradient (AG): It computes spatial resolution of fused image. The larger value of AG denotes fused image is of higher spatial resolution

$$G = \frac{1}{n}\sum\sqrt{\left(\Delta I_x^2 + \Delta I_y^2\right)/2} \quad (8)$$

Edge Strength (ES): It determines the normalized weighted performance of fused image with respect to the input image. Higher value of ES indicates better edge information.ES is sobel edge operator

$$G = \sqrt{(G^2{}_X + G^2{}_Y)} \quad (9)$$

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Results are compared with existing Haar wavelet transform with proposed hybrid transform DWT-PCA in terms of performance evaluation metrics such as Standard Deviation(SD), Average Gradient(AG) and Edge Strength(ES), it is very clear from the comparison that the proposed algorithm provided better results.

Table 1. Comparative analysis of existing (Haar) and proposed (DWT-PCA) algorithm

Evaluation Parameters/Wavelet	SD	AG	ES
Haar (Existing)	0.205963	0.259743	0.053901
DWT-PCA(Proposed)	0.2878	0.271	0.0558

The Performance of different evaluation metrics graphically shown for the existing and proposed algorithms

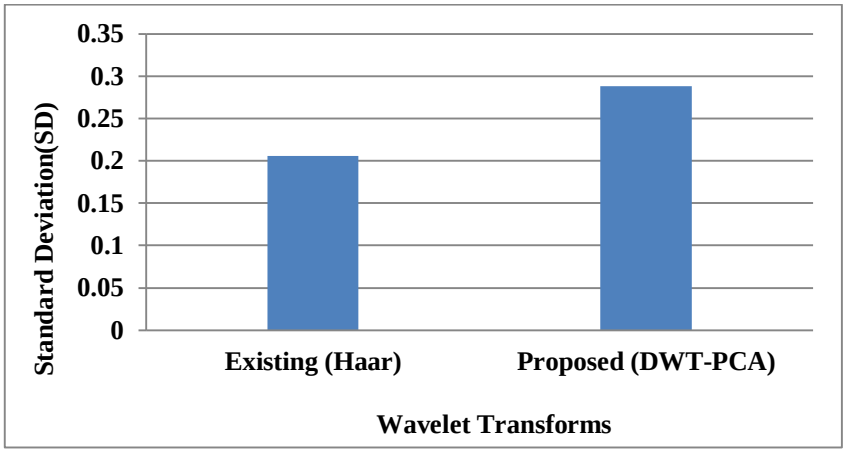

Figure-5: Comparison of Standard Deviation (SD)

From the above figure 5, it can be noted that evaluation metric Standard Deviation is high for the DWT-PCA algorithm compared to the Haar algorithm.

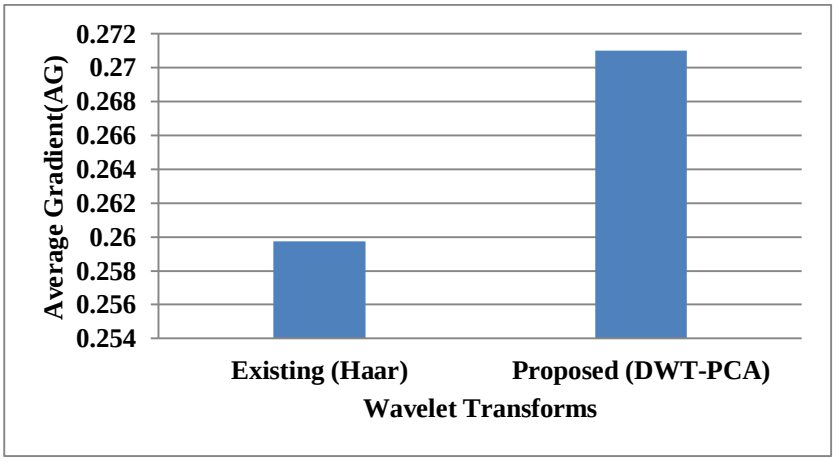

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Figure-6: Comparison of Average Gradient (AG)

From the above figure 6, it can be noted that the evaluation metric Average Gradient is more for proposed algorithm DWT-PCA compared to the Haar algorithm.

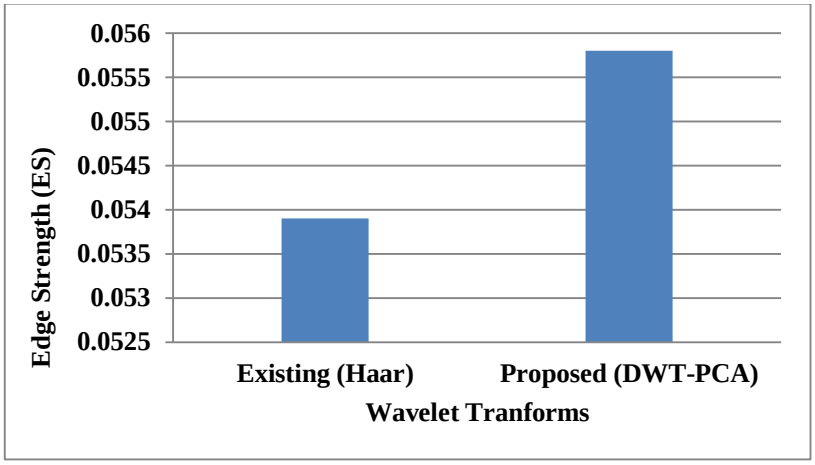
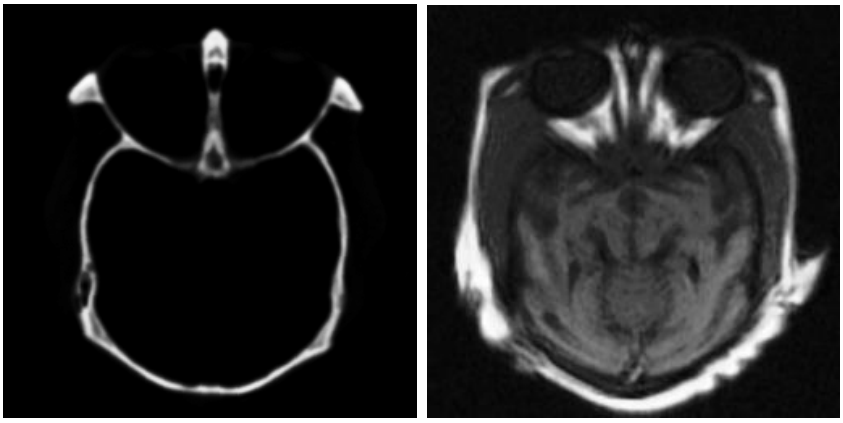


Figure-7: Comparison of Edge Strength (ES)

From figure 7, it is clear that Edge Strength metric is more for the algorithm DWT-PCA compared to the Haar algorithm.

The source medical images CT and MRI and fused images for the existing and proposed algorithms



(a) CT Image **(b) MRI Image**

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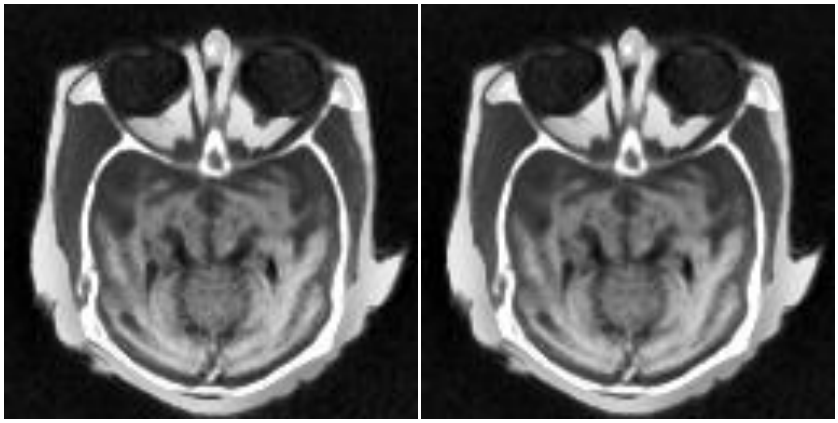

(c) Haar (Existing) **(d) DWT-PCA (Proposed)**

Figure-8: (a) & (b) CT & MRI images, (c) & (d) fused images of Existing and proposed algorithms

From figure8 it can be noted that fused image of DWT-PCA algorithm is much clear than fused image of Haar Wavelet transform.

Conclusion

In this proposed algorithm Discrete Wavelet Transform (DWT) is used to determine the approximation and detailed coefficients of medical images. The weight maps computed with pixel by pixel comparison of two approximation and six detailed coefficients. Guided Filter is used to refined weight maps. With this refined weight maps result an approximation and wavelet coefficients are obtained by weighted fusion algorithm, Principle Component Analysis (PCA) technique is applied before obtaining CT and MRI images by employing of Inverse Discrete Wavelet Transform (IDWT), subjective and objective performance analysis of the proposed hybrid DWT-PCA algorithm is compared with existing algorithm with the help of performance evaluation metrics like SD, AG and ES, proved that proposed algorithm provided better results.

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