Wavelet based Image Fusion Techniques

[1]Mirajkar Pradnya P.
Asst. Professor, Electronics & Telecommunication Dept.
ADCET, Ashta,
Researcher, E&Tc Dept. Sinhgad Acadmy of Engg. Pune
[1]pradnya.mirajkar@yahoo.com

[2] Ruikar Sachin D.
Asst. Professor, Electronics & Telecommunication Dept.
Sinhgad Acadmy of Engg. Pune
[2]ruikaretcdept@gmail.com

***Abstract*: The fusion of images is the process of combining two or more images into a single image retaining important features from each. Fusion is an important technique within many disparate fields such as remote sensing, robotics and medical applications. The result of image fusion is a single image which is more suitable for human and machine perception or further image-processing tasks. The image fusion algorithm based on wavelet transform is proposed to prove the geometric resolution of the images, in which two images to be processed are firstly decomposed into sub images and then the information is performed using these images under the certain criteria and finally these sub images are reconstructed into result image with plentiful information. In this paper three different image fusion methods based wavelet transform are implemented. And the results are compared and best method is found.**

Keywords: Image Fusion; Wavelet Transform; Filter mask; Stationary wavelets

I. INTRODUCTION

The goal of image fusion is to integrate complementary information from multi-sensor data such that the fused images are more suitable for human visual perception and computer-processing tasks such as segmentation, feature extraction, and object recognition. The fusion of low-resolution multi-spectral images and high-resolution panchromatic images is a widely used procedure because the fused images possess complementary information from these different sources. Ideally, the method used for generating multi-resolution spatial high-resolution images should not distort the spectral characteristics in the multi resolution spectral resolution fused images

The most common approach of image fusion, known as pixel-based fusion, consists of comparing information among the pixels in the same location or pixels in the same region in different images. So far, pixel-based fusion has attracted much attention and many interrelated methods have been proposed such as weighted means and multi-resolution analysis. Feature based fusion can be achieved by the region based fusion framework and more intelligent rules are applied depending on different region features. Wavelet transform is a signal analysis method similar to image pyramids is the discrete wavelet transform. Wavelet transforms have been successfully used in many fusion schemes. A common wavelet analysis technique used for fusion is the discrete wavelet transform (DWT). With rapid advancements in technology, it is now possible to obtain information from multisource images. However, all the physical and geometrical information required for detailed assessment might not be available by analyzing the images separately. In multisensory images, there is often a trade-off between spatial and spectral resolutions resulting in information loss. Image fusion combines perfectly registered images from multiple sources to produce a high quality fused image with spatial and spectral information. It integrates complementary information from various modalities based on specific rules to give a better visual picture of a scenario, suitable for processing.

Here, we use wavelet transform and four Image fusion methods. Hybrid architecture based on wavelet transform method proposes a hybrid fusion method which integrates both pixel based rules and region based rules using mask in a single fused image. Stationary Wavelet Transform (SWT) method is similar to Discrete Wavelet Transform (DWT) but the only process of down-sampling is suppressed. In Image fusion by adaptive decomposition, images are fused by regions from different focused images. These three methods are implemented and results are compared.

II. WAVELET BASED IMAGE FUSION TECHNIQUES:

i) *Hybrid Architecture Based On Wavelet Transform*:

This method proposes a hybrid fusion method which integrates both pixel based rules and region based rules [3] using mask in a single fused image [1]. Pixel based rules operate on individual pixels in the image, but does not take into account some important details like edges, boundaries and salient features larger than a single pixel. Use of region based method may reduce the contrast in some images and does not always succeed in effectively removing ringing artifacts and noise in source images. The inadequacies of these two types of fusion rules point to the importance of developing a hybrid algorithm based architecture combining the advantages of both. Hybrid architecture in Fig. 1 uses different rules for fusing low and high frequency sub images of wavelet decomposition.

Test images are decomposed using discrete wavelet transform [2]. The approximations are subjected to pixel based maximum selection rule. A 3X3 square mask and odd order rectangular averaging mask (5X7) are each applied to detail images [1]. The 5X7 averaging filter mask gives a better performance with less noise when compared to a square mask. The new sets of coefficients from each source image are added to get new approximations and details.

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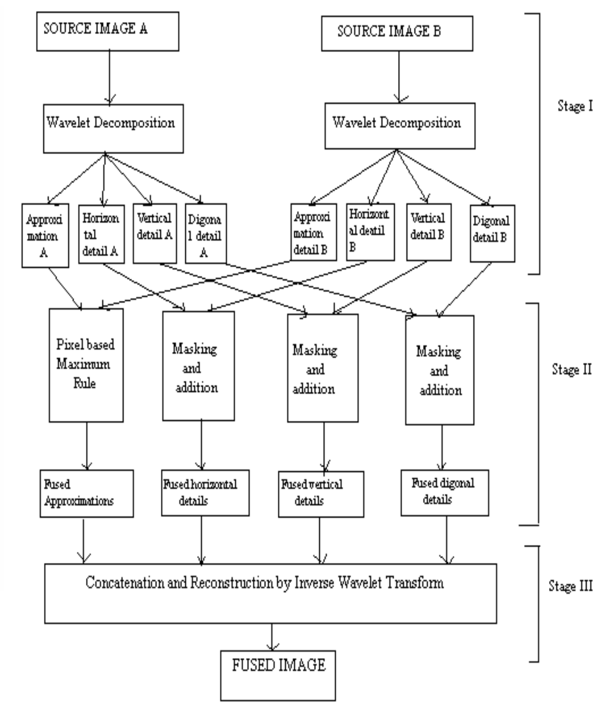

Fig.1 Mask based image fusion

Final fused coefficient matrix is obtained by concatenation of new approximations and details A pixel based maximum selection algorithm is used for approximations while square and averaging filter masks are applied to detail coefficients. High pass square filter mask helps in enhancing the salient features edges. Averaging filter mask removes noise by taking the mean of the gray values of the window surrounding the centre pixel.

Results for hybrid architecture based on wavelet transform:

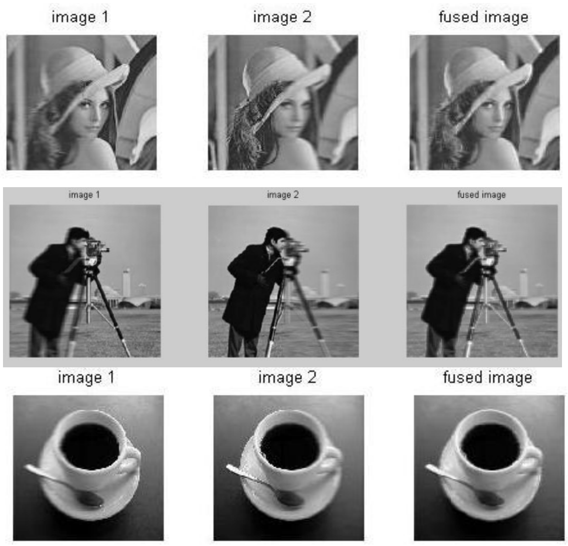

Fig.2 Results of Hybrid *architecture based on wavelet transform*

ii) SWT Based Image Fusion:

Stationary Wavelet Transform (SWT) is similar to Discrete Wavelet Transform (DWT) but the only process of down-sampling is suppressed that means the SWT, [4,5,6] is translation-invariant. The 2-D SWT decomposition scheme is illustrated in Fig 3.

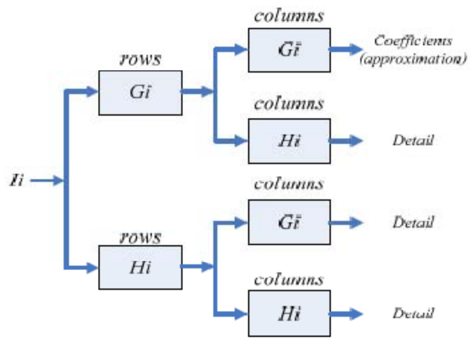

Fig.3: SWT decomposition scheme

The 2D Stationary Wavelet Transform (SWT) is based on the idea of no decimation. It applies the Discrete Wavelet Transform (DWT) and omits both down-sampling in the forward and up-sampling in the inverse transform. More precisely, it applies the transform at each point of the image and saves the detail coefficients and uses the low frequency information at each level. The Stationary Wavelet Transform decomposition scheme is illustrated in Fig 3 where *Gi* and *Hi* are a source image, low pass filter and high-pass filter, respectively. Fig 3 shows the detail results after applying SWT to an image using SWT at 1 to 4 levels

Result analysis for SWT Method at Level 1:

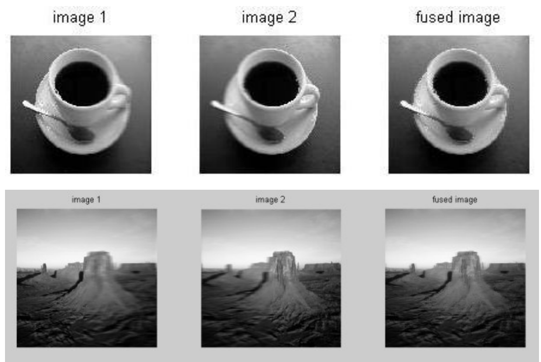

Fig.4- Results of SWT Method at Level 1

Results analysis for SWT Method at Level 2:

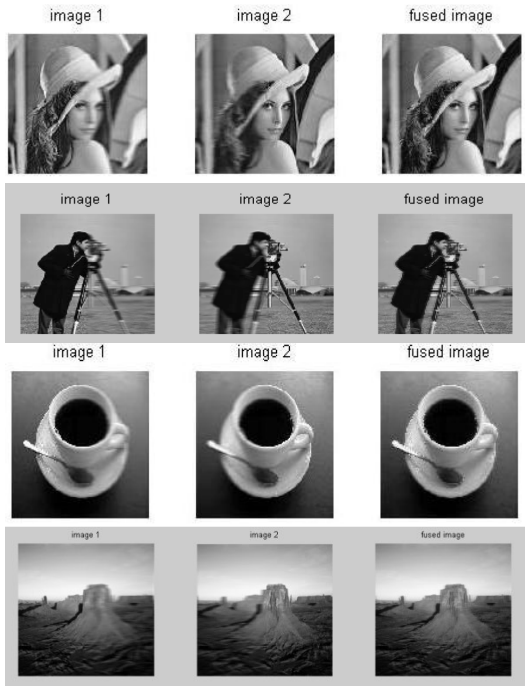

Fig.5- Results of SWT Method at Level 2

iii) *Wavelet Based Image Fusion By Adaptive Decomposition*:

This method presents a wavelet-based fusion strategy which includes adaptive decomposition to generate regions in source images simultaneously, and combine the regions with wavelet coefficients. The local measurement value (LMV), [7] is calculated to select the wavelet coefficients based on the quadtree data structure. The existing fusion rule can be applied on the corresponding results from the above process for regions.

Image Fusion by Adaptive Decomposition**:**

In the proposed results, images are fused by regions from different focused images. For choosing regions appropriately, the adaptive decomposition algorithm can detect them more effectively from the wavelet coefficients than from the original image. The adaptive decomposition is processed recursively by comparing the LMV with the threshold value *M*. The LMV is extracted from wavelet coefficients of the source images. Given two sub images, the formula LMV is defined as:

$$LMV_{m,n} = \frac{1}{A}\sum_{i=1}^{m}\sum_{j=1}^{n}[D_{LL}^{m}(i,j) - D_{LL}^{n}(i,j)]$$

where *DLL* value is calculated from the wavelet coefficients of low frequency band. *A* is the number of pixels in regions *m* and *n*. Then average the difference of *DLL* value from two regions *m* and *n*. The threshold value M is the initial LMV of region m and n.

The quadtree [8] represents a partition of image in two dimensions by decomposing the region into four equal quadrants, sub-quadrants, and so on. Each node in the tree either has exactly four children, or has no children (a leaf node). A quadtree with a depth of n may be used to represent an image consisting of $2n \times 2n$ pixels. Then we apply the adaptive decomposition method to divide the source images. Below figure shows the results of adaptive decomposition based on quadtree

Fig.6 - The Image divided by Adaptive Decomposition

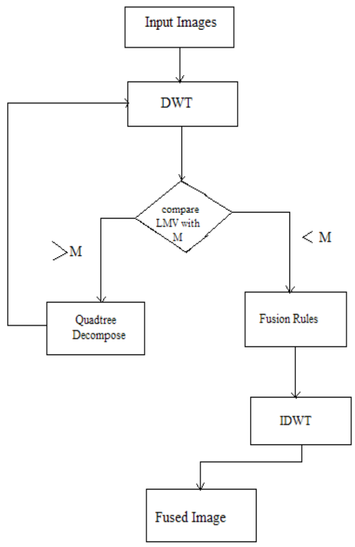

Fig.7- Image fusion by Adaptive Decomposition

Results Analysis for Wavelet Based Image Fusion by Adaptive Decomposition Method:

Fig. 8- Results of Wavelet Based Image Fusion by Adaptive Decomposition Method

III. EXPERIMENTAL ANALYSIS AND COMPARISON:

For the comparison of results of three different methods same images are used. Total 4 images are used with size 256×256. For performing the experiment some noise is added in the images. Left half part and right half part of images are blurred respectively. This database is used for performing an experiment shown in Table1. And the results of comparison are shown in Table 2.

ORIGINAL IMAGE	SOURCE IMAGES	IMAGE SIZE
(a) LENA	1) LEFT PORTION IS FOCUSED 2)RIGHT PORTION IS FOCUSED	256X256
(b) CAMERAMAN	1)LEFT PORTION IS FOCUSED 2)RIGHT PORTION IS FOCUSED	256X256
(c) COFFEE CUP	1)LEFT PORTION IS FOCUSED 2)RIGHT PORTION IS FOCUSED	256X256
(d) SCENE	1)LEFT PORTION IS FOCUSED 2)RIGHT PORTION IS FOCUSED	256X256

Table 1- Source Images used for Experiment

IV. CONCLUSION

The concept of wavelet transform and wavelet based image fusion with four different methods is studied. The hybrid architecture gives promising results in all test cases and can be further extended to all types of images by using different averaging, high-pass and low-pass filter masks. SWT is similar to DWT; Experiments are performed on two levels, and gives good results than all other methods. The last method Wavelet based Image Fusion by Adaptive Decomposition presents a wavelet-based fusion strategy which includes adaptive decomposition to generate regions in source images simultaneously, and combine the regions with wavelet coefficients. Experiments show that this method has better fusion results than existing image fusion methods without adaptive decompositions. But in our experiment we have got good results for Stationary Wavelet Based Image Fusion method at level 2 compared to all other methods.

Objective performance evaluation is done by taking Mean Square Error (MSE) and Signal to Noise Ratio (SNR) and Peak Signal-to-Noise Ratio (PSNR).

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Table 2- Comparison of three methods based on MSE, SNR and PSNR

IMAGE	Hybrid Method			SWT Level 1			SWT Level 2			AWDM		
	MSE	SNR	PSNR	MSE	SNR	PSNR	MSE	SNR	PSNR	MSE	SNR	PSNR
LENA	10.1545	27.9976	76.1285	16.1339	23.9760	72.1068	15.1050	24.5484	72.6792	18.3125	22.8758	71.0066
CAMERAMAN	14.5301	24.2779	73.0162	16.1065	23.3833	72.1216	15.3342	23.8101	72.5484	17.3747	22.7250	71.4633
COFFEE CUP	7.9849	28.8243	78.2163	7.0756	29.8743	79.2663	6.6196	30.4529	79.8449	9.2910	27.5084	76.9004
SCENE	13.2822	24.9984	73.7962	5.3133	32.9564	81.7543	4.5995	34.2095	83.0073	10.0152	27.4505	76.2484