International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol. 2, Issue. 5, Sep.-Oct. 2012 pp-4298-4301 ISSN: 2249-6645

Different Image Fusion Techniques –A Critical Review

Deepak Kumar Sahu[1], M.P.Parsai[2]
[1, 2](Department of Electronics & Communication Engineering, Jabalpur Engineering College, Jabalpur MP, India)

ABSTRACT : *Image Fusion is a process of combining the relevant information from a set of images into a single image, where the resultant fused image will be more informative and complete than any of the input images. Image fusion techniques can improve the quality and increase the application of these data. This paper presents a literature review on some of the image fusion techniques for image fusion like, primitive fusion (Averaging Method, Select Maximum, and Select Minimum), Discrete Wavelet transform based fusion, Principal component analysis (PCA) based fusion etc. Comparison of all the techniques concludes the better approach for its future research.*

Keywords: *Discrete Wavelet Transform (DWT), Mean Square Error (MSE), Normalized correlation (NC), Peak signal to noise ratio (PSNR), Principal Component Analysis (PCA),*

I. INTRODUCTION

Image fusion means the combining of two images into a single image that has the maximum information content without producing details that are non-existent in the given images[1][2]. With rapid advancements in technology, it is now possible to obtain information from multi source images to produce a high quality fused image with spatial and spectral information [2] [3]. Image Fusion is a mechanism to improve the quality of information from a set of images. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics .Use of the Simple primitive technique will not recover good fused image in terms of performance parameter like peak signal to noise ratio (PSNR), Normalized correlation (NC), and Men square error (MSE). Recently, Discrete Wavelet Transform (DWT) and Principal Component Analysis(PCA),Morphological processing and Combination of DWT with PCA and Morphological techniques have been popular fusion of image[4][5][6]. These methods are shown to perform much better than simple averaging, maximum, minimum.

This report is organized as follows: Section II presents brief description of image Fusion techniques, Section III gives Performance Measures parameter of Fusion techniques , Section IV presents performance comparison of those techniques and finally, conclusion is presented in Section V.

II. IMAGE FUSION TECHNIQUES

The process of image fusion the good information from each of the given images is fused together to form a resultant image whose quality is superior to any of the input images .Image fusion method can be broadly classified into two groups –1.Spatial domain fusion method 2.Transform domain fusion

In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired result. In frequency domain methods the image is first transferred in to frequency domain. It means that the Fourier Transform of the image is computed first. All the Fusion operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. Image Fusion applied in every field where images are ought to be analyzed. For example, medical image analysis, microscopic imaging, analysis of images from satellite, remote sensing Application, computer vision, robotics etc [7][8]. The fusion methods such as averaging, Brovey method, principal component analysis (PCA) and IHS based methods fall under spatial domain approaches. Another important spatial domain fusion method is the high pass filtering based technique. The disadvantage of spatial domain approaches is that they produce spatial distortion in the fused image. Spectral distortion becomes a negative factor while we go for further processing such as classification problem [8].

Spatial distortion can be very well handled by frequency domain approaches on image fusion. The multi resolution analysis has become a very useful tool for analyzing remote sensing images. The discrete wavelet transform has become a very useful tool for fusion. Some other fusion methods are also there such as Laplacian-pyramid based, Curvelet transform based etc. These methods show a better performance in spatial and spectral quality of the fused image compared to other spatial methods of fusion [8].

There are various methods that have been developed to perform image fusion. Some well-known image fusion methods are listed below [3]:-
(1) Intensity-hue-saturation (IHS) transform based fusion
(2) Principal component analysis (PCA) based fusion
(3) Multi scale transform based fusion:-
(a) High-pass filtering method
(b) Pyramid method:-(i) Gaussian pyramid (ii) Laplacian Pyramid (iii) Gradient pyramid (iv) Morphological pyramid (v) Ratio of low pass pyramid
(c) Wavelet transforms:- (i) Discrete wavelet transforms (DWT) (ii) Stationary wavelet transforms (iii) Multi-wavelet transforms
(d) Curvelet transforms

2.1 IMAGE FUSION ALGORITHMS

Due to the limited focus depth of the optical lens it is often not possible to get an image that contains all relevant objects in focus. To obtain an image with every object in focus a multi-focus image fusion process is required to fuse the images giving a better view for human or machine perception. Pixel-based, region-based and wavelet based fusion algorithms were implemented [9].

2.1.1. SIMPLE AVERAGE

It is a well documented fact that regions of images that are in focus tend to be of higher pixel intensity. Thus

this algorithm is a simple way of obtaining an output image with all regions in focus. The value of the pixel P (i, j) of each image is taken and added. This sum is then divided by 2 to obtain the average. The average value is assigned to the corresponding pixel of the output image which is given in equation (1). This is repeated for all pixel values.

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

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

2.1.2. SELECT MAXIMUM

The greater the pixel values the more in focus the image. Thus this algorithm chooses the in-focus regions from each input image by choosing the greatest value for each pixel, resulting in highly focused output. The value of the pixel P (i, j) of each image is taken and compared to each other. The greatest pixel value is assigned to the corresponding pixel [7] [9].

2.2. DISCRETE WAVELET TRANSFORM (DWT)

Wavelets are finite duration oscillatory functions with zero average value [1]. They have finite energy. They are suited for analysis of transient signal. The irregularity and good localization properties make them better basis for analysis of signals with discontinuities. Wavelets can be described by using two functions viz. the scaling function f (t), also known as 'father wavelet' and the wavelet function or 'mother wavelet'. Mother wavelet (t) undergoes translation and scaling operations to give self similar wavelet families as given by Equation.

$$\psi_{a,b}(t)=\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right), (a, b\epsilon R), a > 0 \quad (2)$$

The wavelet transform decomposes the image into low-high, high-low, high-high spatial frequency bands at different scales and the low-low band at the coarsest scale which is shown in fig: 2. The L-L band contains the average image information whereas the other bands contain directional information due to spatial orientation. Higher absolute values of wavelet coefficients in the high bands correspond to salient features such as edges or lines [1][7][10]. The basic steps performed in image fusion given in fig. 1.

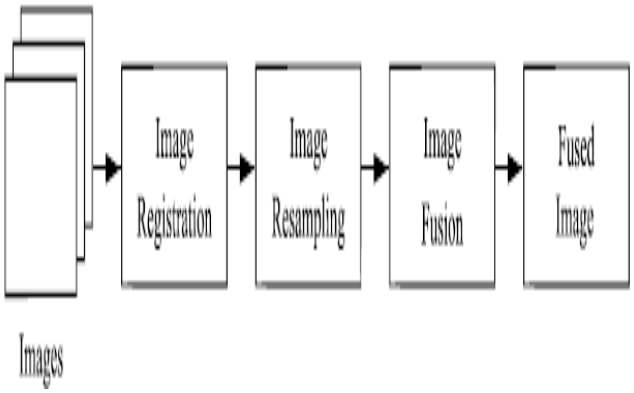

Fig1: Preprocessing of image fusion

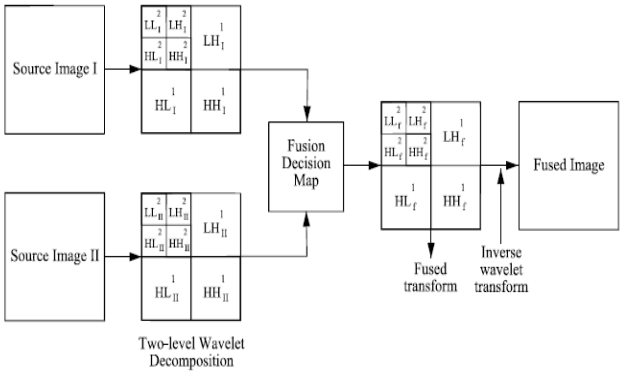

Fig. 2: Wavelet Based image fusion

The wavelets-based approach is appropriate for performing fusion tasks for the following reasons:-

(1) It is a multi scale (multi resolution) approach well suited to manage the different image resolutions. Useful in a number of image processing applications including the image fusion [3][7].

(2) The discrete wavelets transform (DWT) allows the image decomposition in different kinds of coefficients preserving the image information. Such coefficients coming from different images can be appropriately combined to obtain new coefficients so that the information in the original images is collected appropriately.

(3) Once the coefficients are merged the final fused image is achieved through the inverse discrete wavelets transform (IDWT), where the information in the merged coefficients is also preserved.

2.3. PRINCIPAL COMPONENT ANALYSIS (PCA)

PCA is a mathematical tool which transforms a number of correlated variables into a number of uncorrelated variables. The PCA is used extensively in image compression and image classification. The PCA involves a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. It computes a compact and optimal description of the data set. The first principal component accounts for as much of the variance in the data as possible and each succeeding component accounts for as much of the remaining variance as possible. First principal component is taken to be along the direction with the maximum variance. The second principal component is constrained to lie in the subspace perpendicular of the first. Within this Subspace, this component points the direction of maximum variance. The third principal component is taken in the maximum variance direction in the subspace perpendicular to the first two and so on. The PCA is also called as Karhunen-Loève transform or the Hotelling transform. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. and its basis vectors depend on the data set [11].

III. PERFORMANCE MEASURES

The general requirements of an image fusing process are that it should preserve all valid and useful pattern information from the source images, while at the same time it should not introduce artifacts that could interfere with subsequent analyses. The performance

measures used in this paper provide some quantitative comparison among different fusion schemes, mainly aiming at measuring the definition of an image.

3.1 PEAK SIGNAL TO NOISE RATIO (PSNR)

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation [2][9]. The PSNR measure is given by:-

$$PSNR(dB) = 20log \frac{255\sqrt{3MN}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(B'(i,j)-B(i,j))^2}} \quad (3)$$

Where, B - the perfect image, B' - the fused image to be assessed, i – pixel row index,
j – Pixel column index, M, N- No. of row and column

3.2 ENTROPY (EN)

Entropy is an index to evaluate the information quantity contained in an image. If the value of entropy becomes higher after fusing, it indicates that the information increases and the fusion performances are improved. Entropy is defined as:-

$$E = -\sum_{i=0}^{L-1} p_i \, log_2 \, p_i \quad (4)$$

Where L is the total of grey levels, $p = \{p_0, p_1, \ldots . p_{L-1}\}$ is the probability distribution of each level [9].

3.3 MEAN SQUARED ERROR (MSE)

The mathematical equation of MSE is giver by the equation (5)

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} - B_{ij})^2 \quad (5)$$

Where, A - the perfect image, B - the fused image to be assessed, i – pixel row index,
j – pixel column index, m, n- No. of row and column

3.4 NORMALIZED CROSS CORRELATION (NCC)

Normalized cross correlation are used to find out similarities between fused image and registered image is given by the following equation (6)

$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} * B_{ij})}{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})^2} \quad (6)$$

IV. COMPARISON BETWEEN VARIOUS FUSION TECHNIQUES

In the reference [9] ,[12] we found that the value of the PSNR and Entropy in average method is less than as compared to value of other frequency domain method like SWT and laplacian method which means fused image are not exactly to registered image. That is why transform domain method are more suitable as compared to spatial domain method. But in some case Spatial domain play a very important role in image fusion that contain high spatial information in fused image. Same thing is also noticed in [2] and [4]. Table is given below.

Table1: Statics result of different fusion methods for lena image [9].

Fusion method	PSNR	IOI	EN
Average	25.4810	0.9848	7.2228
Select maximum	26.8663	0.9939	7.2071
Laplacian pyramid	57.1387	0.9854	7.2297
Morphological pyramid	54.1061	0.9788	7.2053
SWT	59.1387	0.9851	7.2322
Proposed method	**67.0832**	**0.9977**	**7.2494**

In [3][4][8][11] the proposed advanced DWT fusion method is compared with existing transform domain methods. Table2 show the advanced DWT method gives higher IQI and entropy.

Table2: Image quality evaluation results of the fused images tested on the two simulated image pair lena I1 and lena I2 [4]

Imagery	Ref.	Input A	Input B	Eval.	Laplacian	Gradient	Contrast	Ratio	Morpho.	DWT	aDWT
Lena-I1	7.31	7.29	7.29	Entropy	**7.46**	7.2	7.44	7.38	7.38	7.42	7.45
	147.77	89.53	116.55	SF	145.59	121.98	145.9	92.68	126.03	142.19	**151.71**
				IQI	0.96	0.93	0.96	0.92	0.93	0.96	**0.96**
				RMSE	3.03	22.27	**1.53**	5.91	8.79	2.06	2.75
Lena-I2	7.31	7.36	7.33	Entropy	**7.56**	7.34	7.47	7.35	7.42	7.53	7.52
	147.77	92.34	119.76	SF	152.18	125.92	116.14	81.28	121.62	150.93	**159.17**
				IQI	0.95	0.94	0.94	0.9	0.92	0.94	**0.95**
				RMSE	11.31	15.17	14.85	13.41	8.51	12.47	**6.74**

In [2] a new fusion method based on combination of pixel and energy rule is proposed. Comparison with pixel and energy method show the proposed method gives better result.

Table3: Comparison between pixel region and hybrid fusion rule based on MSE and PSNR [2].

Source images	Fusion Rule	MSE	PSNR in decibels
CT/MRI Scan	Pixel	207.56	24.96
	Energy	206.22	25.03
	Hybrid	190.95	25.32
Clocks	Pixel	106.27	27.87
	Energy	85.92	28.79
	Hybrid	67.97	29.81
Cameraman	Pixel	180.57	25.56
	Energy	120.28	27.33
	Hybrid	114.29	27.55
Girl	Pixel	411.15	21.99
	Energy	428.84	21.81
	Hybrid	275.73	23.73
Lenna	Pixel	233.62	24.45
	Energy	188.52	25.38
	Hybrid	109.05	27.75

4.1 COMPARISON OF DIFFERENT IMAGE FUSION TECHNIQUES:-

S.N	Fusion Technique/Algorithm	Domain	Measuring Parameters	Advantages	Disadvantages
1.	Simple Average[12][9]	Spatial	PSNR-25.48 EN-7.22	This is the simplest method of image fusion.	The main disadvantage of Pixel level method is that this method does not give guarantee to have a clear objects from the set of images.
2.	Simple Maximum[8] [12]	Spatial	PSNR-26.86 EN-7.20	Resulting in highly focused image output obtained from the input image as compared to average method.	Pixel level method are affected by blurring effect which directly affect on the contrast of the image
3.	PCA[11]	Spatial	NC-0.998 PSNR-76.44	PCA is a tools which transforms number of correlated variable into number of uncorrelated variables, this property can be used in image fusion.	But spatial domain fusion my produce spectral degradation.
4.	DWT[3][4][8]	Transform	RMSE-2.06 EN-7.42	The DWT fusion method may outperform the slandered fusion method in terms of minimizing the spectral distortion. It also provide better signal to noise ratio than pixel based approach.	In this method final fused image have a less spatial resolution.
5.	Combine DWT, PCA[7][9]	Transform	PSNR-67.08 EN-7.24	Multi level fusion where the image undergoes fusion twice using efficient fusion technique provide improved result .output image contained both high spatial resolution with high quality spectral content.	This method is complex in fusion algorithm. Required good fusion technique for better result.
6.	Combination of Pixel & Energy Fusion rule [2]	Transform	PSNR=27.75	Preserves boundary information and structural details without Introducing any other inconsistencies to the image.	Complexity of method increases.

V. CONCLUSION:-

Although selection of fusion algorithm is problem dependent but this review results that spatial domain provide high spatial resolution. But spatial domain have image blurring problem. The Wavelet transforms is the very good technique for the image fusion provide a high quality spectral content. But a good fused image have both quality so the combination of DWT & spatial domain fusion method (like PCA) fusion algorithm improves the performance as compared to use of individual DWT and PCA algorithm. Finally this review concludes that a image fusion algorithm based on combination of DWT and PCA with morphological processing will improve the image fusion quality and may be the future trend of research regarding image fusion.

REFERENCES

[1]. Deepali A.Godse, Dattatraya S. Bormane (2011) **"**Wavelet based image fusion using pixel based maximum selection rule" International Journal of Engineering Science and Technology (IJEST), Vol. 3 No. 7 July 2011, ISSN : 0975-5462

[2]. Susmitha Vekkot, and Pancham Shukla "A Novel Architecture for Wavelet based Image Fusion". World Academy of Science, Engineering and Technology 57 2009

[3]. Shih-Gu Huang, "Wavelet for Image Fusion"

[4]. Yufeng Zheng, Edward A. Essock and Bruce C. Hansen, "An Advanced Image Fusion Algorithm Based on Wavelet Transform – Incorporation with PCA and Morphological Processing"

[5]. Shrivsubramani Krishnamoorthy, K P Soman," Implementation and Comparative Study of Image Fusion Algorithms" .International Journal of Computer Applications (0975 – 8887) Volume 9– No.2, November 2010

[6]. Jonathon Shlens, "A Tutorial on Principal Component Analysis". Center for Neural Science, New York University New York City, NY 10003-6603 and Systems Neurobiology Laboratory, Salk Insitute for Biological Studies La Jolla, CA 92037

[7]. Gonzalo Pajares , Jesus Manuel de la Cruz "A wavelet-based image fusion tutorial" 2004 Pattern Recognition Society.

[8]. Chetan K. Solanki Narendra M. Patel, "Pixel based and Wavelet based Image fusion Methods with their Comparative Study". National Conference on Recent Trends in Engineering & Technology. 13-14 May 2011

[9]. M .Chandana,S. Amutha, and Naveen Kumar, " A Hybrid Multi-focus Medical Image Fusion Based on Wavelet Transform". International Journal of Research and Reviews in Computer Science (IJRRCS) Vol. 2, No. 4, August 2011, ISSN: 2079-2557

[10]. Stavri Nikolov Paul Hill David Bull Nishan Canagarajah "WAVELETS FOR IMAGE FUSION

[11]. V.P.S. Naidu and J.R. Raol, "Pixel-level Image Fusion using Wavelets and Principal Component Analysis". Defence Science Journal, Vol. 58, No. 3, May 2008, pp. 338-352 Ó 2008, DESIDOC

[12]. Anjali Malviya, S. G. Bhirud ." Image Fusion of Digital Images" International Journal of Recent Trends in Engineering, Vol 2, No. 3, November 2009