

## Fusion of Medical Images in Wavelet Domain: A Hybrid Implementation

Satya Prakash Yadav<sup>1,\*</sup> and Sachin Yadav<sup>2</sup>

**Abstract:** This paper presents a low intricate, profoundly energy effective MRI Images combination intended for remote visual sensor frameworks which leads to improved understanding and implementation of treatment; especially for radiology. This is done by combining the original picture which leads to a significant reduction in the computation time and frequency. The proposed technique conquers the calculation and energy impediment of low power tools and is examined as far as picture quality and energy is concerned. Reenactments are performed utilizing MATLAB 2018a, to quantify the resultant vitality investment funds and the reproduction results show that the proposed calculation is very quick and devours just around 1% of vitality decomposition by the hybrid combination plans. Likewise, the effortlessness of our proposed strategy makes it increasingly suitable for continuous applications.

**Keywords:** Medical image fusion, wavelet transform, DWT, DCT, ICA, fusion techniques, multimodal fusion.

### 1 Introduction

Because of headway in imaging advances, there have been numerous improvements during the ongoing years in the picture preparation and information combination strategies for better information acquisitions [Pavithra and Bhargavi (2013)]. In picture combination, different pictures or their recognized highlights or spatial ascribes are purposeful united to deliver an individual melded picture with the utilization of single or numerous modalities to acquire improved and attractive outcomes. It is a generally new strategy that has its foot set in different fragments, for example, picture upgrades, reconnaissance; apply autonomy, crime scene investigation, therapeutic analysis, restorative imaging, and remote detecting. This system has a demonstrated clinical application in medicinal imaging strategies (MRI, PET, CT, and so forth.) for order and pre-analysis of maladies.

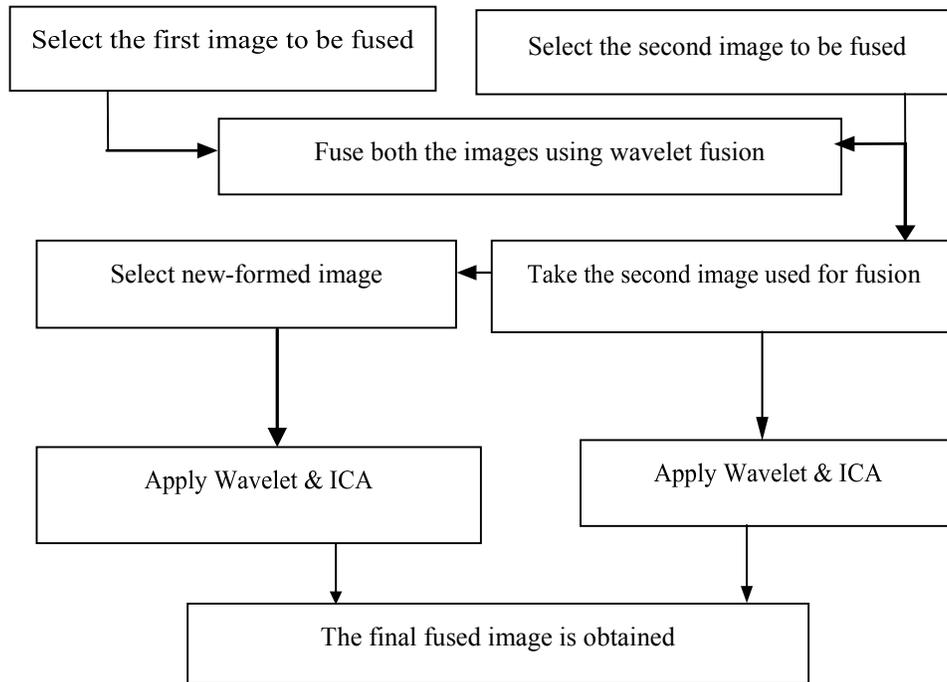
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<sup>1</sup> Department of Information Technology, ABES Institute of Technology (ABESIT), Ghaziabad, India.

<sup>2</sup> Department of Computer Science and Engineering, G. L. Bajaj Institute of Technology and Management (GLBITM), Greater Noida, India.

\* Corresponding Author: Satya Prakash Yadav. Email: satya.yadav@abesit.in.

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**Figure 1:** Fusion process using wavelet domain

With mechanical progression and specialized focal points, different inductive and dependable imaging modalities are being accessible for medicinal and clinical research and studies. Therapeutic imaging advancements, MRI, PET, or CT outputs are a couple of instances of such modalities under-use in restorative investigations. Moreover, with quick developments of the processing and imaging innovations, the demonstrative advances in the field of restorative science have increased much trust lately. In addition to this, these advances have helped in making illness determination a lot simpler and easy to understand. For the most part, picture combination is mixed from a few comparable individual info pictures to fit in one complete intertwined picture. In this manner, picture combination is incorporated and consolidated and is taken out from a set of enlisted pictures to make it lucid and free from bending [Yadav and Yadav (2018)]. This is fundamentally planned for getting a melded picture which is data and highlight rich, incorporated, mutilation free, from a progression of various pictures. In this way, the picture that is created as yield ought to contain data precision and distinction for the machines and human observations or to be utilized for cutting edge investigation and preparing [Sharma (1999)].

**Table 1:** lists various applications, advantages, and disadvantages of image fusion

Method	Domain	Advantage	Disadvantage
Hybrid Wavelets	Spatial-at tribute	A simplest amongst all methods.	This technique does not assure to obtain clearer objects from the images set.
Simple	Spatial	An image fusion method with the most straightforward approach.	Pixel levels procedure does not promise to output distinguished products through the input graphic pair.
PCA	Spatial	PCA is usually a tool that alters the amount of co-related variables directly into various unrelated parameters.  Application: graphic fusion.	Presence of spectral deterioration due to spatial domain.

**2 Literature survey**

A few research works have been started and done over the most recent 2 decades in the zone of restorative picture combination. Diverse logical diaries have been distributed in such a manner. We have surveyed a couple concerning their critical commitments.

Swathi et al. [Swathi and Bindu (2013)] anticipated a combination procedure for depicting different perspectives on a scene through the Daubechies wavelet transform to discover the picture’s coordinating coefficients. This combination practice is started with the assessment of coefficient esteems through edge standard deviation. The portrayal of the nearby varieties is utilized inside the square for standard deviation.

Srikanth et al. [Srikanth and Sujatha (2013)] referenced a strategy to accomplish intertwined wavelet coefficients in a yield picture in the wake of utilizing the wavelet

transforms on info pictures. Better data can be acquired utilizing the advancement of the info picture satisfied by the intertwined pictures, for example, those from MRI and CT, for the specialist and the therapeutic activity readiness framework. Multi-methodology wavelet transform is the procedure used to intertwine medicinal pictures. This exploration is particularly centered around the benefits of the wavelet transforms and their calculations on the CT and MRI medicinal pictures. The combination can be introduced to foresee the premise of the mean quadrangle mistake.

Bhanusree et al. [Bhanusree and Chowdary (2013)] concentrated second-age wavelet transform for picture combination and researched the qualities coefficients at various recurrence areas. Low-recurrence coefficients are generally utilized in a neighborhood to select the estimating criteria, while coefficients of a high recurrence are utilized for the window property and for watching the qualities of nearby pixels in the picture. The rational part of this exploration is to adjust the pictures utilizing the multi-center picture combination system. The framework C language utilizes the pixel level combination calculation to assess the consequence of shading pictures dependent on the Xilinx Spartan 3 Embedded Development Kit (EDK) field programmable door cluster (FPGA) standard.

Penmetsa et al. [Penmetsa, Narahariseti and Rao (2012)] anticipated a double-tree complex wavelet transform technique that removes the unwanted noise of shading pictures. The complex discrete wavelet transform (CDWT) is the main method that executes genuine and nonexistent pieces of the pictures and initially originates from the discrete wavelet transform (DWT). Guess results as for visual distinction were acquired from shading picture combination utilizing the DWT strategy, yet the double-tree complex wavelet transform (DT-CWT) is the technique that settled this issue and delivered a superior outcome than the DWT.

Jaywantrao et al. [Jaywantrao and Hasan (2012)] proposed the DT-CWT technique, which is directionally discerning to combine the pictures and to shift invariant, which displays a discrete equivalent of a time-invariant framework. An effective combination procedure having a few modalities or instruments is of incentive in medicinal imaging, remote detecting, video reconnaissance, barrier, and even for mechanical uses. These days, a combination of 2D and 3D pictures is broadly utilized in the field to navigate the framework and in engineered opening radar. Hence, a calculation for 2D and 3D pictures is vital. The fundamental factor for these 2D and 3D pictures is time, because the execution of a continuous combination framework was connected to explore different avenues regarding multi-point of convergence pictures. The proposed research is to build up a calculation that utilizes time as a correlative factor to assess the outcomes that are different from those that have been executed already.

Pavithra et al. [Pavithra and Bhargavi (2013)] anticipated multi-dimensional and multi-central picture goals with their wavelet transform to accomplish the angle and smoothness. There are a few methods accessible, for example, multi-point of convergence pictures and multi-sensor satellite pictures, to get the intertwined data of the human mind. The CT and MR pictures are generally used to recover data of the combination of multi-modular medicinal pictures. Wavelet transform is currently contrasted with the visualization of fused image on qualitative and quantitative parameters. After the trial examination of all combination strategies, including the

proposed strategy, a superior outcome is brought from the wavelet transform for the proposed technique. It is a scientific part of the picture combination, while mutual gradience covers the regions of uniform force and is likewise summed in the intertwined picture to limit commotion. It's anything but an area subordinate system.

Sruthy et al. [Sruthy, Parameswaran and Sasi (2013)] proposed the hypothesis and benefits of the double-tree complex wavelet transform in picture handling. The DT-CWT is a gathering of low-recurrence similar to high-recurrence pictures and is utilized to bring the first picture from the combination of various sub-band frequencies in source pictures. These two recurrence groups are fundamentally used to acquire the genuine and fanciful segments of the complex pictures. The DT-CWT utilizes two stages for the combination of pictures. To begin with, it will utilize the DT-CWT to combine the pictures. Second, it will utilize opposite discrete wavelet transform to insert the first picture.

After utilizing this system, the picture can be ordered with two parameters and a recurrence band, which are the genuine and fanciful parameters having a low-recurrence band and a high-recurrence band. The recurrence band of the first information picture ought to be high, and it resolves picture quality and pinnacle signal-to-commotion proportion (PSNR). The issue that emerges with a wavelet transform is relics, for example, associating and coefficient handling, which bother the forward and backward change of pictures and the fragile harmony between them. A combination of a geometric picture additionally develops issues of directional selectivity and of handling edges with edges. The double-tree complex wavelet transform is likewise free from associating, by which these issues can be settled.

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Singh et al. [Singh, Dwivedi and Negi (2012)] prime inspiration for creating the double-tree complex wavelet transform was shift invariance. In ordinary wavelet deterioration, little changes of the information sign can move vitality between yield sub-groups. Move invariance can likewise be accomplished in the DWT by multiplying the inspecting rate. This is affected in the DT-CWT by wiping out the down inspecting by 2 after the first level channel. Two completely obliterated trees are then created by down examining, affected by taking initially even and afterwards odd examples after the primary degree of channels. To get uniform interims between the two trees tests, the consequent channels need a large portion of an example diverse deferral in one tree. Application to picture can be accomplished by divisible complex separating in two measurements.

Computer-based intelligence [Deng, Wu and Yang (2011)] depicted an edge identification procedure by a vigilant administrator, just as another wavelet-based change calculation, to

break information pictures. We distinguish the low-level recurrence and the abnormal state recurrence segments with extra vertical and slanting edges to acquire the limit data. There are a few techniques that decay multi-scale pictures utilizing the discrete wavelet transform to think about the vitality by every pixel, and to choose the steadiness of an edge point. Subsequently, framework has expanded broadening power for the insightful gathering, in light of its dwindled computational multifaceted nature by means of first figuring a developed up wavelet channel into lifting steps. This technique will demonstrate its value in keeping up edge data and giving a superior special visualization.

It suggests a sort of common, or a blend of (or basic) squares of slips among previews. The mean squared mistake (MSE) for a monochrome picture is:

$$\frac{1}{N^2} \sum_I^N \cdot \sum_j^N ((X(i, j) - Y(i, j))^2) \quad (1)$$

and the MSE for a color image is:

$$\frac{1}{N^2} \sum_I^N \cdot \sum_j^N [(r(i, j) - r^*(i, j))^2 + ((g(i, j) - g^*(i, j))^2) + ((b(i, j) - b^*(i, j))^2)] \quad (2)$$

PSNR is characterized as reconstructions of higher quality image compression. Suggest square mistakes, peak signal-to-noise ratio, and compression ratios are ascertained from the accompanying articulations.

$$PSNR = 10 \log_{10} \frac{255^2}{MSE} \quad (3)$$

$$\text{Compression Ratio} = \frac{\text{Original-Image-Size}}{\text{Compressed-Image-Size}} \quad (4)$$

Any weight shape utilizes one of the encoding systems to encode the actualities. The encoding movement is to a perfect degree basic for the achievement of the heap contraption. It comprises of the delineation of the realities. It comprises of the portrayal of the actualities in a structure reasonable for limitation and transmission. The time required to play out this task is hinted as encoding time. The turnaround approach for encoding is unraveling, and the standing out time required from loosening up an encoded measurement is translating time. At the point where all is expressed as played out, the measurements to be compacted could be tended to in the time or spatial region. In exhibiting the records, it ended up clear that it is unquestionably progressively advantageous to adapt to the information in the recurrent zone. Thus, the information in time-space ought to be changed in the recurrent region. The Haar wavelet is characterized by

$$\Psi(x)=f(x) = \begin{cases} -1, & x \in (1/2, 1) \\ 1, & x \in (0, 1/2) \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

With the similar improvement in the wavelet concept, the wavelet remodel is extensively implemented in the domain of scientific photo compression, scientific photograph reinforcing, face detection, and in medical picture registers. With a similar improvement in the wavelet concept, wavelet rework is widely implemented in the area of scientific pictures [Srikanth and Sujatha (2013)].



**Figure 2:** MATLAB implementation of the graphical user interface

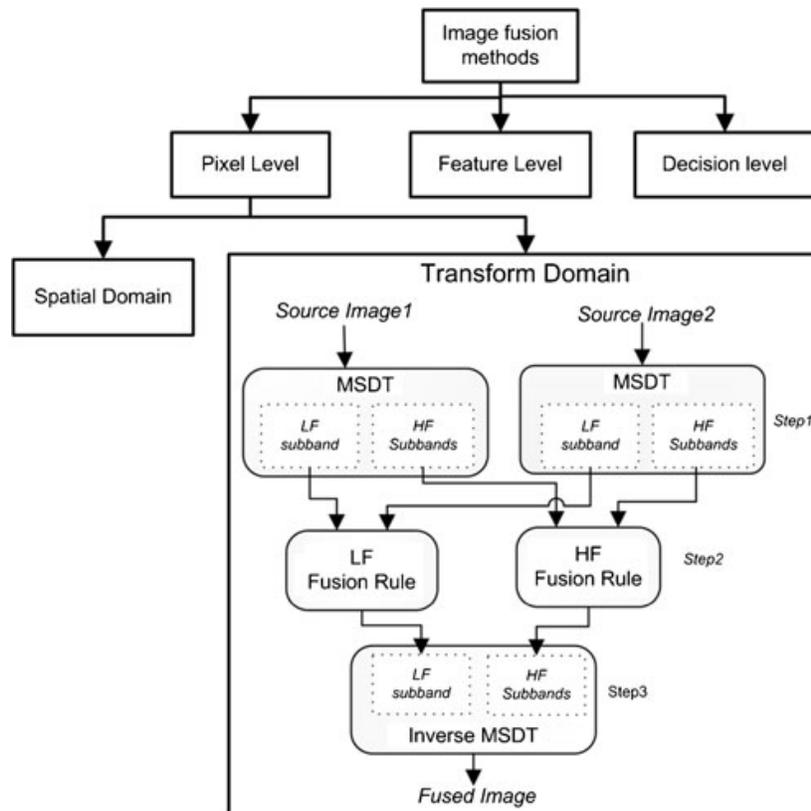
Regardless, in clinical viewpoints, the restorative pictures have uncommon qualities that change from picture to picture, which is heterogeneity of pictures. Additionally, therapeutic pictures suggest living body parts, organs, and tissues. Despite whether obtained with the same way of thinking and looked for after recuperation rules, shape, structure, estimation, or size of these things may move from subject to subject. Besides, the dim article portraying out as common structures cannot maintain a strategic distance from the image base. Various examinations have endeavored to execute different counts for the reason with their individual techniques and achievements in restorative picture mix. In any case, a motorized picture examination should not make false alerts. Along these lines, a mix of multimodal pictures is basic in the clinical assurance procedure and should be improved.

### 3 Pre-processing in image fusion

Picture Fusion begins with the catching of picture with the assistance of multi-sensors and afterwards, the pre-handling happens. The work like adjustment of brightness and extending of differentiation is dealt with during pre-handling. This is done because two unique pictures that have been taken at various points may cause contortion.

A wavelet transform is a mathematical tool which is utilized to extract the detailed information of a patient in a single image. The band pass (low pass and high pass) is the uncommon quality of the discrete wavelet transform, which breaks down the volume of pictures to recover the recurrence and figure out which picture will be appropriate to consolidate or which pictures must be expelled from the combined volume coefficient picture [Li, Kwok and Wang (2001)]. The wavelet which limits the waves has limited

vitality to break down the time data in the sign and to circulate all through the recurrence space [Kor and Tiwary (2004)]. There are two methodologies used to get the time and recurrence data. First is Fourier change which uses just sine and cosine waves in the time-space on the time-recurrence plane and the second is WT (wavelets transform) which is utilized to break down the sign with the low recurrence having each degree of pixels to a coarser resolution [Gunatilaka and Baertlein (2001)]. Since the signal information with respect to frequency and time cannot be known at random point in the time-frequency plane this is reason, this invention goes by the name of “WT” [Kaur and Mann (2014)]. The picture WT disintegrates the first picture into four sub-pictures of four quartered size each. As shown in Fig. 3.



**Figure 3:** Functional representation of multi-resolution scheme at the different levels

These sub-images have the details of vertical, horizontal, and diagonal components to perform on the row and then columns for retrieving two types of results that are, three high-frequency bands (LH, HL, HH) which extract the edges and one low-frequency band (LL) which does the approximation. The next level of decomposition will again re-divide only target at low-frequency components with the same four quarter size, but the next level decomposition can be performed by using one of the LL, LH, HL and HH bands [El-Mezouar, Taleb, Kpalma et al. (2010); Solanki and Patel (2011); Zheng, Zheng,

Hu et al. (2010)]. Since wavelet transformation is based on functions that are localized in both space & frequency; therefore, it is more useful than Fourier transforms.

**4 Mathematical techniques**

The wavelet is a procedure to restrict the waves in the time and recurrence space to have the limited vitality or sign to break down into a lot of scaling capacity just as wavelet work. The wavelet transform is a procedure of decaying the pictures from an arrangement by which at least two pictures are converted into a solitary picture, holding the significant highlights from each of the first picture [Singh, Dwivedi and Negi (2012)]. The wavelet premise set begins with two symmetrical capacities which are utilized for wavelet transform advancement through non-symmetrical capacities that are utilized for consistent wavelet transform.

**4.1 The scaling function**

The scaling capacity is utilized for space restriction to cover the low recurrence of surmised a picture at the various degrees of estimation. The scaling capacity is a development work by which we can foresee precisely where this spatial recurrence exists [Sruthy, Parameswaran and Sasi (2013)]. The channel coefficients are commonly controlled by scaling capacity or scaling channel where both scaling capacity and scaling channel are equivalent. The subsequent condition of scaling capacity is as pursue

$$\phi_{j,k}(n) = 2^{j/2} \phi(2^j n - k) \tag{6}$$

where:

{ $\phi_{j,k}(n)$ } = Scaling function

j=Scaling parameter

k=Shift parameter

n=Discrete function argument (x -axis)

$2^{j/2}$  =Amplitude / Magnitude of scaling function (y-axis)

j,k  $\in$  Z (Set of integers space)

Frequency signal diagram of scaling function

Let put j=0, k=0

$$\Phi_{0,0}(n) = 2^{0/2} \Phi(2^0 n - 0)$$

$$\Phi_{0,0}(n) = 1 \Phi(n)$$

Since n=0 and  $\Phi_{0,0}(n) = 1$

Let put j=1, k=0

$$\Phi_{0,0}(n) = 2^{1/2} \Phi(2^1 n - 0)$$

$$\Phi_{1,0}(n) = 2^{1/2} \Phi(2n)$$

Since n=1/2 and  $\Phi_{1,0}(n) = 1.414$

Then amplitude will be 1.414 with width 0.5

Let put j=1, k=3

$$\Phi_{1,3}(n) = 2^{1/2} \Phi(2^1 n - 3)$$

$$\Phi_{1,3}(n) = 2^{1/2} \Phi(2n - 3)$$

Since n=1.5 and  $\Phi_{1,3}(n) = 1.414$

Then amplitude will be 1.414 with width 1.5

The general scaling function for higher shifted version will be added together as  $\Phi_{0,0}(n)$ ,  $\Phi_{1,0}(n)$ ,  $\Phi_{0,1}(n)$  etc. and can be written as

$$\Phi(n) = \sum_k h_\phi(k) \cdot \sqrt{2} \cdot \Phi(2n-k) \quad (7)$$

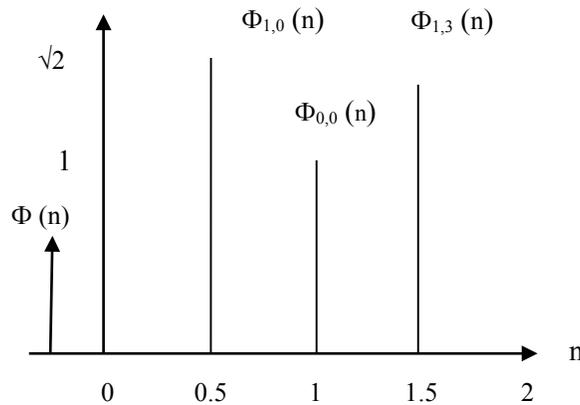
where:

$\Phi(n)$ =Scaling function

$n$ =It is discrete variable

$\Phi(2n-k)$ =Higher order function

$h_\phi(k)$ = Some coefficient which can be obtained by  $\Phi_{j,k}(n)$  like  $\Phi_{0,0}(n)$ ,  $\Phi_{1,0}(n)$ ,  $\Phi_{0,1}(n)$  etc.



**Figure 4:** Frequency signal diagram of scaling function

Similarly, way we can obtain Discrete Scaled function  $\omega_\phi(j, k)$ , and can be written as

$$\omega_\phi(j, k) = \sum_m h_\phi(m - 2k) \omega_\phi(j + 1, m) \quad (8)$$

Thus, the scaling function for multi-resolution analysis must have

- Integer translates of orthogonal.
- Sub-spaces spanned at low resolution.
- Represented with arbitrary precision and the weighted sum of the expansion functions of sub-space can be used to express the expansion.

#### 4.2 The wavelet function

Wavelet function is a type of scaling function which satisfies the requirements for describing the scaling function. The weighted sum of shifted or double resolution can be expressed by scaling function [Swathi and Bindu (2013)]. This can be represented as

$$\Psi_{j,k}(n) = 2^{j/2} \Psi(2^j n - k) \quad (9)$$

where:

$\{\Psi_{j,k}(n)\}$ =Wavelet function

$j$ =Wavelet parameter

$k$ =Shift parameter

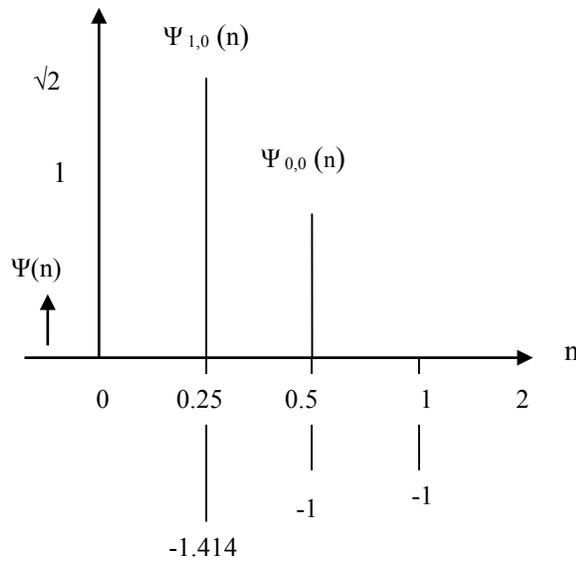
$n$ =Discrete function argument (x –axis)

$2^{j/2}$ =Amplitude / Magnitude of Wavelet function (y-axis)

$j,k \in \mathbb{Z}$  (Set of integers space)

Frequency signal diagram of wavelet function

<p>Let put <math>j=0, k=0</math></p> $\Psi_{0,0}(n) = 2^{0/2} \Psi(2^0 n - 0)$ $\Psi_{0,0}(n) = 1 \Psi(n)$ <p>Since <math>n=0</math> and <math>\Psi_{0,0}(n) = 1</math></p> <p>Then amplitude will be 1 with width 1</p> <p>width 0.5</p>	<p>again put <math>j=1, k=0</math></p> $\Psi_{1,0}(n) = 2^{1/2} \Psi(2^1 n - 0)$ $\Psi_{1,0}(n) = \sqrt{2} \Psi(2n)$ <p>since <math>n=1/2</math> and <math>\Psi_{1,0}(n) = \sqrt{2} = 1.414</math></p> <p>then amplitude will be 1.414 with</p>
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**Figure 5:** Frequency signal diagram of the wavelet function

The general wavelet function for higher shifted version will add them together as  $\Psi_{0,0}(n), \Psi_{0,1}(n)$  etc., and can be written as

$$\Psi(n) = \sum_k h_k \Psi(k) \sqrt{2} \Phi(2n-k) \tag{10}$$

where:

$\Psi(n)$ =Wavelet function

$\Phi(2n-k)$ =It is a higher-order scaling function

$k$ =Shift parameter

$n$ =Discrete function argument (x-axis)

$h\Psi(k)$ =Some coefficient which can be obtained by  $\Psi_{j,k}(n)$  like  $\Psi_{0,0}(n), \Psi_{1,0}(n)$  etc.

$j,k \in \mathbb{Z}$  (Set of integers space)

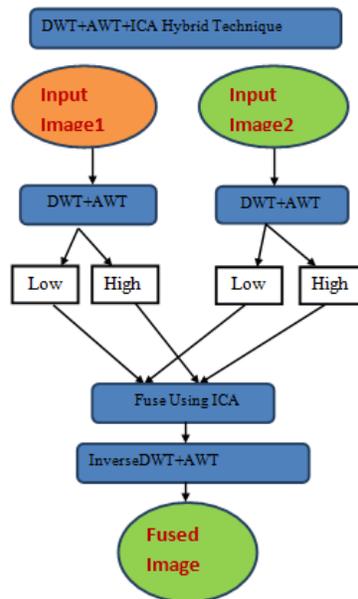
Therefore, we can say that  $\Psi_{j,k}(n)$  is used to represent the wavelet function, where  $\Phi_{j,k}(n)$  is used to represent the scale function, which is used to scale the given sub-space by a factor of  $2^{j/2}$ . After these steps, it is easier to apply scaling and the wavelet function to filter the image to achieve space frequency localization.

### 5 Related methods and scope

The combination strategy is of three sorts, which are the pixel level, the element level, and the choice level. Pixel level combination is the base procedure to meld the pictures from which data is being derived; pixel to pixel, from a lot of pixels in the establishment picture. This kind of combination procedure utilizes the spatial or frequency space, which produces yield pictures by safeguarding all the reasonable [Srikanth and Sujatha (2013)].

Property-level combination utilizes pixel powers, edges, or surfaces to get the notable uniqueness. It is utilized for arrangement or finding the picture conduct. This will deliver the identical characteristic from the source picture after combination [Bhanusree and Chowdary (2013)].

Choice-level combination is utilized for complex pictures. It is essentially used to create and bring data from a lot of establishment pictures, and after that to firmly apply decision standards to feature surely understood comprehension [Penmetsa, Narahariseti and Rao (2012)].



**Figure 6:** Wavelet transforms fusion of input images (the fusion process)

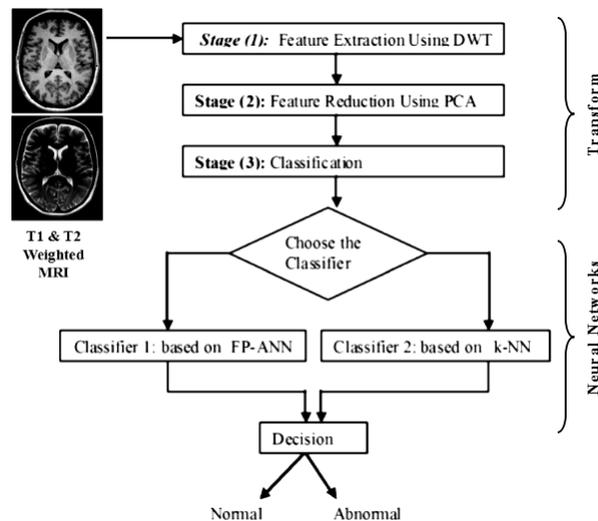
A PET and MR mind picture combination procedure dependent on the wavelet transform was introduced by Solanki et al. [Solanki and Patel (2011); Singh, Dwivedi and Negi (2012)] proposed a comparable technique.

After the wavelet transform and dim level combination, a great combination result is accomplished by altering the anatomic and auxiliary data in the gray matter (GM) region and dealing with the spectral information in the white matter region of the cerebrum.

Usually for medical imaging studies, gathering parallel information of cerebrum imaging from a solitary subject is currently normal [Sruthy, Parameswaran and Sasi (2013); Swathi and Bindu (2013)]. Different scientists (e.g., Pavithra, Hong, Li, Kwok, and Wang) have together proposed a compelling and basic visually impaired source partition procedure which beneficially joins Independent Component Analysis (ICA) and canonical correlation analysis (CCA) for performing various tasks combination of information. This gives the right association and high exactness for estimation of two datasets where the source can have either distinctive or common correlation features between datasets. The undertaking related initiation that is represented by a refined dataset highlight is adequately more manipulable than four-dimensional information because of its diminished measurements.

**6 Proposed hybrid image fusion methods**

Existing conventional combination calculations require the capacity to get the prevalent quality pictures. To show signs of improvement, the prevalence and execution of the proposed strategy is utilized to join the consolidation of the two calculations [FP-ANN (Feed forward-Artificial Neural Network) and K-NN (K-Nearest Neighbour)]. Apply the two level changes before combination process. These changes present prevalent quality for melded subtleties, upgraded treatment of bended diagram, and better portrayal of info images [Jaywantrao and Hasan (2012); Deng, Wu and Yang (2011)]. Fig. 7 demonstrates the procedure stream of the half breed calculation.



**Figure 7:** Medical Image Fusion Using Hybrid Technique

However, the benefits of multimodal fusion come at a certain price that may produce complication in the process of analysis. This may be due to the properties of the different modalities involved, for example, the execution-time of various types of multimodal imaging devices are different, which tends to affect the strategy of fusion that is espoused.

### **6.1 Hybrid fusion algorithm (FP-ANN and K-NN)**

Hybrid supervised machine learning fusion method utilizing FP-ANN and K-NN is used to obtain the classification of images under two categories, either normal or abnormal for feature extraction. The initial phase in the proposed fusion method includes the pre-handling of the MRI and CT images. The DWT is an effective tool for feature extraction because they allow analysis of images at various levels of resolution. This technique requires large storage and is computationally more expensive. Hence, an alternative method for dimension reduction scheme is used. To reduce the feature vector dimension and increase the discriminative power, the principal component analysis (PCA) has been used. PCA is used to give more accurate and fast solution than the conventional methods of brain tumor classification.

The K-NN is known as a simple but robust classifier and is capable to produce high performance results even for complex applications. The K-NN uses a distance of features in a data set to determine which data belongs to which group. A group is formed when the distance within the data is close, while many groups are formed when the distance within the data is far. In the MRI and CT research, the K-NN is widely used as a classifier to classify to generate images of the organs in the body. For example, the K-NN was used to classify epileptic and normal brain activities through the MRI and CT images.

Artificial Neural Network (ANN) is a well-known classifier used to process feature rich data. FP-ANN is also extensively used as classifier for automated detection of pathological tissue without any need for the pathological testing, similar to the KNN. For example, in EEG (electroencephalogram) signals research, the ANN is employed to analyze anesthesia depth monitoring, Parkinson disease, and epileptic seizure.

A hybrid method using DWT-DCT-ICA for Feature Extraction, ICA for Feature reduction and DWT-DCT classifier proves high statistical measures.

Algorithms:

- Get the source images.
- Input images resized into 256×256.
- Obtain high pass directional sub-band coefficients and low pass sub-band coefficients of input images at each scale and each direction by the wavelet transform.
- The FP-ANN and the K-NN are used to perform the decomposition based on complete multiscale and multi-direction respectively.
- Decompose the multimodal medical images using the DWT-DCT into complex coefficient sets. For both the coefficient sets, thresholds are calculated for each decomposition level.
- Absolute differences of all wavelet coefficients from their corresponding threshold are calculated.
- Absolute differences of corresponding coefficients of both the source modalities are

compared and the coefficient having larger value of absolute difference from the threshold is selected, to form coefficient set of the fused image.

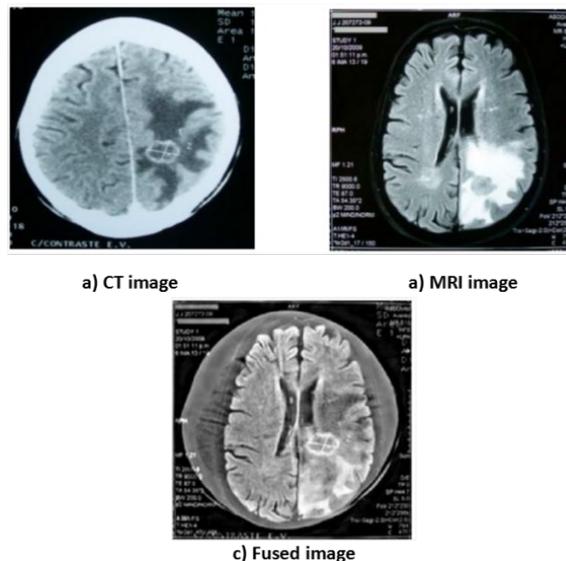
- Finally, the DWT-DCT and DWT-DCT-ICA are applying on the combined coefficient set to obtain the final output image.

Finish

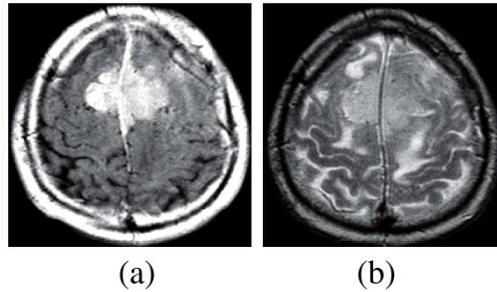
The results are discussed on the distinct classification of the medical images utilizing either the K-NN or the FP-ANN for brainwave balancing application. In addition to that the outcomes were based on the accuracy of the PSNR for different classifiers. In conclusion, proposed hybrid algorithm gives better results in terms of accuracy and the PSNR compared to the DCT, the DWT, and the IWT respectively for this application.

### 6.2 Experimental result

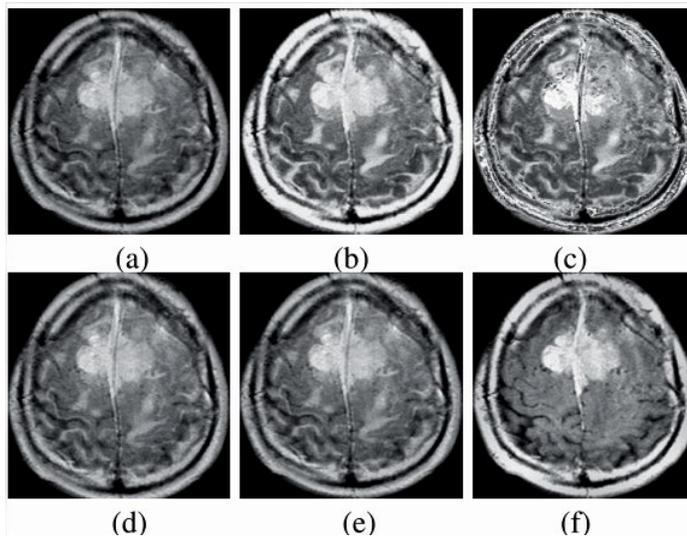
The strategies proposed for executing combination of multi-centered pictures utilizing DWT-DCT-ICA take the accompanying structure when all is said in done. The pictures are changed into wavelet space by taking the DWT-DCT-ICA. MATLAB codes are written to take the DWT-DCT-ICA of the two pictures. In each sub-band, action proportion of the two pictures is considered dependent on the above proposed combination techniques at that specific scale and space. A melded wavelet transform is made by taking pixels from that the wavelet transform that shows more noteworthy action at the pixel areas. The reverse DWT-DCT is the melded picture with clear center around the entire picture. Picture Fusion in the Wavelet transform space has higher vigor against measurable assaults contrasted with picture combination in spatial area and Discrete Cosine Transform area. However, Spatial and Discrete cosine change strategy have a PSNR superior to other procedure.



**Figure 8:** Result of fused brain CT and MRI images in hybrid mode



(a) MRI T1 Contrast; (b) MTR T2 input images

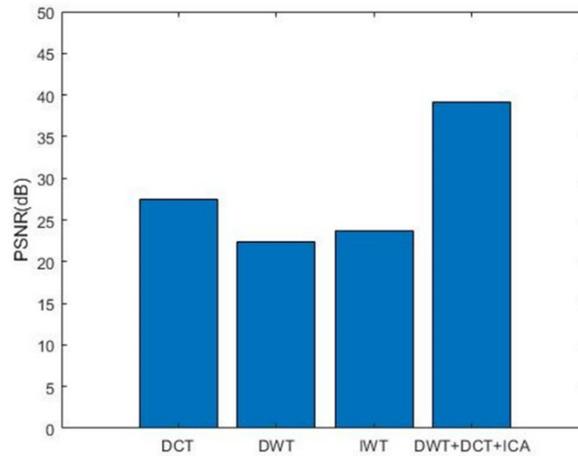


**Figure 9:** Fusion result of (a) MRI T1 (contrast) (2) MRI T2 scans using; (a) Average-Pixel (b) Fuzzy inference system (c) Neuro-fuzzy inference system (d) WT+ICA (e) WT+PCA (f) DWT+DCT+ICA

Mix of at least two systems of picture combination, (for example, the wavelet transform, fluffy techniques, the DWT, the ICA, the PCA, the ANN, and so forth) is also observed to be powerful in investigation of therapeutic pictures. The algorithmic approach is to manage the combination of pictures are, however, limited by the imaging hardware. Additionally, creating multimodal filtering instruments is a charming errand because of its danger of bringing the patients into potential harm of overabundance radiations, broadened examination period, and extended gear costs. It incorporates looking at similitude issues of the basic innovations as the goals, space, time, and quickened examination vary from machine to machine. The issue is considered progressively basic being developed of cutting edge combination calculations and instruments for use in therapeutic exercises continuously as in guided automated medical procedures.

### 6.3 Performance evaluation metrics

The performance metrics is evaluated on both existing and proposed algorithms. Qualitative study of the output image is evaluated based on the visual quality of the final outcome. However, quantitative study is evaluated based on the image fusion parameters. The output is compared for similarities and dissimilarities with the source images. Some of the performance metrics are as follows:



**Figure 10:** Performance analysis

**Table 2:** PSNR calculation of image fusion using hybrid method (DWT+DCT+ICA)

Technique	Existing PSNR	Proposed Technique	Proposed PSNR
DCT	27.45		
DWT	22.36		
IWT	23.76	DWT+DCT+ICA	39.12

## 7 Conclusion

In this paper, we introduced a half and half picture combination calculation dependent on the DWT and the ICA trailed by a 2D channel for upgrading purposes and assessed the outcomes. The source pictures are partitioned in non-covering squares and then the combination is applied to the relating squares of the two source pictures which were to be melded. It is led by a 2-arrange process; where, right off the bat, modes 0-8 are applied on the source pictures and coefficients from the source pictures for every mode are utilized in the combination procedure. Three distinctive combination principles are applied for the combination process between the pictures by rehashing the equivalent for different modes. In the subsequent stage, eight intertwined pictures acquired (one from every mode) by applying the combination guidelines are melded into a solitary picture utilizing ICA. At this point, this combined MRI images goes through the 2-D channel added towards the end of the calculation to get an upgraded yield. This last separated

result is the necessary yield which is contrasted with the other combination systems to get the outcome.

### **8 Future scopes**

These applications incorporate in retinopathy, night vision, the combination of multimodality CT and MRI mind pictures, improving the aftereffects of the restorative picture division of highlight extraction, and in medicinal imaging examination and demonstrative frameworks applications.

Multi-wavelets based picture mix can be used to achieve a prevalent nature of combined pictures. Explains the efficiency of a multi-wavelet technique over the regular wavelet transform systems in picture combinations drew in with remote detecting in far off territories. The comparison can be received in future undertakings too and can be affirmed depending on the improvement of picture quality measures and portrayals.

The enlistment of pictures has not been directed in this work. Picture alinement and enrollment will doubtlessly improve the viability of the examinations as enormous gathering of even unregistered pictures can be considered as a source set of pictures for information. It would be similar to the aid possibility of examining a set of test or quality pictures accommodated to assess the calculations for combining the pictures.

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**Conflicts of Interest:** I hereby declare that there is no conflict of interest related to this manuscript (article) entitled “Fusion of Medical Images in Wavelet Domain: A Hybrid Implementation” with manuscript id: “CMES-8459 Proof”.

### **References**

- Bhanusree, C.; Chowdary, P. A.** (2013): A novel approach of image fusion MRI and CT image using wavelet family. *International Journal of Application or Innovation in Engineering & Management*, vol. 2, no. 8, pp. 1-4.
- Deng, A.; Wu, J.; Yang, S.** (2011): An image fusion algorithm based on discrete wavelet transform and canny operator. *International Conference on Computer Education, Simulation and Modeling*, pp. 32-38.
- El-Mezouar, M. C.; Taleb, N.; Kpalma, K.; Ronsin, J.** (2010): An IHS-based fusion for color distortion reduction and vegetation enhancement in IKONOS imagery. *IEEE Transactions on Geo-Science and Remote Sensing*, vol. 49, no. 5, pp. 1590-1602.
- Gunatilaka, A. H.; Baertlein, B. A.** (2001): Feature-level and decision-level fusion of non coincidently sampled sensors for land mine detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 23, no. 6, pp. 577-589.
- Jaywantrao, P. G.; Hasan, S.** (2012): Application of image fusion using wavelet transform in target tracking system. *International Journal of Engineering Research & Technology*, vol. 1, no. 8.

- Kaur, D.; Mann, P. S.** (2014): Medical image fusion using gaussian filter, wavelet transform and curvelet transform filtering. *International Journal of Engineering Science & Advanced Technology*, vol. 4, no. 3, pp. 252-256.
- Kor, S.; Tiwary, U.** (2004): Feature level fusion of multimodal medical images in lifting wavelet transform domain. *26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, vol. 1, pp. 1479-1482,
- Li, S.; Kwok, J. T.; Wang, Y.** (2001): Combination of images with diverse focuses using the spatial frequency. *Information Fusion*, vol. 2, no. 3, pp. 169-176.
- Pavithra, C; Bhargavi, S.** (2013): Fusion of two images based on wavelet transform. *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 2, no. 5, pp. 1814-1819.
- Penmetsa, K. R.; Naraharisetti, V. P.; Rao, N. V.** (2012): An Image fusion technique for color images using dual-tree complex wavelet transform. *International Journal of Engineering Research & Technology*, vol. 1, pp. 2278-0181.
- Sharma, R. K.** (1999): *Probabilistic Model-based Multisensor Image Fusion (Ph.D. Thesis)*. Oregon Graduate Institute of Science and Technology, Portland, Oregon.
- Singh, R. P.; Dwivedi, R.; Negi, S.** (2012): Comparative evaluation of DWT and DT-CWT for image fusion and De-noising. *International Journal of Applied Information Systems*, vol. 4, pp. 40-45.
- Solanki, C. K.; Patel, N. M.** (2011): Pixel based and wavelet based image fusion methods with their comparative study. *National Conference on Recent Trends in Engineering & Technology*, vol. 13, pp. 13-14.
- Srikanth, J.; Sujatha, C. N.** (2013): Image fusion based on wavelet transform for medical diagnosis. *International Journal of Engineering Research and Applications*, vol. 3, no. 6, pp. 252-256.
- Sruthy, S.; Parameswaran, L.; Sasi, A. P.** (2013): Image fusion technique using DT-CWT. *International Mutli-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s)*, pp. 160-164.
- Swathi, K. V.; Bindu, C. H.** (2013): Modified approach of multimodal medical image using daubechies wavelet transform. *International Journal of Advanced Research in Compute and Communication Engineering*, vol. 2, no. 11, pp. 4199-4201.
- Yadav, S. P.; Yadav, S.** (2018): Fusion of medical images in wavelet domain: a discrete mathematical model. *Ingeniería Solidari*, vol. 14, no. 25, pp. 1-11.
- Zheng, H.; Zheng, D.; Hu, Y.; Li, S.** (2010): Study on the optimal parameters of image fusion based on wavelet transform. *Journal of Computational Information Systems*, vol. 6, no. 1, pp. 131-137.