Comparison of Image Fusion techniques using wavelets

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Abstract: Image fusion plays a vital role in many fields, such as medical diagnosis, remote sensing, and robotics. Image fusion combines the necessary information from two reference images and provides a new suitable image for human and machine perception for further image-processing tasks such as feature extraction and object recognition. Wavelet transform is designed in a way that it provides good frequency for low frequency components and high temporal resolution for high frequency components. This paper represents the analysis of various image fusion techniques using wavelet transform. The results through various fusion techniques are compared.

Keywords: Image fusion, Discrete Wavelet Transform (DWT), Entropy, Root Mean Square Error (RMSE), Peak Signal to Noise Ratio (PSNR).

I. INTRODUCTION

Image fusion is a process of combining two or more images. The resultant image will be more informative then the two reference images. It is a mechanism for improving the quantity of an image. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics. Fusion techniques include the simplest method of pixel averaging to more complicated methods such as principal component analysis and wavelet transform fusion. Image fusion improves reliability by reducing redundant information and also improves capability using complementary information.

Image fusion domains:
Image fusion method is divided into two domains:
Spatial domain: In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired result.
Transform domain*:* In transform domain method image is first transferred in to frequency domain.
There are different Image fusion levels which are as following:
Pixel level: The pixel-level method works either in the spatial domain or in the transform domain. Image fusion at pixel level amounts to integration of low-level information, in most cases physical measurements such as intensity.

Feature level: The feature-level algorithms typically segment the image into contiguous regions and fuse the regions together using their properties. The features used may be calculated separately from each image or they may be obtained by the simultaneous processing of all the images.

Decision level*:* Decision level fusion uses the outputs of initial object detection and classification as inputs to the fusion algorithm to perform the data integration.

II. LITERATURE REVIEW

Gonzalo Pajares et.al. [1] proposed image fusion based on wavelet decomposition, i.e. a multiresolution image fusion approach. DWT on two remote sensing images was performed. The DWT combined the coefficients from different images and performed 2D-IDWT using backward 2D pyramid algorithm. Different fusion rules were used for fusing different images; such as coefficient grouping, coefficient combining and activity level measurement. The presence of a high number of edges in the source images was analyzed that gave poor results and the wavelets worked suitably when the images are smooth and without rapid intensity changes.

Deepak Kumar Sahu et.al. [2] proposed the image fusion techniques such as; primitive fusion (Averaging Method, Select Maximum, and Select Minimum), Discrete Wavelet transforms based fusion, Principal component analysis (PCA) etc. The performance in transform and spatial domain was analyzed. In transform domain, DWT and IDWT had been applied to the input images. By using combined DWT and PCA, they analyzed the multilevel fusion, in which input images undergoes fusion twice and the fused image contained both high spatial resolution with high quality spectral content.

Mukta V. Parvatikar et.al. [3] analyzed the performance of different image fusion techniques such as; simple average, maximum, minimum, Brovey method (BT), intensity hue saturation (IHS), PCA and DWT. The spatial domain techniques provided high spatial resolution but also had some disadvantages like image blurring problem, was proposed. The Wavelet transform was a better technique for image fusion providing high quality image content.

Deron Rodrigues et.al. [4] proposed the comparison of various fusion rules to fuse wavelet coefficients in the image fusion process. Fusion using many fusion rules such as; max-max, min-min, linear-linear, down_up-up_down, Up_Down-Up_Down Fusing rules was performed. It had been analyzed that Up_Down- Up_Down Fuse rule gave the higher entropy.

Yong Yang et al. [6] performed image fusion in medical applications using MRI and CT scan images as input images. They had analyzed various fusion technique such as; pixel averaging, gradient pyramid, DWT and coefficient combining. In order to improve the quality of the resultant image, all the combined coefficients were analyzed by a window based reliability confirmation. The fused image was constructed using the inverse wavelet transform with the composite coefficients. The coefficient combining method preserved more practical information in the fused image with higher spatial resolution and less variation with the source images.

Anjali A. Pure et.al. [5] proposed that Curvelet transform (CT) is more practical for analyzing the images having curved shape edges. A new image fusion technique based on the combination of wavelet and a fast discrete, CT transform was proposed. It described the curved shapes of images and analyze the better image features.

III. IMAGE FUSION TECHNIQUES

A. Simple average method:

In this method, the resultant fused image is obtained by taking the average intensity of corresponding pixels from both the input images. This method belongs to spatial domain.

$$F(i,j) = \frac{A(i,j)+B(i,j)}{2} \quad (1)$$

Where F-fused image, A and B –input images.

This technique is simple, easy to implement, and works well for images taken from same sensor. It has also few disadvantages like reduced contrast and also introduces some noise which reduces quality of an image.

B. Simple minimum method

The final fused image is obtained by selecting the minimum
intensity of corresponding pixels from both the input images. This method belongs to spatial domain.

$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} \min A(i,j)B(i,j) \quad (2)$$

Where F-fused image, A and B –input images.

C. Simple maximum method

In this method, the resultant fused image is obtained by selecting the maximum intensity of corresponding pixels from both the input images.

$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} maxA(i,j)B(i,j) \quad (3)$$

Where F - fused image, A and B – input images.

These techniques produces highly focused resulting image as compare to final image of average method.
There are some disadvantages like pixel level method is affected by blurring effect which directly affect on the contrast of the image.

IV. WAVELET TRANSFORM

Wavelet transform is a type of signal representation that can give the frequency content of the signal at a particular instant of time. They can be described by using two functions namely the scaling function f (t) or father wavelet and the wavelet function ψ (t) or mother wavelet. The mother wavelet through translation and scaling produces various wavelet families which are used in the transformation. The Discrete Wavelet Transform has the property that the spatial resolution is small in low-frequency bands but large in high-frequency bands. This is because the scaling function is treated as a low pass filter and the mother wavelet as high pass filter in DWT implementation.

A. Discrete wavelet transform (DWT):

Discrete wavelet transform can offer a more precise way for image analysis. It decomposes an image into low frequency band and high frequency band in different levels. DWT improves the quality of the new image since it works on feature extraction. The fusion algorithm is performed at the pixel level.

a) Haar wavelet: Haar wavelet is simplest possible wavelet. It is not continuous and therefore not differentiable. It reversible without edge effects.
b) Daubechies wavelet (db): db wavelet has balanced frequency response. They use overlapping window in which high frequency coefficients reflects all high frequency changes.
c) Biorothogonal wavelet (bior): bior wavelets feature a pair of scaling functions and associated scaling filters one for analysis and one for synthesis. There is also a pair of wavelets and associated wavelet filters one for analysis and one for synthesis.

The DWT transform divides an image into low and high frequency bands and it represents first order DWT. The low-low (LL) band at the coarsest scale and low-high (LH), high-low (HL), high-high (HH) spatial frequency bands at different scales.

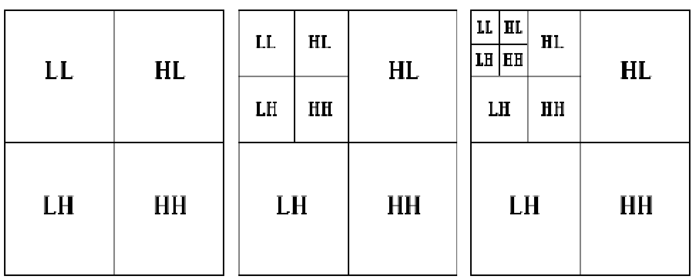

Fig.1 *Wavelet Transform (a) Single Level decomposition, (b) Two level decomposition, (c) three level decomposition*

The LL band contains less spatial resolution and also contains the approximation detail of the original image. The other sub-part of image shows the detailed information. Decomposition can be done at four different stages. At first stage of decomposition there are four frequency bands. At next stages, decomposition is applied to low-low band of current decomposition that forms recursive decomposition. Finally, the N^{th} stage will have 3N+1 and one low-low frequency band.

B. Preprocessing for Image fusion:

1) *Image registration*: Images to be fused are taken with different sensors having different orientations. These images are required to be registered.

2) *Image resizing:* Fusion only occurs on the images which are having the same size, so the input images are required to be resizing if they are not of same size. It can be done by interpolating the smaller size by rows and columns duplication.

3) *Image enrichment:* It includes two steps; first is conversion of image into grayscale and second step is equalizing the histogram of images for enrichment of the contrast.

4) *Steps used in algorithm for image fusion using DWT:*
a) Read and register the two input images.
b) Apply 2-D discrete wavelet transform on both images and creates wavelet tower decomposition.
c) By using different fusion operators fuse the each level of decomposition.
d) After fusion process get the wavelet pyramid.
e) To reconstruct the original image, apply inverse discrete wavelet transform and finally get the fused image F.

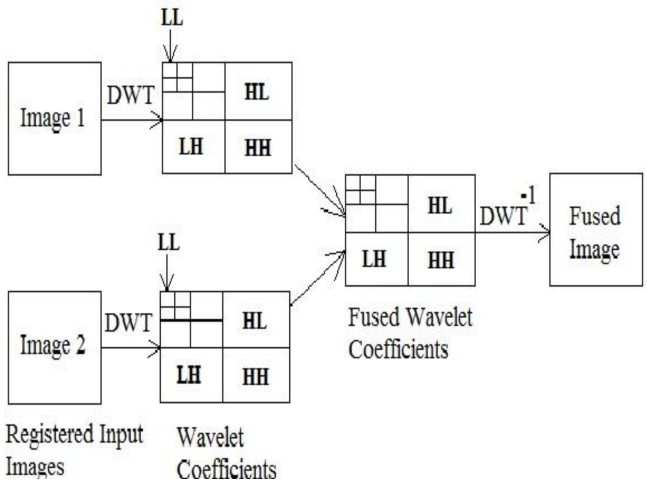

Fig. 2 *wavelet based image fusion*

V. PARARMETERS OF PERFORMANCE

A. Entropy (EN) :

EN 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. EN can be defined as:

$$EN = -\sum_{i=0}^{L-1} p_i \log 2\, p_i \qquad (4)$$

Where $p = \{p_0, p_1, \ldots \ldots \ldots p_{L-1}\}$ probability distribution at each level, L=no. of total grey levels.

B. Root Mean Square Error (RMSE) :

RMSE events the quantity of change per pixel in an image due to the processing. It is given by:

$$RMSE = \sqrt{{}^{1}/_{mn} \sum_{i=1}^{m} \sum_{=1}^{n} \left(A_{ij} - B_{ij}\right)^2} \quad (5)$$

Where m, n- no. of rows and columns, i-pixel row index, j-pixel column index, A-perfect image, B-fused image.

C. Peak signal to noise ratio (PSNR):

PSNR is an engineering term for the ratio between the maximum possible power of a signal and the power of undignified noise that affect the fidelity of its image.

$$PSNR = 20log_{10}\left[\frac{L^2}{RMSE}\right] \quad (6)$$

Where L - no. of grey levels in an image.

VI. IMPLEMENTATION

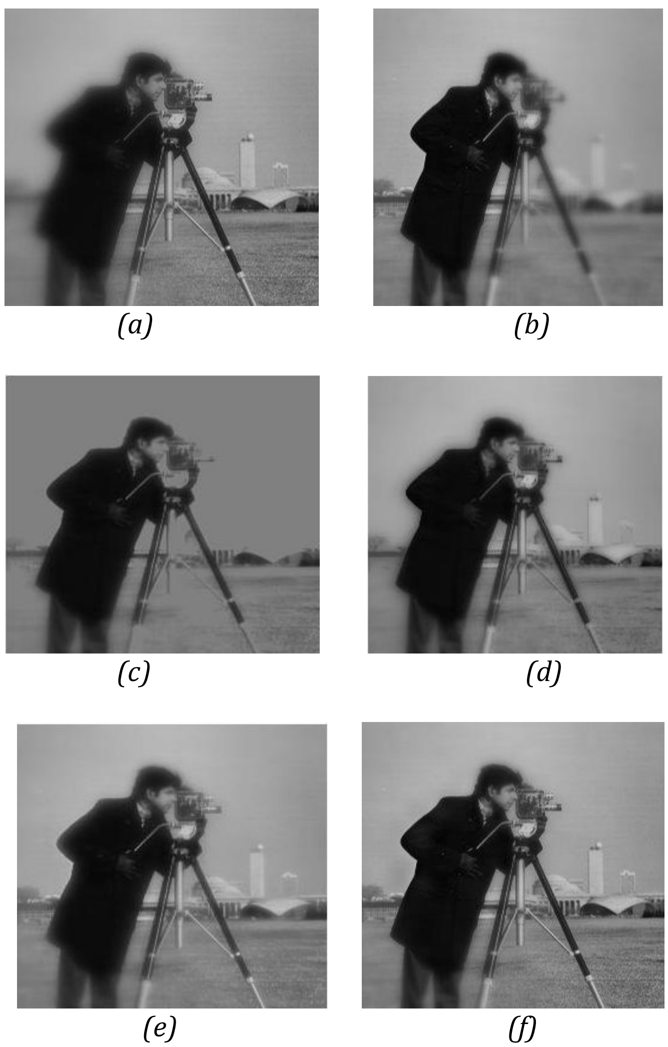

Fig.3*(a) right focused,(b)left focused,(c) fused image using average method, (d) fused image using minimum method, (e) fused image using maximum method, (f) fused image using DWT method.*

A. Analysis tables:

TABLE 1
IMAGE QUALITY EVALUATION FOR FUSED IMAGE USING SPATIAL DOMAIN ALGORITHMS.

Algorithm	Domain	EN	RMSE	PSNR
Simple Average	Spatial	5.3451	118.56	6.6518
Minimum	Spatial	6.0143	121.9074	6.4102
Maximum	Spatial	6.0736	121.2	6.4564

TABLE 2
IMAGE QUALITY EVALUATION FOR FUSED IMAGE USING DIFFERENT DWT WAVELET AT DIFFERENT LEVELS USING MEAN-MAX FUSION RULE.

DWT	Transform		EN	RMSE	PSNR
	Wavelet	Level			
Haar	Haar	2	6.9132	10.5314	27.6811
	Haar	5	7.0047	10.2517	27.9148
Db	db3	2	6.9743	10.2650	27.9036
	db6	4	6.9937	9.5236	28.5548
Bior	bior2.2	3	6.9244	9.7145	28.3780
	bior3.9	5	6.9310	9.5013	28.5751

VII. CONCLUSION

This paper compares the study of various image fusion techniques. These techniques are useful to create a single enhanced image for suitable human vision. The DWT decomposes an image into high and low levels of frequency bands. The fused image is retrieved by applying inverse - DWT.
This paper concludes that DWT performs better fusion results than the spatial domain techniques because DWT allows decomposition in different kinds of coefficients preserving image information. Spatial domain technique gives high spatial resolution with some blurring problem. Image fusion using wavelet transform provides good quality images.

REFERENCES

[1] G. Pajares, Jesús Manuel de la Cruz, "A wavelet-based image fusion tutorial," *Elsevier*, pp.1855-1872, March 2004.

[2] D. K. Sahu, and M.P.Parsai, "Different Image Fusion Techniques –A Critical Review," *International Journal of Modern Engineering Research*, vol. 2, pp.4298-4301, Sep.-Oct. 2012.

[3] M. V. Parvatikar and G. S. Phadke, "Comparative Study of Different Image fusion Techniques," *IJSET*, vol.3, pp.375-379,April 2014.

[4] D. Rodrigues, H. A. Virani, and S. Kutty, "Multimodal Image Fusion Techniques for Medical Images using Wavelets," International *Journal of Research in Advent Technology*, Vol.2, No.3, pp.310-313, March 2014.

[5] A.A. Pure, N. Gupta, M. Shrivastava, "An Overview of Different Image Fusion Methods for Medical Applications," *International Journal of Scientific & Engineering Research*, Volume 4, Issue 7, July-2013.

[6] Y. Yang, D. S. Park, S. Huang and N. Rao, "Medical Image Fusion via an Effective Wavelet-Based Approach," *EURASIP Journal on Advances in Signal Processing*, Vol.2010,13 pp.1-13, March 2010.

[7] V.P.Sawant, "Fusion Algorithm for Images based on Discrete Multi-wavelet Transform," *IOSR Journal of VLSI and Signal Processing*, Volume 2, pp.22-27, Issue 3 May – Jun. 2013.

[8] Y.Zheng, "*Image Fusion and Its Applications*".

[9] M.Misti, Y.Misti, G.Oppenheim, J.M. Poggi, "*Wavelet toolbox™,User guide*".