Image Fusion an Application of Digital Image Processing using Wavelet Transform

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Abstract- In today's era digital image processing has wide areas of application. One of the most important applications of image processing is in image fusion. Image fusion is a technique which is used for combining relevant information from two or more images into a single image. This fused image contains more information than any of the two input images. The fused image can have complimentary spatial and spectral resolution characteristics. We can apply this method in remote sensing application as well as satellite imaging application. In this proposed work, two images are fused based on the wavelet transform using different fusion technique. The objective of this Proposed work is to fuse two images in such a way that we can get better result which contain more information. The respected results will evaluate using parameters like Pseudo Signal to Noise Ratio, Root Mean Square Error, Standard Deviation and Entropy.

Keywords— Image Fusion, Wavelet Transform, Peak Signal to Noise Ratio, Root Mean Square Error, Standard deviation, Entropy, Spatial resolution, Spectral resolution.

1.Introduction

Image fusion technique is very important in digital image processing. In this technique, two images are merge to get more and accurate information. In traditional data fusion, data fusion can be divided into three levels these levels are pixel level fusion, feature level fusion and decision level fusion. These different fusion levels have different algorithms and have different application. The fusion is a technique is used for remote sensing and mapping application. For that purpose different types of sensor technology is used. There are different types of sensor are available. In many remote sensing and mapping application the fusion of multispectral and panchromatic image is very important issue. In the field of satellite image classification the quality of the image classifier is affected by the fused image quality. For that purpose many image fusion techniques and software tools have been developed. The well-known method include the Brovery, the IHS(Intensity. Hue, Saturation) colour model, the PCA (Principal Component Analysis) method and wavelet based method. Image fusion is also having an application in satellite image fusion as well as in medical image fusion.

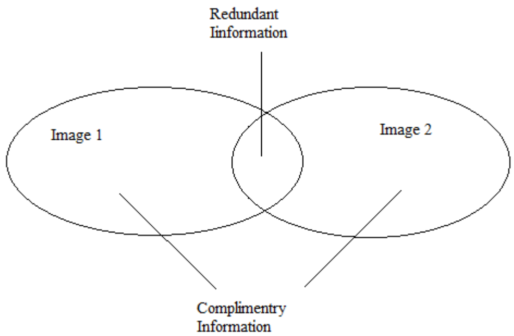

Figure 1.1 Basic Image Fusion Scheme

Above figure shows the basic image fusion scheme. In this figure image 1 and image 2 are combined to extract the information between those two images into a single image. This figure consist of the two section namely that is redundant information and complimentary information. The reliability of image is improved by redundant information and the capability of image is improved by complimentary information.

2. Related Work

Various types of method are proposed in literature review which are used for image fusion.

Navneet kaur, et. al [1] Presented "Review On: Image Fusion Using Wavelet and Curvelet Transform" Image fusion refers to the process of combining the information from two or more images into a single highly informative image. The resulting fused image contains more information than the input images. In this paper, two medical images are fused based on the Wavelet Transform (WT) and Curvelet transform using different fusion techniques. The objective of the fusion of an MR image and CT image of the same organ is to obtain a single image containing as much information as possible about that organ for diagnosis.

Myungjin Choi, et al. [2] introduced a new method based on a curvelet transform, which represents edges better than wavelets. Since edges play a fundamental role in image representation, one effective means to enhance spatial resolution is to enhance the edges. The curvelet-based image fusion method provides richer information in the spatial and spectral domains simultaneously. They performed Landsat ETM+ image fusion and found that the proposed method provides optimum fusion results.

Sweta Mehta, et. al. [3] introduced the Curvelet Transform and uses it to fuse images. The experiments show that the method could extract useful information from source images to fused images so that clear images are obtained. In this paper we put forward an image fusion algorithm based on Wavelet Transform and the Curvelet Transform. Low and high frequency coefficients are choosen according to different frequency domain after Wavelet and the Curvelet Transform. 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.

Yufeng Zheng, et al.[4] Presented The fusion performance of the advanced DWT (*a*DWT) method proposed here was compared with six other common methods, and, based on the four quantitative measures, was found to perform the best when tested on the four input image types. Since the different image sources used here varied with respect to intensity, contrast, noise, and intrinsic characteristics, the *a*DWT is a promising image fusion procedure for inhomogeneous imagery.

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Alparone L., et al.[7] presented a novel image fusion method, suitable for pan-sharpening of multispectral (MS) bands, based on multi-resolution analysis (MRA). The low-resolution MS bands are sharpened by injecting high-pass directional details extracted from the highresolution panchromatic (Pan) image by means of the curvelet transform, which is a non-separable MRA, whose basis function are directional edges with progressively increasing resolution.

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Dr.S.S.Bedi, et. al [8] describes Image fusion is a tool that serves to combine multi sensors images by using advanced image processing techniques. Particularly it serves best in medical diagnosis i.e. computed tomography (CT), magnetic resonance image (MRI), scan provides different types of information, by fusing them we can get accurate information for better clinical diagnosis.

The algorithm proposed by the authors has its own pros and cons, with respect to that we will going to propose efficient architecture for image fusion which will be used in various domain, also the statistical parameters like peak signal to noise ratio, entropy, standard deviation and root mean square error will be evaluated to prove our method will be efficient with respect to others proposed method.

3. System Architecture

Image Fusion is a method where we add or merge two images to acquire useful Information. It is very useful technique. For Fusing Images we can use different transform Techniques. Figure below shows the block diagram for wavelet transform based image fusion.

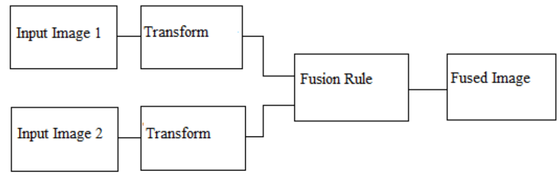

Figure 3.1 Basic Image Fusion Block Diagram

Above figure shows the generalized block diagram of image fusion technique. Image fusion is a process of extracting the information from two images into a single image. As shown in above block diagram the first step is to take input image first and input image second then apply wavelet transform to those images. After that wavelet coefficient are generated. The next step is to apply fusion rule to those images after applying the fusion rule fused image is extracted. The proposed work is given below.

1. To study the different techniques for image fusion.

2. To study different transforms with respect to image fusion in digital image processing.

3. To design image fusion techniques using transform method.

4. Verification of results based on design techniques

3.1 Introduction to Wavelet Transform

Wavelet transform is one of the most efficient tool for image processing. In this proposed work two types of wavelet transform are used.

3.1.1 Discrete Wavelet Transform.

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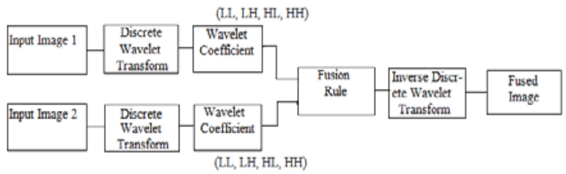

Figure 3.1.1.1 Discrete Wavelet Transform Based Image Fusion.

Above figure shows the block diagram of discrete wavelet transform based image fusion. The first step is to take the two images that is input image one and input image two from the image database. Next step is to apply discrete wavelet transform to those images. After applying the discrete wavelet transform the wavelet coefficient. The next step is to apply fusion rule to those images. After that inverse wavelet transform is applied to get the fused image.

The discrete wavelet transform (DWT) is an implementation of the wavelet transform in which discrete set of the wavelet scales and translations obeying some defined rules. In other words, this transform decomposes the signal into mutually orthogonal set of wavelets, which is the main difference from the continuous wavelet transform (CWT), or its implementation for the discrete time series sometimes called discrete time continuous wavelet transform(DTCWT).

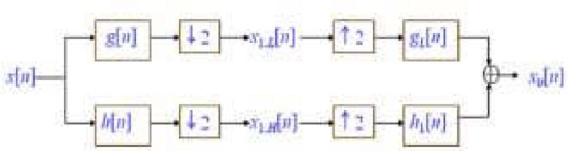

Figure 3.1.1.2 Block diagram of DWT and IDWT

Above block diagram shows the reconstruction process of inverse discrete wavelet transform from discrete wavelet transform. Where h(n), g(n), h1(n) and g1(n) can be constructed by using quadrature mirror filter(QMF)[12].

3.1.2 Stationary Wavelet Transform.

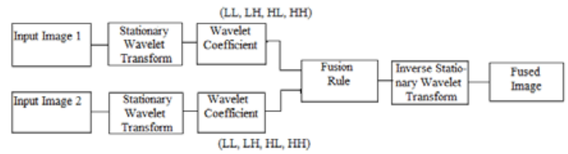

Figure 3.1.2.1 Stationary Wavelet Transform Based Image Fusion.

Above figure shows the block diagram of stationary wavelet transform based image fusion. The first step is to take the two images that is input image one and input image two from the image database. Next step is to apply stationary wavelet transform to those images. After applying the stationary wavelet transform the wavelet coefficient. The next step is to apply fusion rule to those images. After that inverse wavelet transform is applied to get the fused image.

The stationary wavelet transform is very much similar to discrete wavelet transform only difference is that the process of down sampling is supressed that's why stationary wavelet transform is translation invariant. It does so by suppressing the down-sampling step of the decimated algorithm and instead up-sampling the filters by inserting zeros between the filter coefficients. Algorithms in which the filter is up-sampled are called "à trous", meaning "with holes". As with the decimated algorithm, the filters are applied first to the rows and then to the columns. In this case, however, although the four images produced (one approximation and three detail images) are at half the resolution of the original; they are the same size as the original image. The 2-D SWT decomposition scheme is illustrated in Figure 4.3.2.1[13].

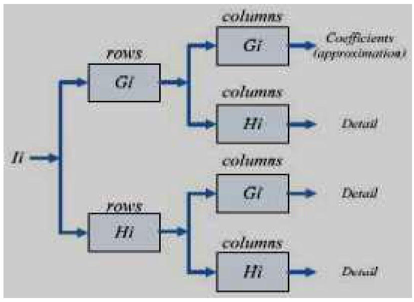

Figure 3.1.2.2 SWT decomposition scheme[14].

3.2 PERFORMANCE PARAMETERS

In this proposed work result are evaluated by focusing on four performance parameters that is peak signal to noise ratio(PSNR) and root mean square error(RMSE), standard deviation(SD) and entropy(E).

3.2.1 Peak Signal to Noise Ratio(PSNR)

The mathematical relation for PSNR is given below,

$$PSNR = 10\log_{10}\left(\frac{peak*peak}{MSE}\right)$$

PSNR is defined as *log* of the ratio between the square of the peak value to the Mean Square Error multiplied to the value 10. This basically projects the ratio of the highest possible value of the data to the error obtained in the data. 5 In our case, at pixel level, the highest possible value is 255. i.e. in a 8 bit gray scale image, the maximum possible value is having every bit as 1 –> 11111111; which is equal to 255. Then the error between the fused image and the input image is calculated as the Mean Square Error and the ratio value is obtained. If both the fused and the input images are identical, then the MSE value would be 0. In that case, the PSNR value will remain undefined[14].

3.2.2 Root Mean Square Error

To find RMSE we have to first calculate Mean Square Error(MSE) which is given by the following relation,

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} - b_{ij})^2$$

Where *m* is the height of the Image implying the number or pixel rows.
n is the width of the image, implying the number of pixel columns.
Aij being the pixel density values of the input image.
Bij being the pixel density values of the fused image.
To calculate RMSE from MSE we take square root of MSE.
Root Mean square error is one of the most commonly used error projection method where, the error value is the
value difference between the input data and the resultant data[14].

3.2.3 Entropy

Entropy is defined as amount of information contained in a signal. Shannon was the first person to introduce entropy to quantify the information. The entropy of the image can be evaluated as,

$$H = -\sum_{i=1}^{G} P(i)\log_2(P(d_i))$$

Where G is the number of possible gray levels, *P(di*) is probability of occurrence of a particular gray level *di* . Entropy can directly reflect the average information content of an image. The maximum value of entropy can be produced when each gray level of the whole range has the same frequency. If entropy of fused image is higher than parent image then it indicates that the fused image contains more information[14].

3.2.4 Standard Deviation

This metric is more efficient in the absence of noise. It measures the contrast in the

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fused image. An image with high contrast would have a high standard deviation.

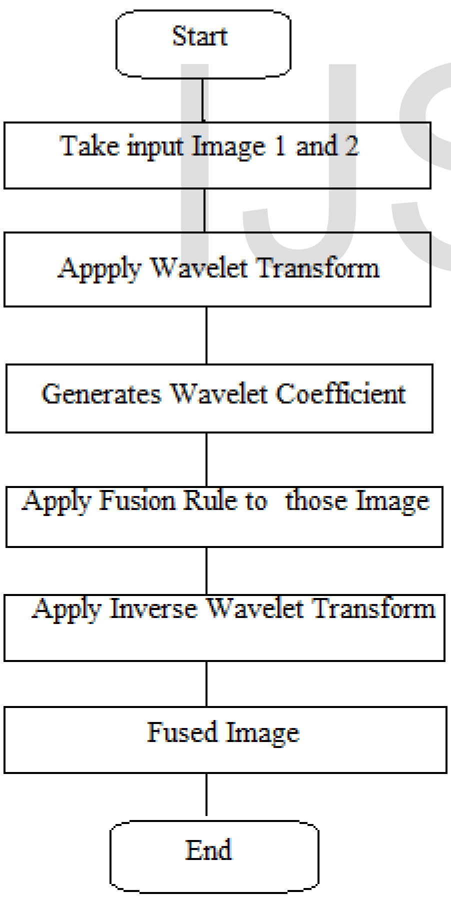
$$\sigma = \sqrt{\sum_{i=0}^{L}\left(i - \bar{i}\right)^2 h_{I_f}(i)}, \cdots \bar{i} = \sum_{i=0}^{L} i h_{I_f}$$

Where hI f (i) is the normalized histogram of the fused image If (x,y) and L is number of frequency bins in histogram[15].

4. Result and Discussion

4.1 Introduction

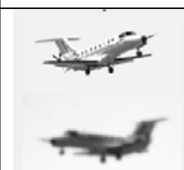
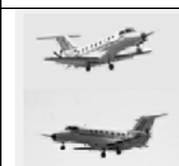
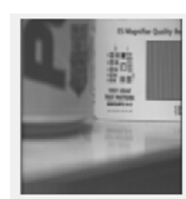
In this section result and discussion based on discrete wavelet transform and stationary wavelet transform are carried out. The flowchart of proposed work is given below.



Flowchart 4.1.1 Image Fusion Flowchart

As shown in above flow chart the first step is to take the first two images from the image database. The next step is to apply the wavelet transform to those images. In this work there is two type of wavelet transform are studied that is discrete wavelet transform and stationary wavelet transform. After application of wavelet transform wavelet coefficient are generated. After that fusion rule is applied to those coefficients. The next step is to apply inverse wavelet Transform to those coefficient to extract the original coefficient. At last the fused image is obtained.

4.2 Result Based On Discrete Wavelet Transform-This shows the result based on Discrete wavelet transform and the performance parameters like peak signal to noise ratio(PSNR), root mean square error(RMSE), standard deviation(SD) and entropy(E) are evaluated.

Input Image 1	Input image 2	Fused Image
		
		
		

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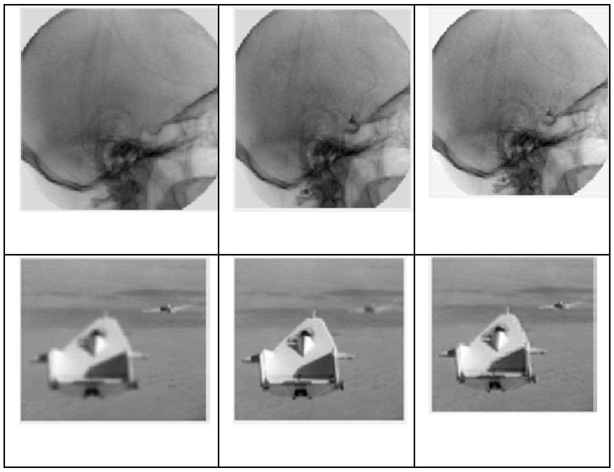
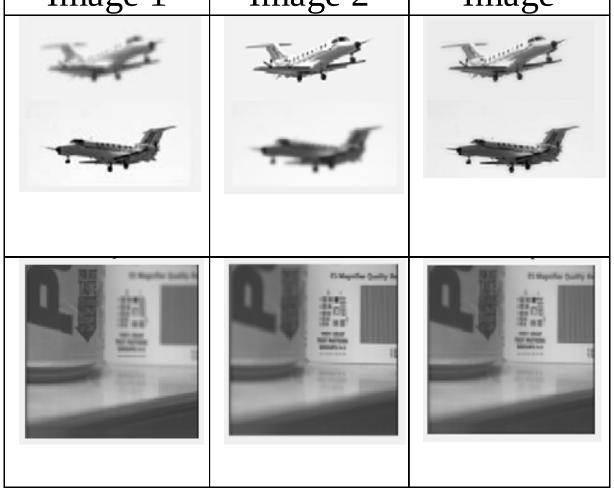


Table 4.2.1 Image Fusion Based on Discrete Wavelet Transform

4.3 Result Based On Stationary Wavelet Transform

In this section the result based on Stationary wavelet transform and the performance parameters like peak signal to noise ratio(PSNR), root mean square error(RMSE), standard deviation(SD) and entropy(E) are evaluated.

Input Image 1	Input Image 2	Fused Image



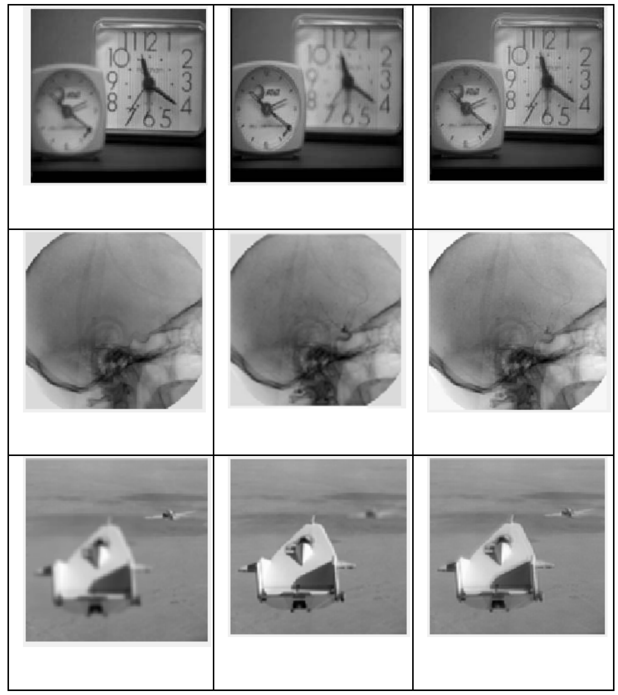


Table 4.3.1 Image Fusion Based on Stationary Wavelet Transform

4.4 Result Analysis

4.4.1 Result Analysis based on Discrete Wavelet Transform.

Image Name	Discrete Wavelet Transform				
	PSNR	MSE	RMSE	SD	Entropy
Image 1	37.515	132.77	11.522	53.878	0.006
Image 2	40.956	27.2229	5.217	46.395	7.116
Image 5	37.883	112.063	10.586	53.408	7.330
Image 4	42.397	14.020	3.744	42.317	0.0009
Image 5	39.214	60.770	7.791	30.116	6.461

Table 4.4.1.1 Evaluation of Result Based on Discrete Wavelet Transform.

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4.4.2 Result Analysis based on Stationary wavelet Transform.

Image Name	Stationary Wavelet Transform				
	PSNR	MSE	RMSE	SD	Entropy
Image 1	38.178	97.8114	9.889	52.392	0
Image 2	41.363	22.569	4.750	46.054	7.060
Image 3	38.766	74.607	8.673	52.174	7.352
Image 4	43.053	10.360	3.218	42.198	0.0009
Image	39.809	46.160	6.941	29.188	6.444

Table 4.4.2.1 Evaluation of Result Based on Stationary Wavelet Transform.

CONCLUSION

In this proposed work image fusion method is introduced which is based on the wavelet transform, which incorporated the statistical parameters like peak signal to noise ratio(PSNR), root mean square error(RMSE), standard deviation(SD) and entropy are evaluated to prove our method will be efficient with respect to others proposed method. As shown in above result for overall images the value of PSNR by discrete wavelet transform is less as compare to the value of PSNR by stationary wavelet transform is more. The value of MSE by discrete wavelet transform is more as compare to the value of MSE by stationary wavelet transform is less. Although the value of RSME by discrete wavelet transform is more as compare to the value of RMSE by stationary wavelet transform is less. Although the value of standard deviation by discrete wavelet transform is more as compare to the value of standard deviation by stationary wavelet transform is less. The value of entropy by discrete wavelet and the value of entropy by stationary wavelet transform is near about same. So from above discussion for overall tested images stationary wavelet transform is best.

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