Image Fusion Techniques-A Comparative Study

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Abstract *— Image fusion is the process of combining relevant information from two or more images into a single image which contains more information than any of the input images. Merging of two or more images produces high resolution multispectral image as it maximizes the relevant information from input images of a scene into a single composite image by reducing uncertainty which further minimize redundancy in the output. In this paper a review has been made on different techniques of image fusion. It includes classification of Image Fusion techniques like Spatial Domain and Frequency Domain which are further classified as Simple Average, Minimum, Maximum, Intensity Hue Saturation, Principle Component Analysis, Laplacian Pyramid, Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Integer Lifting Wavelet Transform.*

Keywords—*Image Fusion, Spatial Domain, Transform Domain, Pyramid Decomposition, Medical Imaging, Remote Sensing.*

I. INTRODUCTION

With the rapid development in high-technology and modern instrumentations, image fusion has become a vital component of a large number of applications which include medical applications, remote sensing, surveillance and navigation. The demand of Image Fusion has been drastically increased due to limitation of improper image capturing, lack of clarity and quality of different scenes [1][19]. Fusion is the process of the result of joining two or more things together to form a single entity. In a similar manner joining or merging of two or more images either captured from different sensors, acquired at different times or having different spatial and spectral characteristics is known as image fusion [2]. Hence image fusion is defined as the process that combines information from multiple images of same scene into a single image which describes the scene better and retains useful information from the input images [3][20]. Image fusion has been receiving increasing attention in the researches for wide spectrum of applications. The image obtained is more informative and is more suitable for various applications like visual perception, computer processing, medical imaging, and remote sensing [4]. This technique thereby improves the quality and applicability of data. This process of getting more information improves the performance of image analysis algorithms used in different applications. The main purpose of image fusion is to remove distortion and to overcome distortion a series of images with different focus settings are acquired and then they are fused together to produce an image which has extended depth of field. .Image registration is one of the important pre-processing step for the fusion i.e. transformation of co-ordinate of one image w.r.t. other [5].

II. CATEGORIZATION OF IMAGE FUSION ALGORITHM

Image fusion can be performed roughly at four different stages: signal level, pixel level, feature level and decision level.

1. ***Signal level fusion:*** It is defined as the process in which signals from different sensors are combined to obtain a new signal which has better signal to noise ratio than original signal.
2. ***Pixel level fusion: -*** **I**t is one of the basic levels of fusion in which pixel by pixel operation is performed on collective information from different images. To improve the performance analysis of different images from same scene is performed.
3. ***Feature level fusion:***- This method of image fusion is also known as intermediate level of fusion which requires extraction of salient features like edges, shape, pixel intensities from input images
4. ***Decision level fusion:*** Decision level is a high level of fusion in which input images are processed individually for information extraction. The information received is then processed by applying decision rule to reinforce common interpretation

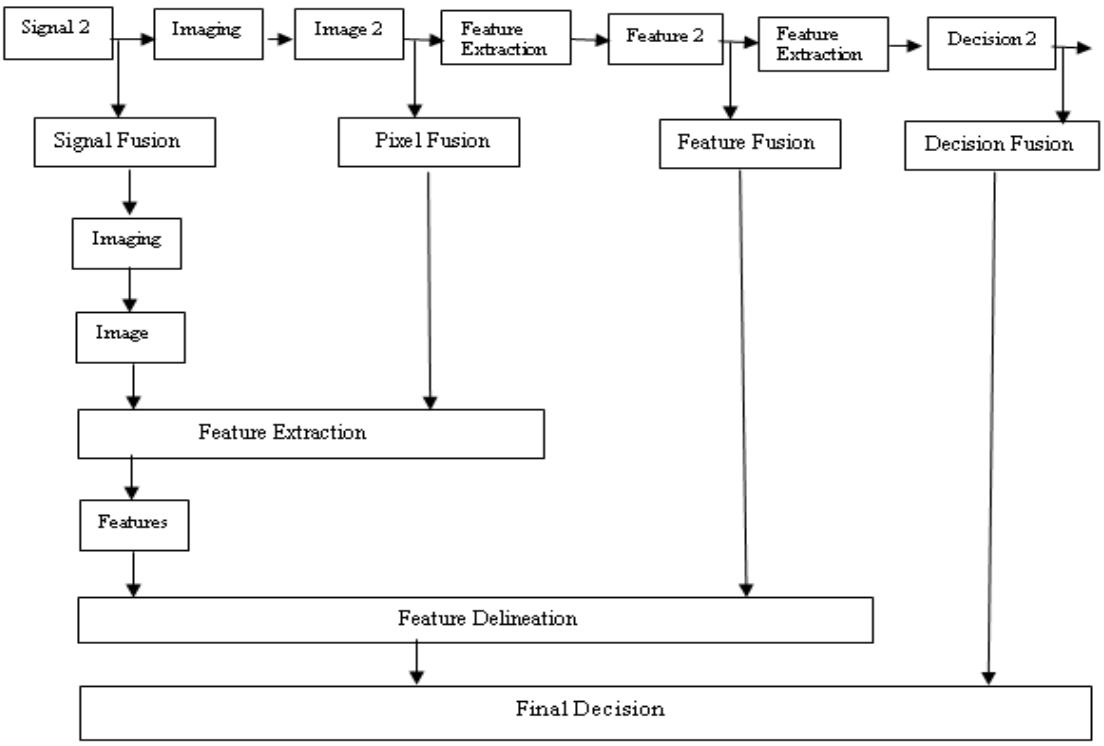

Fig. 1. Categorization of the fusion algorithms

III. IMAGE FUSION TECHNIQUES

There are many techniques available which help in enhancing the quality of image without spoiling it. Image fusion research work started with spatial domain techniques such as averaging, Select maximum and PCA. Then it was soon succeeded by frequency domain techniques. Figure 2 illustrates various types of image fusion techniques [3]

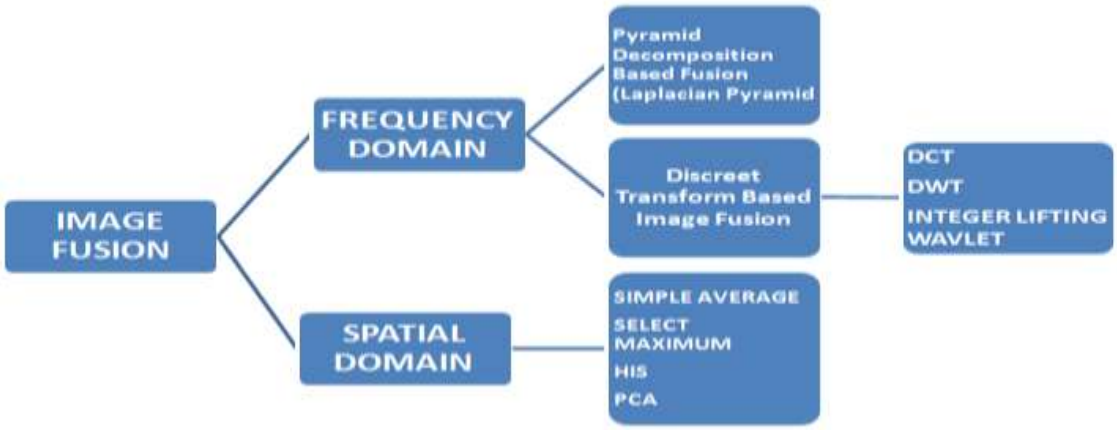

Fig 2 Classification of Image Fusion Techniques

1. Spatial Domain techniques: - In spatial domain techniques, we manipulate the image pixels directly to achieve the desired operation. The fusion techniques such as averaging, select maximum, PCA, HIS falls under spatial domain approaches [5].

A. Simple average: **-** It is the simplest method of image fusion technique. In this fused image is obtained by averaging the input pixels. The region of images which are in focus has higher pixel intensity. Thus with the help of this algorithm we can obtain an output image with all regions in focus [6][7]. The value of the pixel P (i,j) of source images are added and divided by 2 to obtain average value which is assigned to the corresponding pixel of output image using equation (1). The same process is repeated for all pixel values.

$$f(i,j) = \{X(i,j) + Y(i,j)\}/2 \quad \text{..... (1)}$$

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

B. Select maximum method:-Since we know that a single image does not focus on all regions in a scene and the regions which are in more focus has higher pixel values. Thus this algorithm selects the maximum intensity of corresponding pixels from source image and assigned to the corresponding pixel [7][8]

$$f(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} maxX(i,j)Y(i,j). \quad \text{.... (2)}$$

Where X (i,j), Y(i,j) are input images and f(i,j) is fused image.

C. IHS: Technique is the earliest technique used for image fusion. Intensity, Hue and saturation are three basic properties of a colour which give visual representation of an image [2]. IHS is a colour space where hue represents wavelength of colour, saturation represents total amount of white light of a colour and intensity relates to the amount of light penetrate in the eye [9]. HIS method is mainly used to fuse Panchromatic (PAN) and Multispectral (MS) images. This method is used to transform red, green and blue values of an image into Intensity, hue and saturation. Then the reverse transform is applied to get RGB image as an output.

The HIS components can be defined as follows:

I = (R+ G+ B)/3 ---------- (1)

H= (B-R)/3(I-R), S=1-R/I,

when R= Minimum (R, G, B) ---------- (2)

H= (R-G)/3(I-G), S=1-G/I,

when G= Minimum (R, G, B) ----------(3)

H= (G-B)/3(I-B), S=1-B/I,

When B= Minimum (R, G, B) ---------- (4)

Where I, H, S stand for intensity, hue and saturation components respectively; R, G, B mean Red, Green, and Blue bands of multi-spectral image.

D. PCA: **-** It is one of the most popular algorithms for image fusion. Despite of being similar to IHS technique PCA is a statistical technique which is used to transform correlated variables into data sets of uncorrelated variables called principal component[1][10]. The first principal component specifies the variance in the data and each succeeding component specify the remaining variance. PCA is extensively used in image classification and data compression. It is also known as Karhunen- Love Transform or Hotelling Transform.

2. Frequency Domain Techniques

Frequency domain techniques are also known as transform domain techniques. In this method, image is first transformed to frequency domain. Then all the operations are performed on modified image, which further manipulates image brightness, contrast etc. and then inverse transform is applied to get the final resultant image. Frequency domain techniques are further classified as Pyramid based fusion techniques and Discreet transform based image fusion. Laplacian pyramid is an example of Pyramid based fusion technique while DCT, DWT, integer lifting wavelet transform fall under discreet transform method.

A. Laplacian Pyramid: **-** The basic principle of this technique is to decompose the input image into pyramid structure [11]. A pyramid structure consists of many levels of source images which are obtained repeatedly by filtering the lower level image with a low pass filter. Now fusion algorithm is applied for each level of the pyramid using feature selection decision method which selects the most significant pattern from the source images and discards the least significant pattern and then inverse pyramid is applied to get resultant fused image [12].

B. DCT: is a technique where fused images are represented in frequency domain. Finite data points of fused images are represented in terms of a sum of cosine functions of different frequencies. This technique find its major application in MPEG, JVT etc.[13] as it reduces the complexity by decomposing the input images into series of waveform. Images to be fused are divided into blocks of size N*N. DCT coefficients are then calculated by different methods. Further IDCT technique is applied on fused coefficient to get fused image. The same procedure is repeated for each block .The following are the fusion rules used to calculate DCT coefficients:-

1. ***Average Coefficients :-*** In this method, DCT coefficients are obtained from different blocks are averaged to get fused DCT coefficients

2. ***Maximum value coefficient:-*** The DCT components from both image blocks are averaged together and largest magnitude of AC coefficients are chosen, since the detailed coefficient correspond to sharpen brightness changes in the images such as edges and object boundaries etc.[3] However, fused image quality

depends on block size. It should not be less than 8*8.

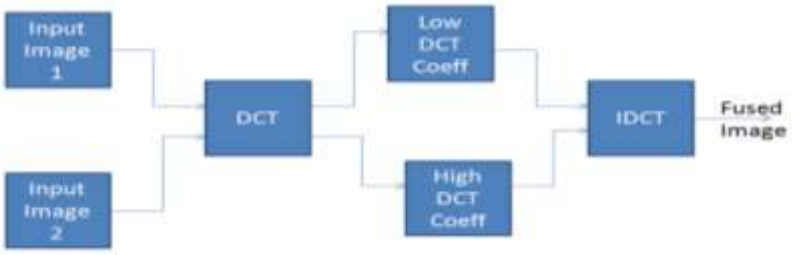

Fig 3: Block Diagram of DCT Fusion Method

C. DWT provides a framework in which input images to be analysed is passed through filter with different cut off frequency at different scales so that images get converted to frequency domain from spatial domain. The resultant output gives the detail coefficient (from the high pass filter) and approximation coefficient (from the low pass filter). It finds application mainly in medical imaging and speech signals. The wavelet transform decomposes the input images into spatial frequency bands of various levels such as low- high, high- low, high- high and low- low groups. Now a general fusion rule is applied to select the coefficients whose values are higher such that most dominant feature is preserved in the multi resolution representation. A new image is formed by performing an Inverse wavelet Transform [1].

D. Integer lifting wavelet transform:-Till now, existing fusion rules are applicable only for fusion of two images. Therefore, fusion algorithm of multiple images based on fast integer lifting wavelet transform is used. This technique is used to calculate wavelet transform as it is faster implementation of wavelet transform. Since earlier techniques involves floating point operations which introduces rounding error due to floating point arithmetic whereas lifting scheme allow us to implement reversible integer wavelet transform.

IV. PERFORMANCE MEASURES: -

The basic requirement of an image fusing technique is that it should be qualitative and classic. Therefore Image fusion technique should be selected in such a way that quality should be sustained. So various performance measures are used which recognize image degradation in comparison to ideal or perfect image [6].Quality assessment can be categorized into two parts. It involves full reference method, where quality is measured with respect to ideal image and No Reference Method, which have no reference image.

1. Full reference methods

a) ***Peak Signal to Noise Ratio:-***The PSNR indicates the similarity between fused image and reference image that affects the fidelity of its representation. The higher the value of PSNR better is the fused image

b) ***Entropy (EN):-*** Entropy is defined as a parameter to measure information contained in fused image. Large value of entropy for fused image indicates more information content than original image.

c) Mean Square Error (MSE):-It is a parameter used to measure image quality of resultant image. Higher the value of MSE means that output image is of poor quality.

d) ***Mutual Information:-*** it calculates the amount of information transferred from the original images to the fused image. The quality is good enough if MI value is large.

2. No reference method:-

a) ***Variance:*** - The variance of image is directly related to variance. It measures the deviation of piel values from the image mean. Image with higher variance have a better contrast for better visualization. But higher value of variance may result because of noise.

b) ***Standard Deviation:*** - It measures the contrast in the fused image. Fused image with higher contrast would have high standard deviation [6].

c) ***Cross Entropy:*** - This method to check quality performance is used to access the performance of fused image when there is no reference image is available It calculates the similarity in information content between input images and fused image. Fused and reference images containing the same information would have low cross entropy.

V. CONCLUSION

This paper reviews a comparative study of various image fusion techniques and a few of image quality assessment parameters. Although selection of fusion technique is application dependent. Therefore we review different spatial and frequency domain techniques. A combination of qualitative and quantitative assessment approach may be the correct way to find out which fusion technique is most appropriate for an application. The advantages disadvantages and applications of various techniques have been concluded in the table given below:

TABLE 1: ADVANTAGES AND DISADVANTAGES OF VARIOUS TECHNIQUES

SNO	Fusion Techniques	Domain	Advantages	Disadvantages
1	Simple Average	Spatial	Easy to use	This technique reduces the resultant image quality by introducing noise into the fused image
2	Select Maximum	Spatial	Highly Focussed Image	Blurred image due to reduction of contrast
3	IHS	Spatial	Simple ,Efficient & Fast Processing	Results in colour Distortion
4	PCA	Spatial	Fast Processing Time & high Special Quality	Spectral Degradation & Colour Distortion
5	Laplacian Pyramid	Frequency	Good Visual Quality	Needs High Processing Time
6	DCT	Frequency	Beneficial in Real Time Applications	Quality of fused image is not up to the mark
7	DWT	Frequency	Better Signal to Noise ratio	Less Spatial Resolution
8	Integer Lifting DWT	Frequency	Provides good result at level 2 decomposition	Time consuming

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