Indian Journal of Image Processing and Recognition (IJIPR)
ISSN: 2582-8037(Online), Volume-1 Issue-1, December 2020

Boundary Based Analysis of Image Fusion using Discrete Wavelet Transform

Moniha Rangaraju, Dharani Krishnan, Balaji E,UmeshK

Abstract: Image fusion is the process of conflating or combing two or more images into a single image in order to implicate the necessary information from the source images. There is plenty of technological advancement present in today's medical imaging field. The main drawback is that each and every imaging modality has its own specialty and limitation. Thus, fusion is used to overcome the shortcoming of displaying vital information in multiple images. Fusion of CT and MRI images aids in extracting useful tidings present in both the hard and soft tissues of the human body. Image fusion of the two input images can be done using various methods such as max, min, mean, Left-Right (LR), Right-Left (RL), Up-Down (UD), Down-Up (DU). The majorly used fusion techniques in this paper include LR, RL, UD and DU fusion.

Index Terms: Image fusion, CT, MRI,DWT, dmey and coif, LR, RL, UD, DU Fusion.

I. INTRODUCTION

Myna A.N and J Prakash have previously worked with the fusion technique of CT and MRI using fuzzy logic and Discrete Wavelet Transform. They conducted experiments of fuzzy logic using various numbers of membership functions for Mamdhani and sugeno FLS. The results obtained from sugeno FLS function to be better than Mamdhani's[1].

B.Rajalingam and Dr.R.Priya attempted a fusion using Curvelet Transform – Pulse Coupled Neural Network (CT-PCNN) technique. They used an MRI and PET image in fusion process and found it to have higher performance and quality than images obtained by traditional methods.[3]

S Rajkumar, Puja Barrdhen, Satya Kumar Akkireddy and ChiragMunshi proposed various different methods namely Iterative Neuro Fuzzy Approach (INFA), Lifting Wavelet Transform with Neuro Fuzzy Approach (LWT-NFA), DWT and Averaging. They concluded that INFA procedure gives an improvement in subjective measure quality and at the same time objective measure quality also when compared with Wavelet Transform techniques. [5]

Manuscript received on 25 November 2020 | Revised Manuscript received on 05 December 2020 | Manuscript Accepted on 15 December 2020 | Manuscript published on 30 December 2020.

* Correspondence Author

Moniha Rangaraju, JSS Academy of Technical Education,Bangalore (Karnataka), India.

Dharani Krishnan, JSS Academy of Technical Education,Bangalore (Karnataka), India.

Balaji E, JSS Academy of Technical Education,Bangalore (Karnataka), India.

Umesh K, JSS Academy of Technical Education,Bangalore (Karnataka), India.

AgarwalRuchi Sanjay, RajkumarSoundarpandian, MarimuthuKaruppiah and RajasekaranGanapathy. They followed three steps including decomposition, fusion and reconstruction by process of DWT-Type2 Fuzzy. Comparison and analysis of the image was done by paramters like image quality index, mean absolute error, peak SNR, normalized cross correlation and found that the important attributes Which are essential for clinical diagnosis, are highly prominent.[6]

II. PROPOSED METHODOLOGY

In this proposed methodology, two input image obtained various imaging modalities namely CT and MRI are used. Discrete Wavelet Transformation is used to decompose both the image components separately. The required level of contrast adjustments is made to the decomposed image. Later the image is fused using either of the four image fusion methods namely Up-Down, Down-Up, Right-Left and Left-Right fusion. Finally, the fused image is reconstructed with Inverse Discrete Wavelet Transformation to obtain the desired fused output image of both the input CT and MRI components.

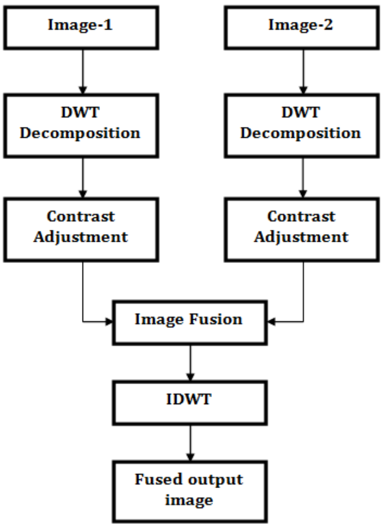

Fig.1 Block diagram of proposed methodology

III. DISCRETE WAVEFORM TRANSFORM

Wavelets are a mathematical function which is found to be useful in both signal processing and image processing. It allows both spatial and temporal analysis of images simultaneously. It is due to the property or fact that the energy of wavelet is concentrated in time and still acquires the wave like (periodic) characteristic nature. They are often used to de-noise images through decomposition and reconstruction stages of varying levels[2].

The most basic prototype wavelet present is called as the mother wavelet. Degradationis very essential. Here the main wavelets used are coif and dmey wavelets explained below. Discrete Wavelet Transform is a transform that is basically used to convert a discrete time image to a discrete wavelet representation. For DWT the mother wavelet is scaled by a power value of two after shifting process.

$$\psi_{j,k}(t) = \frac{1}{\sqrt{2^j}}\psi\left(\frac{t-k2^j}{2^j}\right)$$

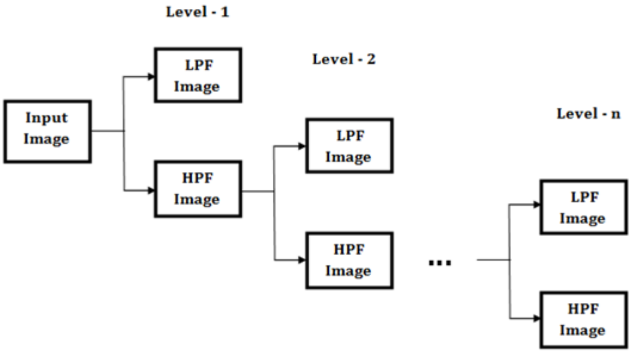

Fig 2.Process of DWT decomposition

IV. IDWT RECONSTRUCTION WAVEFORM

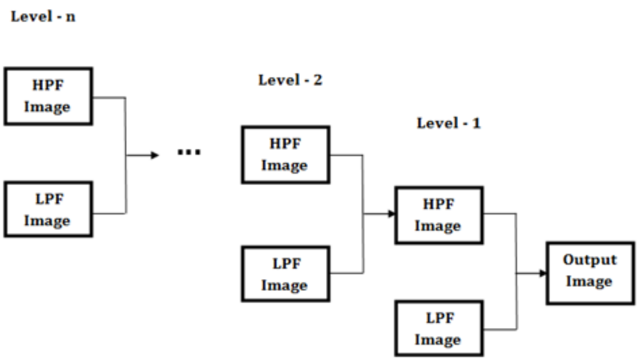

Fig 3 Process of IDWT reconstruction

The discrete wavelet transform itself can be used to identify the inverse discrete wavelet transform (IDWT). When the orthogonal basis was the form of the wavelet in use then the hermitian transpose of DWT will be the result for IDWT. The operators needed for the DWT and IDWT are exactly the same. Also the computation is much more convenient since the filter length is not different from that of DWT. When the basis is biorthogonal then only a few sample will be get additionally added with its existing filter length. In the condition with different filter length it is customary to add zeros for the coefficient to obtain the solution [18]. The IDWT is the inverse function of DWT where the low pass and high pass filter coefficients are fused together and upsampled at each stage of image reconstruction.

Coiflet wavelet:

The Coiflet wavelet function has 2N moments equal to 0 and the scaling function has 2N-1 moments equal to 0, where N is the order of the wavelet[5,7] The two functions have a support of length 6N-1 whereas the filter length is 6N. The properties of this wavelet include orthogonal, biorthogonal and compact support. Coiflet scaling functions also exhibits vanishing moments. In coifN, N is the number of vanishing moments for both the wavelet and scaling functions.

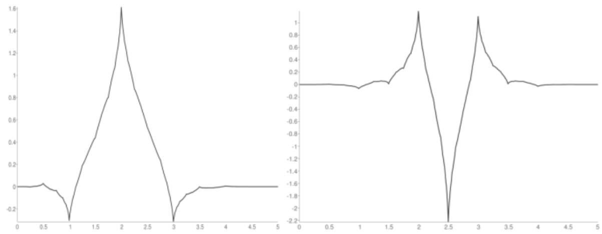

Fig 4 (a) scaling function (b) wavelet function

Vanishing Wavelet Moments:

One of the most important properties of wavelet is that first N moments of the analysis wavelet ~Ψ vanish; i.e.

$M_{\sim\Psi}(0, N] = 0$, for N = 0, 1, 2, 3,…, N-1

The consequences of this property are that

- All polynomials of degree up to (N-1) can be expressed as a linear combination.
- A sufficiently smooth function *f* can be approximated with error by a linear combination.

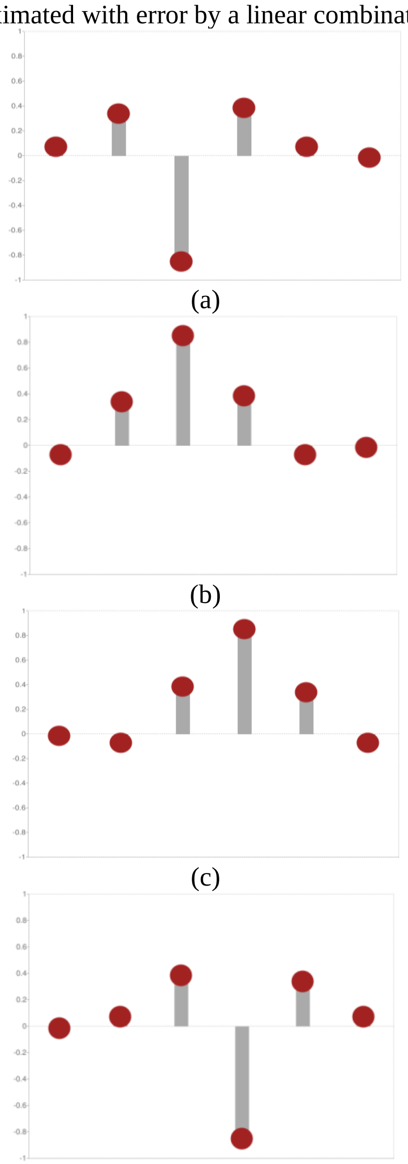

Fig5 (a)decomposition low-pass filter (b) Reconstruction low-passfilter(c) Decomposition high-pass filter (d) Reconstruction high-pass filter

Discrete Meyer Wavelet:

Dmey wavelet is the discrete format of Meyer wavelet function. Meyer's wavelet as shown in equation is fundamentally a solvent method for solving the two-scale equation.

$$G_0(ejw) = \sqrt{2}\ \varepsilon k \emptyset(2\omega + 4k\pi)$$

The discrete Meyer wavelet is infinitely differentiable and can decrease to zero faster than any inverse polynomial.[7] Moreover, it does not produce aliasing errors or distortion. The wavelet and scaling functions are available in the frequency domain. It has orthogonal (scaling sequence should be orthogonal irrespective of the shifts of it by an even number of coefficients) and biorthogonal (wavelet transform is invertible but not compulsorily orthogonal in nature) in properties. It does not have compact support. The support width is infinity but the effective support is from [-8,8]. It is symmetrical and can be applied to both Continuous Wavelet Transform (CWT) and Discrete Wavelet Transform (DWT).

V. RESULTS

UD Fusion:

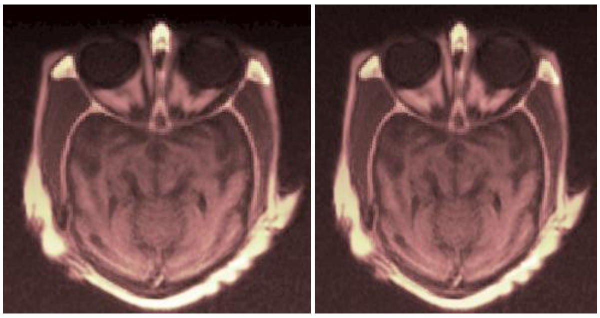

Fig 6(a) Coifletwaveletfused image of CT and MRI using UD technique (b)Dmey fused image of CT and MRI using UD technique.

In this UD Fusion process, the CT component in the fused image can be better viewed or visualized in the upper region than the lower region. Similarly, the MRI component of the fused image is more clearly seen in the lower or "down" region. On comparing both the fused image obtained from coif and dmey wavelet, the upper region of the coif waveform fused image has more predominant dark region due to distortion than that of the dmey waveform fused image. Usage of UD fusion technique makes the information present in the bottom regions of the image more prominent than that present in the top of the image.[9,10]

The approximation coefficient (A.C) and detail coefficient (D.C) used for UD fusion is 0.8 for both. This value was selected by trial and error method for which we get a prominent output. When both A.C and D.C parameters are 0, the fused image obtained is only an MRI. If A.C and D.C aregiven a value equal to or greater than 2.5, there occurs degradation in the MRI component of the fused image.

Table-1 statistical features of Coiflet and Dmey wavelet function using UD Fusion

UD-FUSION	COIF	DMEY
MEAN-1	81.05	83.06
MEAN-2	43.35	41.85
MEDIAN	69	68
RANGE	255	245
SD	56.41	52.97
L1 NORM	1.59E+07	1.63E+07
L2 NORM	4.38E+04	4.37E+04

RL Fusion:

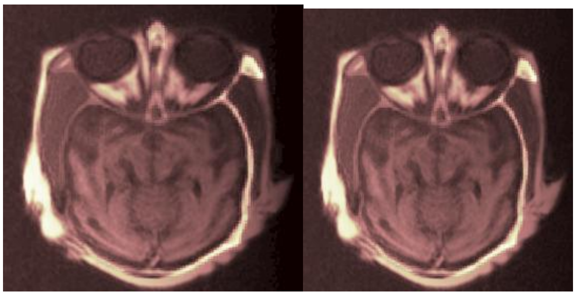

Fig 7 (a) Coiflet wavelet RL fusion (b) Dmey wavelet RL fusion.

For this RL fusion technique, the CT component is clearly viewed in the right hand side of the fused image while the MRI component is highly visualized in the left hand side of the image. In this RL fusion method, the image information present in the left region is higher in clarity when compared the right side of the image. Furthermore, in the fusion image obtained by coif waveform has dark region predominant in the right side of the image and compared against the image output obtained using the dmey waveform.

The approximation coefficient (A.C) and detail coefficient (D.C) used for RL fusion is 1.2 for both.[12,13] This value was selected by trial and error method for which we get a prominent output. When both A.C and D.C parameters are 0, the fused image obtained is only the CT component. If A.C and D.C are given a value equal to or greater than 2, there occurs degradation in the CT component of the fused image.

Table -2 statistical features of Coiflet and Dmey wavelet function using RL Fusion

RL-FUSION	COIF	DMEY
MEAN-1	77.2	81.13
MEAN-2	43.35	44.2
MEDIAN	68	70
RANGE	255	248
SD	52.37	50.1
L1 NORM	1.51E+07	1.60E+07
L2 NORM	4.13E+04	4.23E+04

DU FUSION:

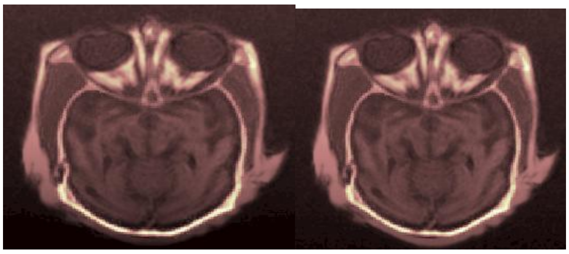

Fig 8 (a) Coiflet wavelet DU fusion (b) Dmey wavelet DU fusion.

In this DU Fusion process, the CT component in the fused image can be better viewed or visualized in the lower region than the upper region. Similarly, the MRI component of the fused image is more clearly seen in the upper region. On comparing both the fused image obtained from coif and dmey wavelet, the bottom region of the coif waveform fused image has more predominant dark region due to distortion than that of the dmey waveform fused image. Usage of DU fusion technique makes the information present in the higher regions of the image more prominent than that present in the lower of the image.[15,16]

The approximation coefficient (A.C) and detail coefficient (D.C) used for UD fusion is 0.8 for both. This value was selected by trial and error method for which we get a prominent output. When both A.C and D.C parameters are 0, the fused image obtained is only the CT image while MRI component vanishes. If A.C and D.C are given a value equal to or greater than 1.5, there occurs degradation in the CT component of the fused image.

Table-3 statistical features of Coiflet and Dmey wavelet function using DU Fusion

DU-FUSION	COIF	DMEY
MEAN-1	67.01	70.53
MEAN-2	53.55	58.65
MEDIAN	59	61
RANGE	255	255
SD	44.8	43.85
L1 NORM	1.32E+07	1.39E+07
L2 NORM	3.57E+04	3.68E+04

LR Fusion:

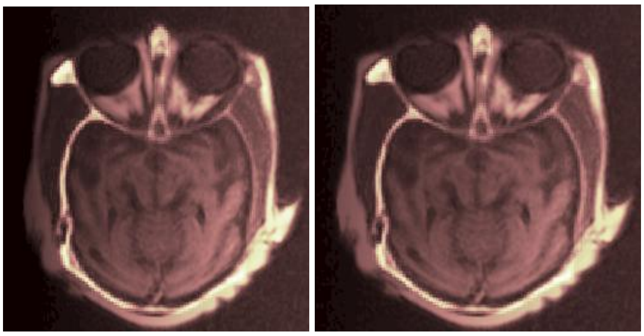

Fig 9(a) Coiflet wavelet LR fusion (b) Dmey wavelet LR fusion.

For this LR fusion technique, the CT component is clearly viewed in the left hand side of the fused image while the MRI component is highly visualized in the right hand side of the image. In this LR fusion method, the image information present in the right region is higher in clarity when compared the left side of the image. Furthermore, in the fusion image obtained by coif waveform has dark region predominant in the left side of the image when judged against the image output obtained using the dmeywavelet.

The approximation coefficient (A.C) and detail coefficient (D.C) used for UD fusion is 1.2 for both. This value was selected by trial and error method for which we get a prominent output. When both A.C and D.C parameters are 0, the fused image obtained is only an MRI and the CT component disappears. If A.C and D.C are given a value equal to or greater than 2.5, there occurs degradation in the MRI component of the fused image.

Table -4 statistical features of Coiflet and Dmey wavelet function using LR Fusion

LR-FUSION	COIF	DMEY
MEAN-1	71.2	72.96
MEAN-2	43.35	38.25
MEDIAN	61	63
RANGE	255	255
SD	51.9	49.22
L1 NORM	1.40E+07	1.44E+07
L2 NORM	3.90E+04	3.90E+03

INFERENCE:

Table -5 Comparison of four fusion type of coiflet wavelet

FUSION TYPE		FUSED OUTPUT IMAGE	
APPROXIMATION COEFFICIENT	DETAIL COEFFICIENT	CT COMPONENT	MRI COMPONENT
LR	RL	PIXELATED	PRESENT
LR	UD	ABSENT	PRESENT
LR	DU	PIXELATED	PRESENT
RL	LR	PRESENT	ABSENT
RL	UD	PRESENT	ABSENT
RL	DU	PRESENT	ABSENT
UD	RL	PIXELATED	PRESENT
UD	LR	ABSENT	PRESENT
UD	DU	PIXELATED	PRESENT
DU	RL	PRESENT	ABSENT
DU	UD	PRESENT	ABSENT
DU	LR	PRESENT	ABSENT

Based upon the statistical values collected and compared between the fused images obtained from both coiflet and dmey wavelets, it is determined that dmey has better output quality. The dmeywavelet based output fused image has lesser dark region caused due to distortion and also higher clarity and resolution when compared with the coiflet counterpart output fused image. Furthermore, the ideal value for fusion using Up-Down, Down-Up, Left-Right and Right-Left fusion were determined. The other combination of different fusion methods for the two different parameters were simulated and observed. It is inferred upon the observation made that the usage of different fusion techniques for D.C and A.C will lead to obtaining either one of the two input images or one component with the other component being highly pixelated. Thus for both the coefficient parameter only the same fusion process has to be given to obtain proper fused image as the output.

Table -5 Comparison of four fusion type of Dmey wavelet

FUSION TYPE		FUSED OUTPUT IMAGE	
APPROXIMATION COEFFICIENT	DETAIL COEFFICIENT	CT COMPONENT	MRI COMPONENT
LR	RL	PRESENT	ABSENT
LR	UD	PRESENT	ABSENT
LR	DU	PRESENT	ABSENT
RL	LR	PIXELATED	PRESENT
RL	UD	ABSENT	PRESENT
RL	DU	PIXELATED	PRESENT
UD	RL	PRESENT	ABSENT
UD	LR	PRESENT	ABSENT
UD	DU	PRESENT	ABSENT
DU	RL	PIXELATED	PRESENT
DU	UD	ABSENT	PRESENT
DU	LR	PIXELATED	PRESENT

VI. CONCLUSION

Image fusion is an important image processing technique required in overcoming the shortcoming of images obtained by multiple medical imaging modalities. In the paper, the proposed method has successfully been used to obtain the fused image having CT and MRI image components. Future works include fusion of multiple input images such as CT, MRI, Ultrasound, PET etc. using the various image fusion methods of LR, RL, UD, DU to obtain a better fused image to enhance the viewing of the region of interest.

REFERENCES

1. Myna A N, Prakash J, “Fusion of CT and MRI Images Based on Fuzzy Logic and Discrete Wavelet Transform “International Journal of Computer Science and Information Technologies,2015, pp. 4512-4519.
2. Santhi .N, Joy jinsu, Ramkuer K, Sathya bama, “Spatial frequency discrete wavelet transform image fusion technique for remote sensing applications” 2019.
3. Rajalingam B, Priya R, “Multimodal Medical Image Fusion Using Various Hybrid Fusion Techniques for clinical Treatment Analysis”research gate, 2018.
4. Kavitha C.T, Chellamuthu. C,” Medical Image fusion based on hybrid intelligence” Elsevier-Applied Soft Computing-2104.
5. Rajkumar Soundrapandiyan, ” CT and MRI Image Fusion based on Wavelet Transform and Neuro-Fuzzy concepts with quantitative analysis”research gate publication,2014.
6. Agarwal Ruchi Sanjay, Rajkumar Soundrapandiyan, Marimuthu Karuppiah” CT and MRI Image Fusion Based on Discrete Wavelet Transform and Type-2 Fuzzy Logic” International Journal of Intelligent Engineering and Systems, 2017.
7. Vijayarajan. R, Muttan. S, "Discrete wavelet transform based principal component averaging fusion for medical images", AEU-Int. J. Electron. Commun-2015, pp. 896-902.
8. Bhateja V, Patel H, Krishn A, Sahu A, "Multimodal medical image sensor fusion framework using cascade of wavelet and contourlet transform domain ns"*IEEESensors* -2015 vol. 15, pp. 6783-6790.
9. Luping.XGuorong. G, Dongzhu. F, “Multi-focus image fusion based on non-subsampled shearlet transform”, IET Image Process- 2013,pp. 633–639.
10. Wei Q, Bioucas-dias J, Dobigeon. N,” Hyperspectral andMultispectral Image Fusion Based on a Sparse Representation”, IEEETrans.Geosci. Remote Sens- 2015, 3658–3668.
11. MitianoudisN,StathakiT, ”Pixel - based and region-basedimagefusionschemesusingICAbases, Inf. Fusion”2007, pp.131–142.
12. Xu,X, Wang Y,Chen S, "Medical image fusion using discrete fractional wavelet transform", Biomed. Signal Process. Control- 2016.vol. 27, pp. 103-111.
13. Liu. Y, Liu. S, Wang Z, “A general framework for image fusion based on multi-scale transform and sparse representation” - 2015, pp. 147-164.
14. Daniel. E, Anitha. A, Gnanaraj. J, "Optimum Laplacian wavelet mask based medical image using hybrid cuckoo search—Grey wolf optimization algorithm” -2017, pp. 58-69.
15. Wang. W, Jiao. L, “Yang S.Fusion of multispectral and panchromatic images via sparse representation and local autoregressive model” -2014, pp. 73-87.
16. Selesnick I.W., Kingsbury N.C, BaraniukR.G.”The dual-tree complex wavelet transform” IEEE Signal Process -2005.
17. Pushkar. S, Roger. L, King, Nicolos. H, Younan, Derrold W. Holcomb, "Estimation of the Number of Decomposition levels for a Wavelet-Based Multiresolution multisensor Image fusion", *IEEE Transactions on Geoscience and Remote Sensing*- 2006, pp. 3674-3686.
18. MetinAkay, “Time Frequency and wavelets in Biomedical signal processing”, IEEE Press, 1998, pp.230-231.