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# Image Fusion using Wavelet Transform: A Review

By Vinay Sahu & Dinesh Sahu
*Sri Satya Sai College Of Engineering, India*

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*Keywords: image fusion, medical image, PCA, wavelet transform.*

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# Image Fusion using Wavelet Transform: A Review

Vinay Sahu [α] & Dinesh Sahu [σ]

*Abstract-* An Image fusion is the development of amalgamating two or more image of common characteristic to form a single image which acquires all the essential features of original image. Nowadays lots of work is going to be done on the field of image fusion and also used in various application such as medical imaging and multi spectra sensor image fusing etc. For fusing the image various techniques has been proposed by different author such as wavelet transform, IHS and PCA based methods etc. In this paper literature of the image fusion with wavelet transform is discussed with its merits and demerits.

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## I. Introduction

Fusion imaging is one of the most contemporary, precise and useful diagnostic techniques in medical imaging today. The new skill has made a clear difference in patient care by compressing the time between diagnosis and treatment. Image fusion is the progression by which two or more images are combined into a single image retaining the important features from each of the original images. Image fusion mingles absolutely registered images from numerous sources to fabricate a high quality fused image with spatial and spectral information [1]. So many image fusion methods have been developed from the past to now such as: the Brovey, the HIS, DCT, DWT, DT CWT and PCA methods etc. These methods functions under spatial domain & have proved to be flourishing in computer vision, robotics, satellite and medical image fusion applications. Now-a-days, Medical image fusion has become a new promising research field. For medical diagnosis, MRI (Magnetic resonance image) and CT (Computed tomography) images are very important. MRI image provides better information about soft tissue and CT image provides detail information about dense structure such as bones. These two images provide complementary information. The main purpose of medical image fusion is to obtain a high resolution image with as much details as possible for the sake of diagnosis. So if these two images of the same organ are fused then the fused image contains as much information as possible for diagnosis of that organ [2]. Researchers have made lot of work on the fusion of MRI &CT images using wavelet transform. Jean Morlet in 1982 introduced the idea of the wavelet transform. Three types of wavelets used in the image fusion are Orthogonal, Bi-orthogonal and A-trous (Non-orthogonal).The image fusion method based on wavelet transform has good spatial & spectral eminence but has limited directivity to deal with the images having curved shapes. The image fusion is classified into three level first pixel level second feature level and third decision level.

*Author α σ: Department of Computer Science & Engg. Sri Satya Sai College of Engineering, Bhopal, M.P, India.*
*e-mails: sahuvinay25@gmail.com, dinesh_sahu20@yahoo.com*

### a) Pixel Level Fusion

It produces a fused image in which information content related with each pixel is concluded from a set of pixels in source images. Fusion at this level can be carry out either in spatial or in frequency domain. However, pixel level fusion may conduct to contrast reduction [4].

### b) Attribute Level Fusion

Attribute level fusion requires the extraction of salient characteristics which are depending on their surroundings such as pixel intensities, edges or textures. These analogous attribute from the input images are fused. This fusion level can be used as a means of creating supplementary amalgamated attributes. The fused image can also be used for classification or detection [5].

### c) Decision Level Fusion

Decision level is a superior level of fusion. Input images are processed independently for information mining. The obtained information is then united applying decision rules to emphasize widespread interpretation [6].

The advantage of multi-sensor image fusion comprise [3]:

i. Improved reliability – The fusion of different measurements can diminish noise and consequently develop the steadfastness of the measured quantity.
ii. Robust system performance – Redundancy in various measurements can help in systems stoutness. In case one or more sensors fail or the performance of a meticulous sensor deteriorates the system can depend on the other sensors.
iii. Compact representation of information – Fusion leads to condensed representations. For example, in remote sensing, instead of storing

imagery from numerous spectral bands, it is moderately more proficient to store the fused information.

iv. Extended range of operation – Multiple sensors that function under different operating conditions can be deployed to expand the effective range of operation. For example, different sensors can be used for day/night operation.

v. Extended spatial and temporal coverage – Joint information from sensors that diverge in spatial resolution can increase the spatial coverage. The identical is true for the secular dimension.

vi. Reduced uncertainty – Joint information from several sensors can diminish the vagueness associated with the sensing or decision process.

The steps carries out for processing the image fusion is shown by figure 1.

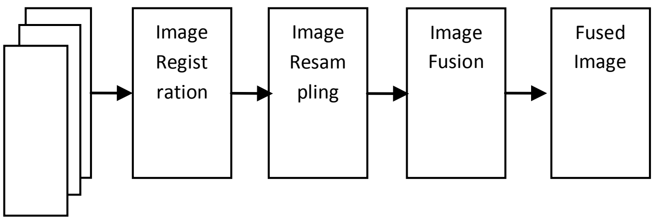


*Figure 1 :* Steps used to fuse the images

In this paper study of different image techniques with their merits and demerits is discuss below. The remaining part of this work is arranged in this manner: section second give description of different technique to fuse two or more images. Section third presents the literature of previous work done and last section gives conclusion about the paper.

## II. Image Fusion Techniques

Image fusion is one of the significant processes to acquire essential features from the common images and to extract these features so many techniques has been developed such as DCT, DWT, DT CWT, IHS and PCA based fusion etc. In this paper some of them is describing with their merits and demerits.

*a) Brovey Transform*

Brovey transform (BT) [7] also known as color regularized fusion is based on the chromaticity transform and the perception of intensity modulation. This method is an unsophisticated to amalgamate data from different sensors which can safeguard the comparative spectral contributions of each pixel but reinstate its complete brightness with the high spatial resolution image. As applied to three MS bands each of the three spectral components (as RGB components) is multiplied by the ratio of a high-resolution co-registered image to the intensity component I of the MS data.

*b) IHS based Fusion*

It is one of the mainly used popular methods by many researchers for blending Panchromatic and Multispectral images. In IHS fusion method the IHS (Intensity, Hue and Saturation) space are converted from the Red, Green and Blue (RGB) space of the Multispectral image. The intensity factor I is replaced by the PAN. Then the reverse transform is applied to get RGB image as an output [8].

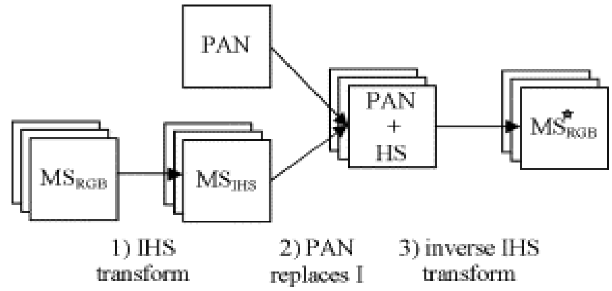


*Figure 2 :* IHS fusion principle

The standard fusion method of IHS technique is as follows:

i. Read the PAN and MS images as inputs
ii. Resize the MS image based on the PAN size
iii. Transform the RGB components to the IHS components
iv. Modify the PAN image with respect to the MS image by using histogram matching of PAN image with Intensity level of MS image
v. Intensity component replaced by the PAN
vi. Reverse transform will obtain high resolution MS image

In IHS fusion, he the transformation of RGB to IHS will be based on the following formulas.

$$\begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{-\sqrt{2}}{6} & \frac{-\sqrt{2}}{6} & \frac{2\sqrt{2}}{6} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ 1 & \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} \quad (1)$$

where v1 and v2 are considered as x and y axes and I (Intensity) as the z axis. The H (Hue) and S (Saturation) can be represented as

$$H = \tan^{-1}\frac{v1}{v2} \quad \text{and} \quad S = \sqrt{v1^2 + v2^2} \quad (2)$$

The representation of RGB – HIS conversion by

$$I = \frac{R+G+B}{3}$$

$$H = \begin{cases} \cos^{-1}(a) & if\ G \geq R \\ 2\pi - \cos^{-1} a & if\ G \leq R \end{cases} \quad (3)$$

$$S = 1 - \frac{3\min(R,G,B)}{R+G+B} \qquad (4)$$

The above two conversion systems are differed based on the saturation. The saturation value is same where the pixels are identical in (1) and (2) that build a saturation barrel in IHHS space. In the conversion system, (3) and (4), we can locate the identical saturation value of the pixels where the saturation is proportional to the intensity values.

*c) Principal Component Analysis (PCA)*

It is a mathematical tool from applied linear algebra. It is a simple parametric method for extracting relevant information from confusing data sets. PCA is a useful statistical technique that has found application in fields such as face recognition and image compression, and is a common technique for finding patterns in data of high dimensions The origin of PCA lie in multivariate data analysis, it has a wide range of other application PCA has been called, 'one of the most important results from applied linear algebra and perhaps its most common use is as the first step in trying to analyses large sets. In general, PCA uses a vector space transform to reduce the dimensionality of large data sets. Using mathematical projection, the original data set, which may have involved many variables, can often be interpreted in just a few variables.

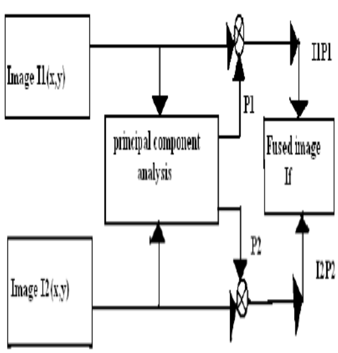


*Figure 3 :* Image fusion development using PCA

*d) Select Maximum/Minimum Method*

A selection process if performed here wherein, for every corresponding pixels in the input images, the pixel with maximum/minimum intensity is selected, respectively, and is put in as the resultant pixel of the fused image. The wavelet-based image fusion methods can be performed in two ways replacement and selection method. Figure 4 gives the general flow diagram for Selection method [9].

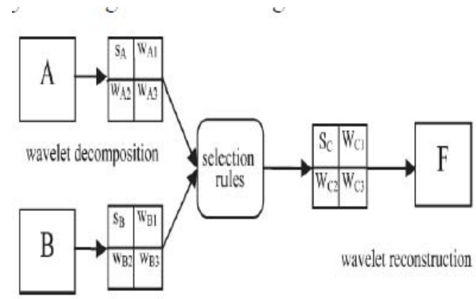


*Figure 4 :* Fusion of image using selection method

*e) Discrete Wavelet Transform (DWT)*

The discrete wavelet transform [10] is a spatial-frequency domain disintegration that presents a bendable multi-resolution analysis of an image. In 1-D, the mean of the wavelet transform is corresponding to the signal as a superposition of wavelets. If a isolated signal is correspond to by f(t) its wavelet decomposition is then

$$f(t) = \sum_{m,n} C_{m,n}\varphi_{m,n}(t) \qquad (5)$$

where m and n are integers. This guarantees that the signal is decomposed into normalized wavelets at octave scales. For an recursive wavelet transform supplementary coefficients a $_{m,n}$ are mandatory at every scale. At each am, n and am-1,n illustrate the approximations of the function 'f ' at resolution 2m and at the coarser resolution 2m-1 correspondingly while the coefficients cm ,n illustrate the difference among one approximation and the other. In order to obtain the coefficients cm ,n and am, n at each scale and position, a scaling function is needed that is similarly defined to equation (6). The convolution of the scaling function with the signal is implemented at each scale through the iterative filtering of the signal with a low pass FIR filter hn. The approximation coefficients am,n at each scale can be obtained using the following recursive relation:

$$a_{m,n} = \sum_k h_{2n-k} a_{m-1}, k \qquad (6)$$

Where the top level a0,n is the sampled signal itself. In addition, by using a related high pass FIR filter gn the wavelet coefficients can be obtained by:

$$c_{m,n} = \sum_k g_{2n-k} a_{m-1}, k \qquad (7)$$

To renovate the original signal the examination filters can be selected from a bi-orthogonal set which have a correlated set of synthesis filters. These synthesis filters $\hat{h}$ and $\hat{g}$ can be used to absolutely renovate the signal using the renovation formula:

$$a_{m-1,l}(f) = \sum_n [\hat{h}_{2n-1} a_{m,n}(f) + \hat{g}_{2n-1} C_{m,n}(f)] \qquad (8)$$

Equations (7) and (8) are implemented by filtering and subsequent down sampling. Conversely equation (6) is implemented by an initial up sampling and a subsequent filtering. A single stage wavelet synthesis and analysis in one dimension is shown in figure(5).

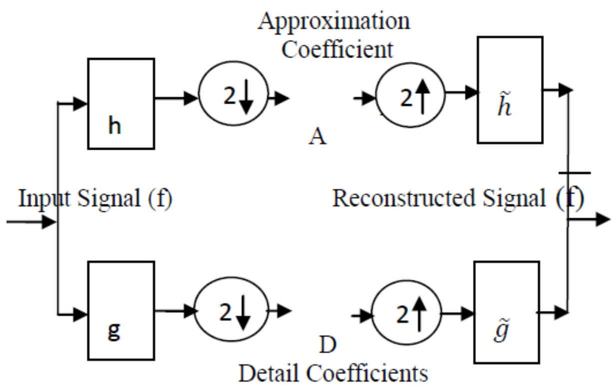


*Figure 5 :* 1-D wavelet analysis and synthesis filter

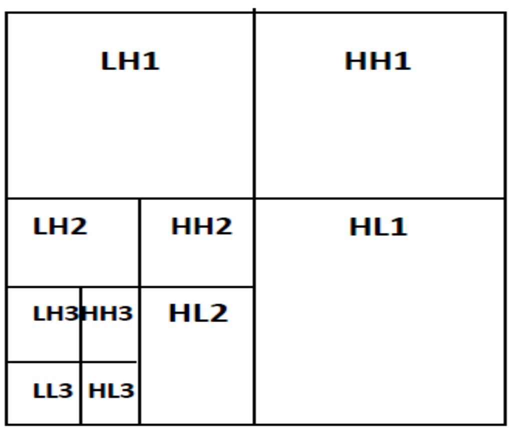


*Figure 6 :* Wavelet decomposition at Level-3

The fusion process of two images using the DWT is shown in. figure (7). The two images used were from a multi-focus set, i.e. two registered images of same scene each with a different camera focus. This figure demonstrates that the coefficients of each transform have considerably different magnitudes within the regions of diverse focus. A straightforward "maximum selection" was used to produce the combined coefficient map. This effectively retains the coefficients of "in focus" regions within the image. This inverse wavelet transform is then applied to the combined coefficient map to produce the fused image which in this case shown an image retaining the focus from the two input images.

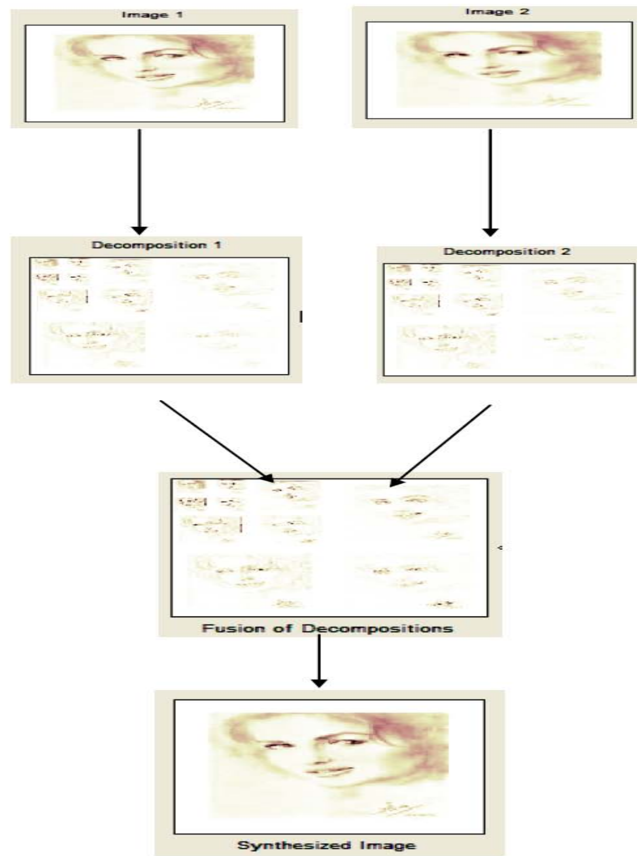


*Figure 7 :* Image fusion using DWT of two Katrina image

*f) Dual Tree Complex Wavelet Transform*

In this method, fusion is executed using the masks to remove information from the decomposed structure of DT-CWT [11]. Figure 8 demonstrates the complex transform of a signal using two split DWT decompositions: Tree a and Tree b.

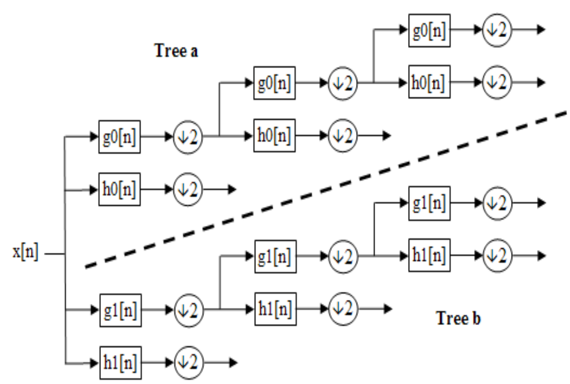


*Figure 8 :* DT-CWT Structure

It can be observed that the DT-CWT structure, involves both real and complex coefficients. It is known that DT-CWT is relevant to visual sensitivity. Fusion procedure involves the formation of a fused pyramid using the DT-CWT coefficients which are obtained from the decomposed pyramids of the source images. The fused image is obtained through conventional inverse dual tree complex wavelet transform or reconstruction process. This results show a significant reduction of distortion.

Resulting fused image is obtained by performing inverse transform of combined coefficient map which shows the oriented nature of complex wavelet sub bands. That is each of the clock hands in different directions is taken correctly by the differently oriented sub bands. In the figure 9 shown the area of region of image more in focus has larger magnitude coefficient. i.e by comparing each and every pixel of both images the values of larger magnitude coefficient alone is taken. Maximum scheme is used to produce the combined coefficient map. It thus takes only the larger coefficient from images to produce the combined coefficient map. Resulting fused image is obtained by performing inverse transform of combined coefficient map which shows the oriented nature of complex wavelet sub bands. That is each of the clock hands in different directions is taken correctly by the differently oriented sub bands. Coefficient fusion rule is applied to magnitude of DT-CWT coefficients as they are complex. Experiment results show that this fusion method is remarkably better than the classical discrete wavelet transform.

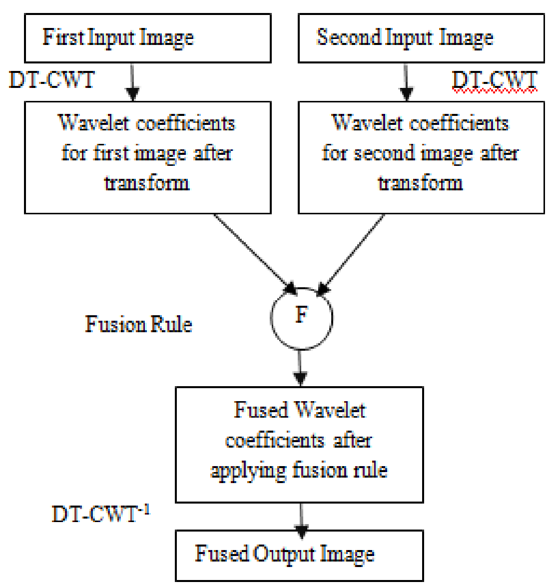


*Figure 9 :* DT-CWT based fusion

DT-CWT is able to conserve subtle texture regions of brain in MRI images. Ringing effects are reduced and it can retain the edge details more clearly. DT-CWT is better than DWT because of its directional selectivity and shift variant nature.

## III. Related Work

*Kanisetty Venkata Swathi et al.* [12] proposed a new approach of multimodal medical image fusion on Daubechies wavelet transform coefficients. The fusion process starts with comparison of block wise standard deviation values of the coefficients. Here the standard deviation can be used to characterize the local variations within the block. The performance of proposed image fusion method is compared with existing algorithms and evaluated with mutual information between input and output images, entropy, standard deviation, fusion factor metrics.

*J. Srikanth et al.* [13] presented the wavelet transforms of the input images are properly pooled the new image is achieved by taking the inverse wavelet transform of the fused wavelet coefficients. The suggestion is to progress the image content by fusing images like computer tomography (CT) and magnetic resonance imaging (MRI) images so as to recommend more information to the doctor and clinical treatment planning system. They demonstrate the application of wavelet transformation to multi- modality medical image fusion. This work covers the selection of wavelet function, the use of wavelet based fusion algorithms on medical image fusion of CT and MRI, implementation of fusion rules and the fusion image quality evaluation. The fusion performance is estimated on the basis of the root mean square error.

*Ch.Bhanusree et al.* [14] analysed the characteristics of the Second Generation Wavelet Transform and put forward an image fusion algorithm high frequency coefficients according to different frequency domain after wavelet. In choosing the low-frequency coefficients, the concept of local area variance was chosen to measuring criteria. In choosing the high frequency coefficients, the window property and local characteristics of pixels were analyzed. Finally, the proposed algorithm in this article was applied to experiments of multi-focus image fusion and complementary image fusion. In this a hardware implementation of a real-time fusion system is proposed. The system is based on Xilinx Spartan 3 EDK FPGA and implements a configurable linear pixel level algorithm which is able to result in color fused images using System C language.

*Kanaka Raju Penmetsa et al.* [15] proposed a DT-CWT method which is used in de-noising of colour images. CDWT is a form of DWT in which complex coefficients (real and imaginary parts) are generated by using a dual tree of wavelet transform. The experiments on a amount of customary colour images carried out to approximate performance of the proposed method. Outcome shows that the DT-CWT method is better than that of DWT method in terms of image visual eminence. Patil Gaurav Jaywantrao et al. [16] proposed the novel relevance of the shift invariant and directionally discerning Dual Tree complex Wavelet Transform (DT-CWT) to image fusion is now introduced. The flourishing fusion of images acquired from assorted modalities or instruments is of great significance in many applications such as medical imaging, infinitesimal imaging, remote

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sensing and robotics. With 2D and 3-D imaging and image indulgence becoming widely used; there is a growing need for novel 3-D image fusion algorithms accomplished of combining 2D & 3-D multimodality or multisource images. Such algorithms can be used in areas such as 2D & 3-D e.g. fusion of images in Target tracking system, Synthetic Aperture Radar (SAR) etc. In case of target tracking system the time is the very vital factor. So we take time as a comparison factor to compare unlike methods which we execute. In order to get better the competence of the project, a far time for the fusion to scuttle is being formulated.

*Pavithra C et al.* [17] presented a method for fusing two dimensional multi-resolution 2-D images using wavelet transform under the combine gradient and smoothness criterion. The usefulness of the method has been illustrated using various experimental image pairs such as the multi- focus images, multi-sensor satellite image and CT and MR images of cross-section of human brain. The results of the proposed method have been compared with that of some widely used wavelet transform based image fusion methods both qualitatively and quantitatively. An experimental result expose that the proposed method produces better fused image than that by the latter. The use of mutually gradient and relative smoothness criterion ensures two fold effects. While the gradient criterion ensure that edges in the images are included in the fused algorithm, the relative smoothness criterion ensures that the areas of uniform intensity are also incorporated in the fused image thus the effect of noise is minimized. It should be noted that the proposed algorithm is domain-independent.

*Hasan Demirel et al.* [18] Complex Wavelet Transform (CWT) is used in image processing. CWT of an image produces two complex-valued low-frequency sub-band images and six complex valued high-frequency sub-band images. DT-CWT decomposes original image into different sub-band images. Then high frequency sub-band images and original low frequency image are undergoes the interpolation. These two real-valued images are used as the real and imaginary components of the interpolated complex LL image, respectively, for the IDT-CWT operation. This technique does not interpolate the original image but also interpolates high frequency sub-band image resulting from DT-CWT. The final output image is high resolution of the original input image. Quality and PSNR of the super resolved image is also improves in this method. There are some problems with wavelet domain also, it introduces artifacts like aliasing, any wavelet coefficient processing upsets the delicate balance between forward and inverse transform leading to some artifacts in the images. Also constructs lack of directional selectivity substantially make difficult modelling and processing of geometric image features like ridges and edges. One resolution to all these problems in Complex Wavelet Transform (CWT). CWT is only somewhat like magnitude or phase, shift invariant and free from aliasing.

*Singh R.et al.* [19] proposed a new weighted fusion scheme using Daubechies complex wavelet transform (DCxWT). Shift sensitivity and lack of phase information in real valued wavelet transforms motivated to use DCxWT for multimodal medical image fusion. It was experimentally found that shift invariance and phase information properties improve the performance of image fusion in complex wavelet domain. Therefore, we used DCxWT for fusion of multimodal medical images. To show the effectiveness of the proposed work, we have compared our method with existing DCxWT, dual tree complex wavelet transform (DTCWT), discrete wavelet transform (DWT), non-sub contourlet transform (NSCT) and contourlet transform (CT) based fusion methods using edge strength and mutual information fusion metrics. Comparison results clearly show that the proposed fusion scheme with DCxWT outperforms existing DCxWT, DTCWT, DWT, NSCT and CT based fusion methods.

*Bull D.R. et al.* [20] presented a new approach to 3-D image fusion using a 3-D separable wavelet transform. Several known 2-D WT fusion schemes have been extended to handle 3-D images and some new image fusion schemes (i.e. fusion by hard and soft thresholding, composite fusion, fusion of the WT maxima graphs) have been proposed. The goal of this paper is to present the new framework for 3-D image fusion using the wavelet transform, rather than to compare the results of the various fusion rules. Wavelet transform fusion diagrams have been introduced as a convenient tool to visually describe different image fusion schemes. A very important advantage of using 3-D WT image fusion over alternative image fusion algorithms is that it may be combined with other 3-D image processing algorithms working in the wavelet domain, such as `smooth versus textured' region segmentation, volume compression, where only a small part of all wavelet coefficients are preserved, and volume rendering, where the volume rendering integral is approximated using multi-resolution spaces. The integration of 3-D WT image fusion in the broader framework of 3-D WT image processing and visualisation is the ultimate goal of the present study.

*Ai Deng et al.* [21] presented a new algorithm based on discrete wavelet transform (DWT) and canny operator from the perspective of the edge detection. First make original images multi-scale decomposed using DWT, and then acquire the level, vertical as well as diagonal edge information by detecting low-frequency and high-frequency components' edges. Where after carry out a comparison of the energy of each pixel and consistency verification to more accurately determine the edge points and ensure the clarity of the fusion image. The comparison between the traditional method and this new method is made from the three aspects: independent factors, united factors and comprehensive evaluation. The experiment proved the usefulness of the method, which is able to keep the edges and obtain better visual effect.

The advantages and disadvantages of the proposed method are described in table 1 below

*Table 1*

| S. No. | Authors | Approaches | Merits | Demerits |
|---|---|---|---|---|
| 1 | Kanisetty Venkata Swathi et al. | Daubechies wavelet transform | It is able to manage different images resolution | It consider only wavelet coefficient value |
| 2 | J. Srikanth et al. | Wavelet Transform | It reduces the storage cost | Not able to maintain edge information efficiently |
| 3 | Ch.Bhanusree et al. | Second Generation Wavelet Transform | It is multi scale dimensionality | It has poor directionality |
| 4 | Kanaka Raju Penmetsa et al. | DT-CWT method | Image visual eminence is better | Has limited directionality |
| 5 | Patil Gaurav Jaywantrao et al. | Dual Tree complex Wavelet Transform (DT-CWT) | It is more flexible and better image visibility and reduces the time variant | It introduce artifacts like aliasing |
| 6 | Pavithra C et al. | wavelet transform using gradient and smoothness criterion | It is able to retain the edge information also minimize the noise | It is domain-independent |
| 7 | Hasan Demirel et al. | Complex Wavelet Transform (CWT) | magnitude or phase, shift invariant and free from aliasing | Most expensive and computational intensive |
| 8 | Singh R.et al | weighted fusion scheme using Daubechies complex wavelet transform (DCxWT) | It is better to retain the edge the information than the DT-CWT | Not able to achieve the expected performance |
| 9 | Bull D.R. et al. | 3-D separable wavelet transform | It is able to enhance the quality of 3-D image | Poor selectivity for diagonally |
| 10 | Ai Deng et al. | discrete wavelet transform (DWT) | It effectively reduce the noise from image | It is a shift- invariant in nature |

## IV. Conclusion

To acquire the crucial features or attributes of the images of common features image fusion is widely used technology. The wavelet transform is one of the most efficient approaches to extract the features by the transformation and decomposition process but this method is not efficient to retain the edge information. In this paper literature study of the fusion techniques is described with their shortcoming. In future work, design such algorithm which can efficiently retain the edge information.

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