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# REVIEW ON IMAGE FUSION TECHNIQUE

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***Abstract***-Today in this digital world image fusion is the most emerging field in the area of image processing. Its main objective is to combine two or more images in such a way as to retain the most desirable characteristics of each in resultant image. This paper discus a review on some of the image fusion techniques (simple average, simple minimum, simple maximum, PCA, DWT) and literature of the image fusion with wavelet transform is discussed with its merits and demerits. Comparison of all the techniques concludes the improved approach for its future research. In this paper also discussed the application of the image fusion in the various field image quality assessment parameters such as, mean, , entropy standard deviation, root mean squared error, mean squared error  Peak signal to noise ratio, signal to noise ratio.

**Keywords—**Image fusion, Magnetic resonance imaging Principle Component Analysis, Computed tomography component; The Discrete Wavelet, Pyramid Decomposition Fusion Algorithm

## 1. INTRODUCTION

In the image processing, the image fusion is one of the major fields. Image Fusion is a method of combining the appropriate information from a set of images into a single image, and then the resultant fused image will be present complete and  more information than any of the input images. Image fusion is defined as the collection of information from a number of registered images without the noise.  It is not possible to have a single image that provide the complete information, so image fusion is required. [1].The general meaning of word fusion is an approach to obtain information that is in several domains [2]. Image Fusion is a procedure to improve quality of information from a set of images [3].In the area of biomedical imaging, two modalities are used  that is the magnetic resonance imaging (MRI) and the computed tomography (CT).The CT scan is especially appropriate for imaging bone structure and tough tissues, the MR images are much better in depicting the soft tissues in the brain that play important roles in detecting diseases affecting the skull base.. The advantages of these images may be fully accomplished by integrating the related features seen in different images through the of technique of image fusion that creates a image with features that are best representative in the individual image [4].  The main objective of the paper is to review the image fusion technique. The basic idea of image fusion shown in figure [5].

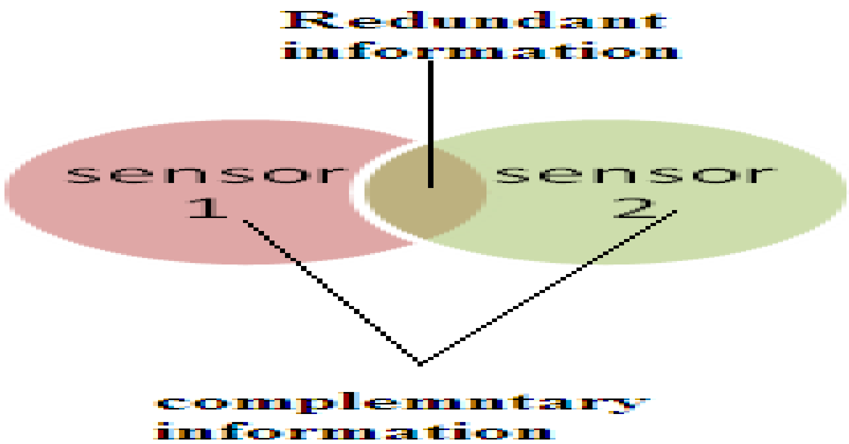


**Fig. 1.1  Image Fusion**

This paper is organized as follows:
Section II gives background of image fusion
Section III gives image fusion technique
.Section IV gives related work of image fusion
Section V gives performance measures of image fusion
Section V1comparision between various techniques of image fusion
Section VII gives the application of image fusion
Section VIII gives the conclusion

## 2. BACKGROUND OF IMAGE FUSION

Image fusion algorithms can be divided into different level:-low, middle, and high; or pixel, feature, and decision levels.

### 2.1 Pixel level

Pixel level fusion used for having high quality raw images. The pixel-level method works either in the spatial domain or in the transform domain. In the pixel level fusion, the input images are fused pixel by pixel followed by the information extraction. Arithmetic operations are widely used in time domain and frequency transformations. Frequency domain is used to implement the pixel level fusion. The main aim of pixel level fusion is to enhance the raw input images and generate an output image with more useful information than either input image. The disadvantage of pixel level fusion is that it is not applicable for images with unbalanced quality level. [6]

### 2.2 Feature level

In feature level fusion, the information is get from each input image separately and then information is fused based on features from input images. Feature-extraction algorithm is requiring effective for both physical channels. The feature detection is typically achieved by using edge enhancement algorithms [6].

### 2.3 Decision level

If two above used fusion techniques are compare then we come to know that decision level fusion is enhanced because the information is extract from all input image individually in the decision level and then decisions are made for each input channel. Decision level fusion is effective for difficult systems with multiple true or false decisions but not appropriate for common applications. At the last, those decisions are fused to form the final decision [6]

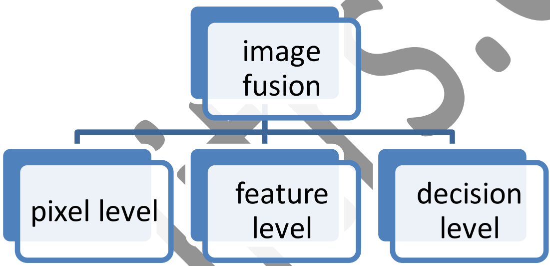


**Fig. 2.1 Three Levels of Image Fusion**

## 3. IMAGE FUSION TECHNIQUES

Image fusion techniques can improve a digital image without harm it. The enhancement methods are of two types namely frequency domain methods and spatial domain methods. In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to attain desired enhancement [1].
There are two image fusion methods:

- Spatial Domain Fusion Method
- Transform Domain Fusion Method

Image Fusion techniques can be sub divided in three different types of techniques that are, Simple fusion techniques, Principal Component Analysis (PCA) based Fusion, Discrete Wavelet Transform (DWT) based fusion and Pyramid based image fusion methods as shown in figure 3 as below [1].

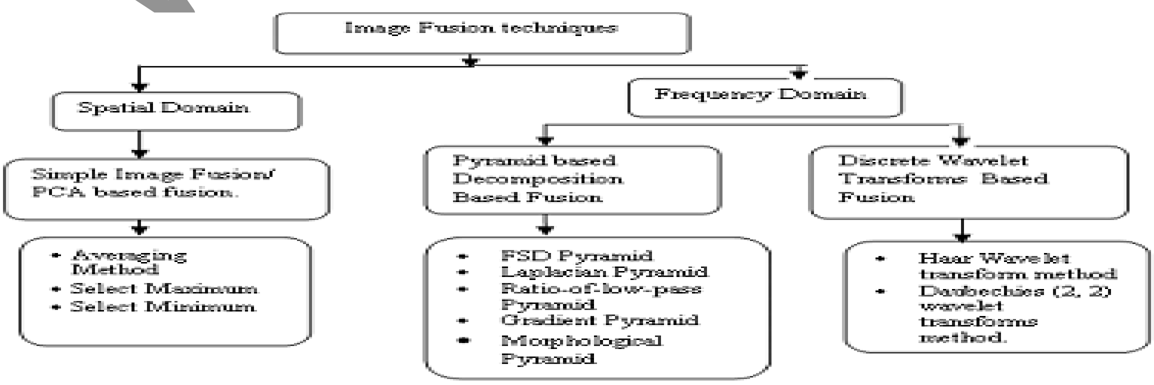


**Fig. 3.1 Categorization of Image Fusion Techniques (ref[ 1])**

### 3.1 Spatial Domain Fusion Method

In his technique, directly deal with the image pixels. The pixel values are manipulated to get desired enhancement.

#### 3.1.1 Simple Fusion Algorithms

Simple Fusion Algorithms mainly perform a very fundamental operation like pixel selection, averaging, addition, and subtraction.

##### 3.1.1.1 Average Method

Average method is that in which averaging every corresponding pixel in the input image.
This is repeated for all pixel values.[8]. The average value is assigned to the equivalent pixel of the output image which is given in below equation [7]

$$\mathbf{K}\ (\boldsymbol{i},\boldsymbol{j}) = \{\boldsymbol{X}(\boldsymbol{i},\boldsymbol{j}) + \boldsymbol{Y}(\boldsymbol{i}.\boldsymbol{j})|\mathbf{2}\} \qquad 3.1$$

Where X (i, j) and Y (i, j) are two input images

##### 3.1.1.2 Select Maximum/Minimum Method: -

In this method, for every equivalent pixel in the input images, the pixel with max/min intensity is elected, respectively, and is put in as the output pixel of the fused image [8].

$$\mathbf{P}\ \mathbf{(i,j)}= \sum_{i=0}^{m}\sum_{j=0}^{n} \mathbf{max}\, \boldsymbol{A}(\boldsymbol{i},\boldsymbol{j})\ \boldsymbol{B}(\boldsymbol{i},\boldsymbol{j}) \qquad 3.2$$

Where A (i, j) and B (i, j) are the input images & P (i, j) is the resultant image. [7]

##### 3.1.1.3 Principle Component Analysis (Pca)

In the Principle Component Analysis technique, the numbers of correlated variables are transformed into number of uncorrelated variables [8].Information flow diagram shown in figure[8]

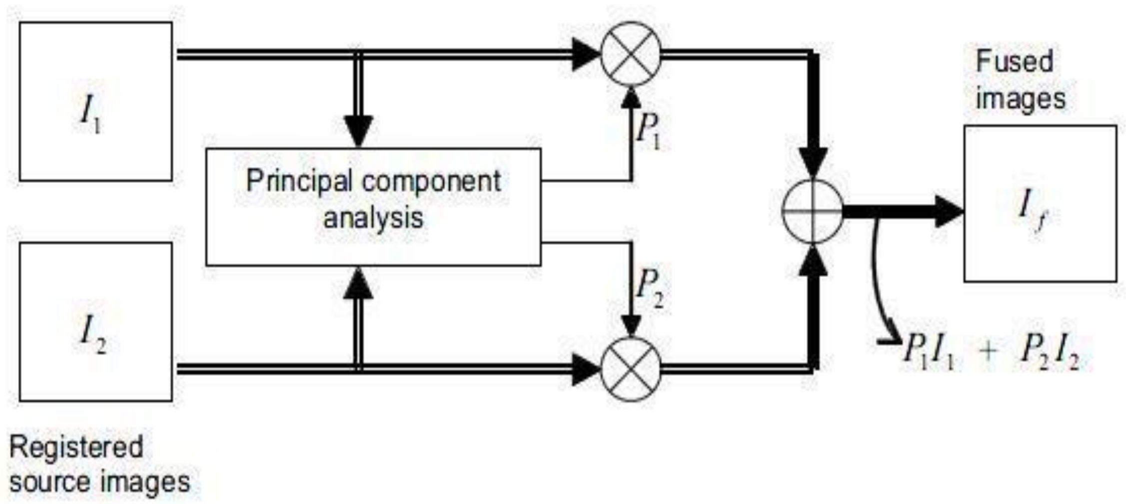


**Fig. 3.2 Information Flow Diagram of PCA(ref [8])**

The fused image in PCA method is [12]

$$\boldsymbol{P}(\boldsymbol{x},\boldsymbol{y}) = \boldsymbol{P_1}\boldsymbol{I_1}(\boldsymbol{x},\boldsymbol{y}) + \boldsymbol{P_2}\boldsymbol{I_2} \qquad 3.3$$

### 3.2 Pyramid Decomposition Fusion Algorithm

An image pyramid is a set of low pass or band pass copies of an image and each copy representing pattern information of a dissimilar scale. At every level of fusion using pyramid transform, the pyramid would be half the size of the pyramid in the earlier level and the higher levels will focus upon the lower spatial frequencies. The fundamental idea for pyramid decomposition is firstly, the source images are fused through the pyramid transform and then the fused image is obtain by using inverse pyramid transform [8]
Typically, every pyramid transform consists of three main phases:
1. Decomposition
2. Formation of the initial image for recomposition.
3. Recomposition

### 3.2.1Types of The Pyramid Decomposition Fusion Algorithm

#### 3.2.1.1 Filter Subtract Decimate Pyramid

In this method the decomposition phases have three main steps [8]

- Low pass filtering using W =. [ $\frac{1}{16}$ $\frac{4}{16}$, $\frac{6}{16}$, $\frac{4}{16}$, $\frac{1}{16}$]
- 2. Now, Subtract the low pass filtered input images and form the pyramid
- Decimate the input image matrices by divide the number of rows and columns.

The recomposition phase would include steps:-

- Undecimating the image matrix by duplicate every row and column
- Low pass filtering with 2*W
- Matrix addition of the same with the pyramid formed in the related level

#### 3.2.1.2 Laplacian Pyramid

The Laplacian pyramidal method is like to FSD pyramid except for an supplementary low pass filtering performed with 2*W . All the additional steps are similar as in FSD pyramid [8].

#### 3.2.1.3 Ratio Pyramid

The Ratio pyramidal method is also similar to FSD pyramid but in the decomposition phase, after low pass filtering the input image matrices; calculate the pixel wise ratio

#### 3.2.1.3Gradient Pyramid:-

In the decomposition process [8] two low pass filters are used W =.[ $\frac{1}{16}$ $\frac{4}{16}$, $\frac{6}{16}$, $\frac{4}{16}$, $\frac{1}{16}$] and V =[ $\frac{1}{4}$, $\frac{2}{4}$, $\frac{1}{4}$]

#### 3.2.1.4 Morphological Pyramid Fusion

Morphological Pyramid is the multi-resolution techniques. It is introduced by Burt and Adelson etc. normally use low or band pass filters as part of the procedure. These filtering operations usually modify the details of shape and the accurate position of the objects in the image. This difficulty has been addressed by using morphological filters to eliminate the image details without adverse effects. [9]

### 3.3 Transform Domain Fusion Methods

#### 3.3.1 Wavelet

A wavelet is defined as that it is a wave-like oscillation with an amplitude that begins at zero, increases, and then decreases back to zero. It can also be said a "small oscillation" like one might see recorded by a seismograph or heart monitor [12].Wavelets are finite duration oscillatory functions and average value is zero. The unpredictability and good localization properties make them better-quality basis for analysis of signals with dis-continuities. Wavelets can be described by using two functions [13]

- Scaling function f (t), also known as father wavelet
- 2- Wavelet functions or mother wavelet ψ (t)
- Mother wavelet ψ (t) undergoes translation and scaling operations to give self-similar wavelet families

A wavelet is a waveform of adequately limited duration that has an average value of zero. The wavelet transform of a signal is shown in fig (4) [14]

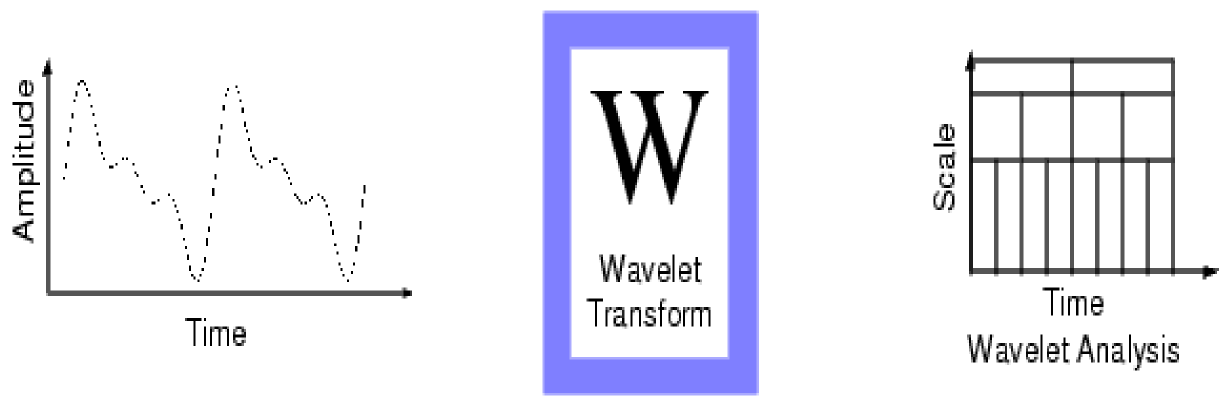


**Fig. 3.3 Wavelet Transform on a Signals (ref[14])**

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Wavelet is a small wave that satisfies the two main properties [15]:

(i) Time:-time integral must me zero

$$\int_{-\infty}^{\infty} \varphi(t)dt = 0 \qquad 3.4$$

(ii) Square of wavelet integrated over time is unity (1)

$$\int_{-\infty}^{\infty} \varphi^2(t)\ dt=1 \qquad 3.5$$

### 3.3.2 The Discrete Wavelet Transform (DWT)

The Discrete Wavelet Transform (DWT) of image signals presents a non-redundant image representation. DWT provides superior spectral and spatial localization of image information compared with other multi level representation. The DWT can be explained as signal decomposition in a set of autonomous, spatially oriented frequency channels. The signal is passed through two corresponding filters and develops as two signals, approximation and Details. This is called decomposition or analysis. Elements can be assembled back into the original signal without overcome of information. This procedure is called reconstruction or synthesis or fusion [11].

#### 3.3.2.1 Image Decomposition:

In the wavelet decomposition process, split the approximation coefficients into two parts. After dividing we get a vector of detail coefficients and a vector of approximation coefficients.. The information lost between two successive approximations is get  in the detail coefficients. Then the next step consists of dividing the new approximation coefficient vector, successive details are not again reanalyzed [18].The figure shown the image decomposition using wavelet transform [12].

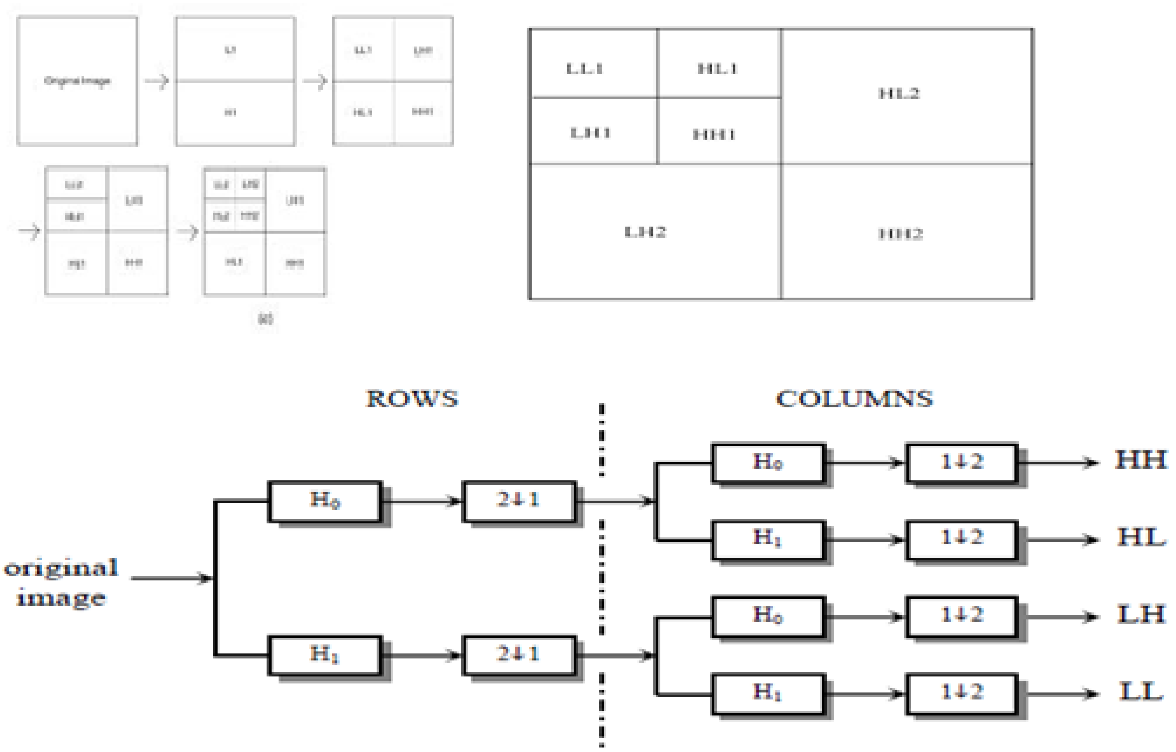


**Fig. 3.4  Image Decomposition using Wavelet Transform(ref[12])**

LL = Horizontal low and Vertical low frequency component.
LH = Horizontal low and Vertical high frequency component.
HL = Horizontal high and Vertical low frequency component.
HH = Horizontal high and Vertical high frequency component

**3.3.2.2Reconstruction of an Image**

The information flow diagram in one level of 2-D image reconstruction is shown in figure 2. [12]

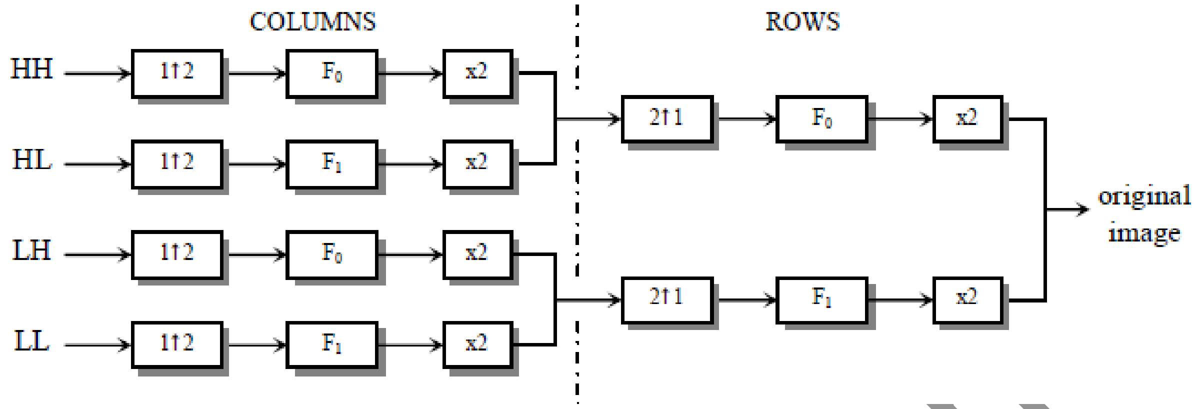


**Fig. 3.5 Image Decomposition Using Wavelet Transform(ref[12])**

**3.3.2.3 Block Diagram of DWT**

The figure 3 shows the main blocks and flow of fusion process using DWT [11]

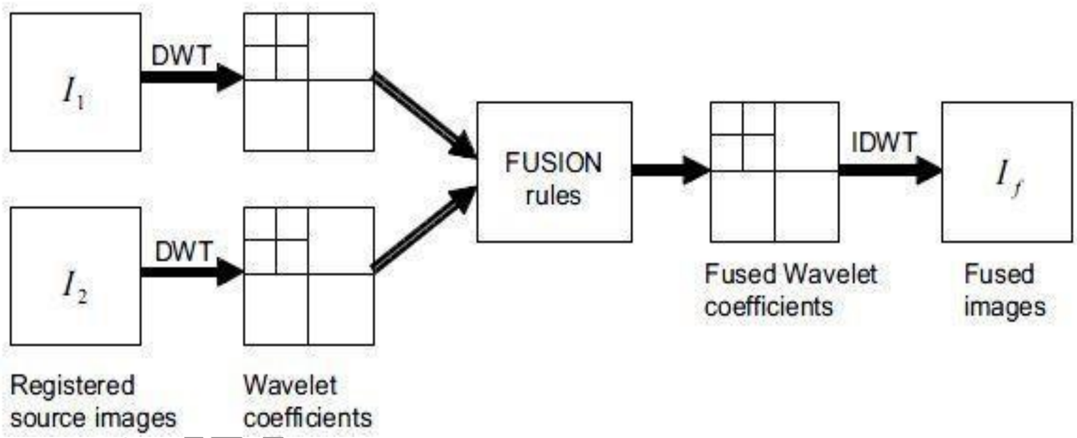


**Fig. 3.6 Information Flow of DWT (ref [11])**

**3.3.2.4 Stage Filtering: Approximations and Details**

Approximations and details are the most significant terms in wavelet analysis. The approximations have the low-frequency, high-scale components of the signal. The details have the high-frequency, low-scale components. The basic level filtering shown in figure [12]

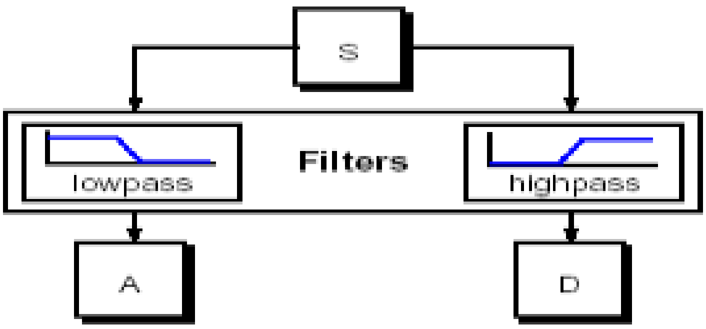


**Fig. 3.7 Basic level filtering (ref[12])**

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**3.3.2.4 Reason**

The wavelets-based approach is applicable for performing fusion tasks for the following reasons [3]:

- It is a multi scale (multi resolution) approach well suitable to manage the different image resolutions.
- The discrete wavelets transform (DWT) allows the image decomposition in unrelated type of coefficients preserving the image information. Such coefficients coming from different images can be properly combined to obtain new coefficients so that the information in the original images is collected properly.
- Once the coefficients are combined then with the help of inverse wavelet transform final fused image is achieved.

**3.3.3 Wavelet Families**

MATLAB has different types of wavelets as follows [15]:

- Haar
- Daubechies
- Biorthogonal
- Coiflets-
- Symlets –
- Morlet
- Mexican
- Meyer wavelets-

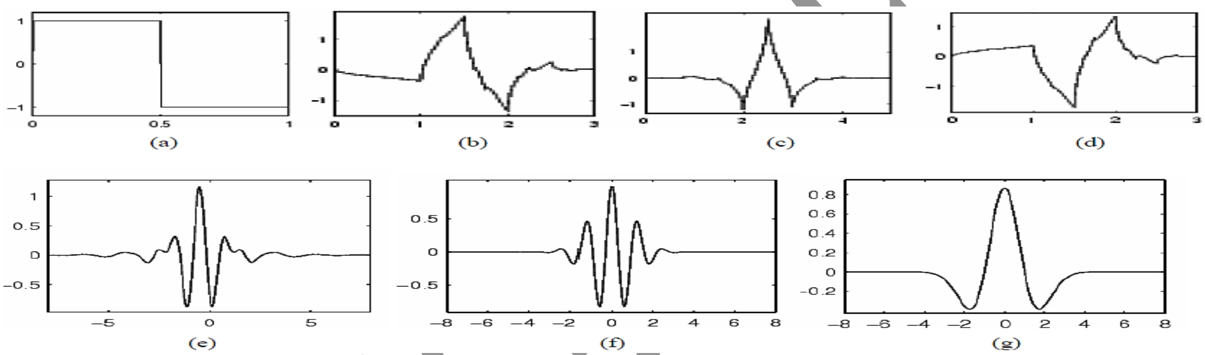

**Fig. 3.8 Wavelet families(a)Haar(b)Daubechies4(c)Coiflet1(d)Symlet2(e)Meyer(f)Morlet(g)Mexican (ref[15])**

## 4. Related Work of Image Fusion

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

**Table 4.1 (Related Work Of Image Fusion)**

| S. No. | Authors | Approaches | Merits | Demerits | Related work |
|---|---|---|---|---|---|
| 1 | Deepali Sale et al. | Wavelet transform | Provide good contrast of an image Contrast of the images. it can enhance the linear edges | Not enhance the curved edges. | [5] |
| 2 | Kusum Rani et al. | Wavelet transform | Multiwavlet gives fine edge and boundary Details. | Not provide the best result. | [9] |
| 3 | Ashishgoud Purushotham et al. | Wavelet transform | Provide good spectral quality | Suffers from noise and has low accuracy for curved edges. | [11] |

| | | | | | |
|---|---|---|---|---|---|
| 4 | Kanisetty Venkata Swathi et al | Daubechies wavelet transform | It is able to manage different images resolution | It consider only wavelet coefficient value | [16] |
| 5 | Kanwaljot Singh Sidhu et al. | Haar And DB3 wavelet | it enhances the visual quality of the images | haar wavelet not provide better quality of an image | [17] |
| 6 | R.J.Sapkal et al. | Wavelet transform | Provide good spectral quality | The wavelet transform provide some noise and has low accuracy for curved edges. | [18] |
| 7 | J. Srikanth et al. | Wavelet Transform | It reduces the storage cost | Not able to maintain edge information efficiently | [19] |
| 8 | 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 | [20] |
| 9 | Ms. Sulochana T1[22] | Wavelet transform | Provide higher PSNR ration | Not provide better result. Difficult to implement | [21] |
| 10 | Ch.Bhanusree | Second Generation Wavelet Transform | It is multi scale dimensionality | It has poor directionality | [22] |
| 11 | Kanaka Raju Penmetsa et al. | DT-CWT method | Image visual eminence is better | Has limited directionality | [23] |
| 12 | Patil Gaurav Jaywantrao et al. | Dual Tree complex Wavelet Transform (DT-CWT) | It provide superior image visibility and reduces the time variant.and more flexible. | It introduce artifacts like aliasing | [24] |
| 13 | Hasan Demirel et al | Complex Wavelet Transform (CWT) | magnitude or phase, shift invariant and alising free | Most expensive and computational intensive | [25] |
| 14 | 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 | [26] |
| 15 | Ai Deng et al. | discrete wavelet transform (DWT) | It effectively reduce the noise from image | It is a shift- invariant in nature | [27] |

## 5. PERFORMANCE MEASURES

The performance measures used in this paper present some quantitative comparison among different fusion schemes, mainly aiming at measuring the definition of an image[28].

***5.1* Mean**

It measures the mean value of the pixels in the image.

$$\textbf{Mean}=\frac{1}{N}\sum_{1}^{N} x_i \qquad 5.1$$

Where,

N=Total number of pixels in the image

$x_i$ =Value of the *i*th pixel

**5.2 Standard Deviation (SD)**

The standard deviation of gray image reflects its clarity and contrast. The increase in standard deviation indicates that the

image is becoming "noisier". The smaller the image contrast, the more affected by noise.

The Standard Deviation (SD) is

$$\sigma_x = \sqrt{\frac{1}{MN-1}\sum_{j=1}^{N}(x(i,j)-\bar{x})^2} \qquad 5.2$$

Where,

x= input image

$\sigma_x$= Standard Deviation of the image

**5.3 Entropy (H)**

Entropy is the information richness which indicates the average information amount contained in the image. Entropy is greater, the greater the quantity of information carried by the fusion image, information richer. It does not measure the similarity of fused image and source image. The larger the value of entropy, better the fusion results

$$\textbf{H}= -\sum_{i=1}^{L} P_i \log(P_i) \qquad 5.3$$

Where,

$P_i$= probability of the occurrence of *i*

**5.4 Root Mean Square Error (RMSE)**

This is used to evaluate the fused image. It presents the amount of deviation present in the fused image compared to reference image. Let be the fused image, is the input image, then

$$\textbf{RMSE}=C \qquad 5.4$$

Where i and j denotes the spatial point of pixels while M and N are the dimensions of the image

**5.5 Peak Signal to Noise Ratio (PSNR*)***

The peak signal to noise ratio PSNR is the ratio between the max value of an image and the magnitude of background noise and is commonly used as a compute the quality of reconstruction in image fusion. It indicates the similarity between two images. The higher value of PSNR the better is the fused image is

$$\textbf{PSNR=10log 10[}\frac{2^n-1)^2}{MSE} \qquad 5.5$$

**5.6 Mean Square Error (MSE)**

It is one of the frequently used measures to capture the deviations between the original and the fused image. It is computed by finding the squared error divided by the total number of pixels in the image. The spatial distortions introduced by the fusion process are measured by MSE. The smaller the value of the error metric, the better the fused image represents the original input image. But it cannot capture the artifacts like blur or blocking artifacts.

$$\mathbf{MSE}=\frac{\sum_{i=1}^{M}\sum_{i=1}^{N}[(I(i,j)-F(i,j)]^{2}}{M\times N} \qquad 5.6$$

Where,

MSE= Mean Square Error
I (i, j) = original image
F (i, j) =fused image
M× $N$= size of the image

**5.7 Signal to Noise Ratio (SNR)**

The SNR is the quantitative description of the quality of the information carried by the radiographic images. The SNR is the measure between the fused and the original image. It measures the ratio between the information and the noise of the fused image. The higher the ratio the less background noise is. It is calculated using the equation,

$$\mathbf{SNR}=\mathbf{10log\ 10}\left(\frac{\sum_{i=1}^{M}\sum_{i=1}^{N}(I(i,j)-F(i,j)^{2}}{\sum_{i=1}^{M}\sum_{i=1}^{N}(i,j)}\right) \qquad 5.7$$

Where,

I (i.j) = original image
F (i, j) = fused image
M, N= size of the image I.

## 6. COMPARISON BETWEEN VARIOUS FUSION TECHNIQUES

The table 6.1 shown the comparison between various image fusion technique [1] [3]

**Table-6.1** (Comparison Between Various Fusion Techniques)(ref[1][3)

| S.No | Fusion Technique/ Algorithm | Domain | Measuring parameter | Advantages | Disadvantages |
|---|---|---|---|---|---|
| 1 | Simple Average | Spatial | PSNR-25.48<br>EN-7.22 | Implementation is very simple. | Not provide the clear resultant image |
| 2 | Simple Maximum | Spatial | PSNR-26.86<br>EN-7.20 | Fused image is highly focused image | More blurring effect. |
| 3 | PCA | Spatial | NC-0.99<br>PSNR-76.44 | PCA is a technique which transforms number of correlated variable into number of uncorrelated Variables, this property can be used in image fusion. | spatial domain fusion may produce spectral degradation |
| 4 | DWT | Transform | NC-0.998<br>PSNR-76.44 | Minimizing the spectral Distortion.It provide better signal to noise ratio. | Fused image is less spatial Resolution |
| 5 | Combine DWT, PCA | Transform | PSNR-67.08<br>EN-7.24 | Provide improved result . | Complex in fusion Algorithm. |
| 6 | Combination of Pixel & Energy Fusion rule | Transform | PSNR=27.75 | Preserves boundary information and and much better result then pixel level. | Complexity of Method increases. |

# 7. APPLICATIONS OF IMAGE FUSION

- Intelligent Robots
- Medical Image
- Military Law enforcement
- Remote Sensing

### 7.1Related Research Fields of Image Fusion

- Automatic object detection
- Image processing
- Parallel and distributed processing
- Robotics sensing
- Remote sensing

## CONCLUSIONS

In this paper reviewed different image fusion techniques. Each technique has its own merits and demerits. These techniques enhance the clarity of the image to some extent but it has been shown that most of the techniques suffer from the problem of color artifacts and roughness of edges of the image. This review results shows that the Spatial domain provides more Spatial resolution and easy to perform, but they have image noise and blurring problem and their outputs are less informative. The Spectral domain techniques are very good techniques for the image fusion and provide a high quality Spectral content, but they exhibit a less Spatial resolution.

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