**I J C T A**, 9(34) 2016, pp. 737-743


# Multispectral Image Fusion using Integrated Wavelets

**D. Bhavana[1], V. Rajesh[2] and S. Koteswara Rao[3]**

**ABSTRACT**

Fusion of visible and IR images is intended to merge input pictures into a fused image that is predicted to be a higher informative for human or machine sense as compared to any of the input pictures. Due to this advantage, Image fusion techniques have shown greater achievements in remote sensing, medical imaging, and visual sense applications. As expected, conventional techniques like simple averaging fusion, select maximum, select minimum algorithms shows degraded performance. The ringing tone given within in the fused image can be turned aside using wavelets with shift invariant property. The proposed fusion technique requires sub-band decomposition using 2D-Discrete Wavelet Transform (DWT) in order to retain both spatial and spectral information. An optimal variant of the daubechies wavelet family has been preferred experimentally for improved fusion results. The Daubechies wavelets family is used to divide the images into detail information and approximate information. The detail information from one image can be injected into another image using different techniques and different fusion rules. It has been concluded that image fusion using wavelets with greater level of decomposition showed superior performance.

***Keywords:*** Fusion, Visual images, IR images, Wavelet Transform, Decomposition.

## I. INTRODUCTION

The need for image fusion for image processing applications has been increased drastically due to constraints like improper image capturing, optical limitation and lack of clarity and quality with a single image sensor. Infrared image contain few detail with high contrast about the captured scene compared to the visual image. On the other hand, visual image contain plenty of high frequency information but has a bad target contrast especially under bad luminance condition [2]. In the recent years a lots of work is being conducted in the area of image processing especially in the aspect of image fusion.

New methods have been proposed regularly on the improvements of the existing techniques and approaches. Image fusion is a technique that is used to combine the similar characteristics of two or more images to get the final fused image. Many applications that require analysis of two or more images of a scene have been benefited from image fusion[1]. It is often suitable to fuse two or more images of different characteristics into a single image such that the resultant fused will be more informative than that of the original source images. Image fusion can be broadly classified into two different categories. They are 1-spatial domain fusion and 2- Transform domain fusion. They can be done in 3 different levels. They are 1-Pixel level, 2- Feature level, 3-Decision level. There are several methods that have been proposed to perform image fusion techniques. These methods are based on the type and level where the fusion has to be applied. Image fusion decreases the storage cost storing of single image with all the necessary and required characteristics is more useful than storing of multiple images which are poor in quality and have less information. Image fusion also increases reliability of an image.

* Assistant Professor, Research Scholoar, Electronics and Communication Engineering, KLUniversity, KLUniversity, Guntur, Andhra Pradesh, India, *E-mail: bhavanaece@kluniversity.in*

** Professor, ECE Department, KL University, Guntur, Andhra Pradesh, India

*** Professor, ECE Department, KL University, Guntur, Andhra Pradesh, India.

The elementary multi-spectral image fusion is to take the average of the grey level source images pixel by pixel. This approach would produce several unwanted consequences and reduced feature contrast. To beaten this problem, multiscale transforms, such as wavelets, Laplacian pyramids, morphological pyramid, and gradient pyramid have been proposed. Multi-resolution wavelet transforms could contribute good localization in both spatial and frequency domains. Discrete wavelet transform would provide directional information in decomposition levels and contain unique information at different resolutions.

With the advance of research in this field, algorithms such as Intensity–Hue–Saturation (IHS) and Brovey transform (BT) have been used to fuse visible and IR images implemented the pixel level decomposition on weighted average fusion law. Though the algorithm was straightforward to implement still the fused image did not explain the existence of the objects from the set of images used a method 'fuse then decompose' approach which expressed input image in the form of gradient maps at each resolution level. Even if it has been noticed that the said technique did not produce tolerable performance but consecutively increased the computational complexity due to the crisis of gradient maps. The widely used fusion rule is maximum selection scheme [3]. In selected maximum pixel intensity approach along with wavelet to perform fusion yielded a focused image but the image experienced blurring and diminished contrast. On the other hand, in DWT, the output image reduced the noise content; it contained high spatial distortion, which did not clarify the objective of image fusion. The method produced an image with less structural comparison with the source images along with low contrast and luminescence. Wavelet basis functions are generally not expressed explicitly as functions [4]. The above discussion acquired the motive to improve the quality of the fused image by removing the artifacts from the images. The reason for choosing the wavelet based technique in comparison to other approaches is that they are confined in time and frequency and can be represented with specific time span. Hence, the wavelets retain time and frequency information, thereby producing a suitable approach for image fusion. Else, these fused images are also handled with denoising, contrast and edge enhancement techniques to improve the visualization of information. Therefore, the proposed work represents a combination of wavelet transform and PCA as an improvement to the limitations mentioned before. The results have been assessed using entropy, fusion factor (FF) and standard deviation as fusion metrics; produced satisfactory performance. The rest of the paper is organized as follows: The proposed fusion approach is discussed in section II. Section III presents experimental results and finally the paper is concluded in section IV.

## II. PROPOSED FUSION METHODS

This part discusses the utilization of PCA fusion rule in wavelet transform as a technique to fuse the complimentary content from visual and IR images into a single image for definite results. Wavelets saves spatial and frequency information of the images to be combined. Although the primary dominance of wavelet transform over another transforms is that it consists of the temporal information of the images. The Wavelet Transform provides a time-frequency representation of the signal which is capable of revealing aspects of data which other signal Analysis techniques overlook [5] .Wavelet transform detects the location and frequency information from the images, which makes it suitable for the image fusion purposes. Multiscale decomposition is very useful for extracting the salient features of images for the purpose of fusion [6]. Furthermore; wavelet transform can easily captures the local features involved in image process.

### (A) Proposed fusion approaches

The first step in the proposed fusion technique involves the pre-processing of visual and IR images, i.e. transforming source images from RGB scale to Gray scale. The next step is decomposing the original images using wavelet transform. This dissolve includes the decomposition of the original images into frequency bands specifically a lower frequency band and other frequency bands. Wavelets can be represented as the solution of the two scaling functions namely father wavelet and mother wavelet or wavelet function. Mother wavelet under goes certain modifications and scaling to produce compatible wavelet families as

$$\mu_{a,b}(t) = \frac{1}{\sqrt{a}}\mu\left(\frac{t-b}{a}\right) \qquad for\,(a,b\in R),\; a>0 \tag{1}$$

where μ (t) represents mother wavelet function, while a & b are scale and transition parameters respectively, given as:

$$a = a_0^{\,i},\; b = m\, a_0^{\,i} b_0 \text{ for } (I, m \in Z) \tag{2}$$

So, the wavelet family can be shown by Eq. (3).

$$\mu_{i.m}(t) = a_0^{-i/2}\,\mu(a_0^{-I}\,t - mb_0) \text{ for } (I, m \in Z) \tag{3}$$

If the original images are decomposed using wavelet transform, the detailed and approximation coefficients are achieved. Principle Component Analysis (PCA) is used as a fusion rule to selectively fuse the approximate wavelet coefficients of source images. PCA is among the most notorious data-analysis tools designed to simplify multidimensional data by tracking new factors supposed to capture the main features [7]. PCA provides to features of the images from original domain to transformed or new domain called PCA domain where they are organized in order of their variance. In PCA domain, fusion is obtained by only preserving those features that hold a pregnant amount of content. This can be obtained by preserving only those components which have high variance. It is a statistical technique that transforms a multivariate data set of inter-correlated variable into a data set of new un-correlated linear combinations of the original variables[8] .The steps convoluted in the proposed PCA design are defined in fig.1. The last step is to apply inverse wavelet transform for the restoration of the processed coefficients.

**BEGIN**

Step 1: Wavelet Coefficients are calculated for both Visible & IR images.

Step 2: Column vectors against wavelet coefficients are computed.

Step 3: Covariance matrix is calculated using column vectors.

Step 4: Diagonal elements of the covariance vector are determined.

Step 5: Eigen vectors and Eigen values of covariance matrix are computed.

Step 6: Large Eigen value is computed by dividing individual element with the mean of Eigen vector. Column vector corresponding to large Eigen value is considered.

Step 7: Perform Multiplication of normalized Eigen vector values through each term of wavelet coefficient matrix.

Step 8: Repeat all the above steps for all the approximation and detailed wavelet coefficients.

Step 9: Compute inverse wavelet transform of scaled matrices which are calculated in step 8.

Step 10: Combine the images calculated in step 9 for reconstruction of images.

Step 11: The Output is a fused image.

**END**

### (B) Wavelet Based Genetic Algorithm

The proposed technique creates a specific 1 x 40 feature vector for each source image. It is a combination of a feature vector based on the mean and standard deviation of the magnitude of the wavelet coefficients and feature vector based on normalized central moments of wavelet edges after multi-resolution decomposition. The two integrated feature vectors are given as inputs to the genetic search. It calculates the optimal weights of the source images, $W_V$, $W_{IR}$ where $W_V + W_{IR} = 1$. To secure efficient accuracy of the solution, the string length, $-\ell$ is measured using equation (3). The population size is approximated to ten percent of $2^{-\ell}$.

$$\Delta e = \frac{\Delta e \ \max - \Delta e \min}{2\ell - 1}$$

It should be noted that $\Delta e\min = 0$ and $\Delta e = 1$ which denotes the range of optimal weights. Therefore, $\ell$ can be calculated for any acceptable choice of Δe. A classical choice of in our case is 0.01. One primary distinction between this proposed method and the others is the precision. To classify the individuals in the population, we used the entropy as the fitness function or cost function given as:

Cost function=entropy (WV*V+ WIR*IR)

## III. EVALUATION OF PROPOSED FUSION APPROACH

If the fusion process is completed, the last step requires is the evaluation of the proposed approach using suitable fusion metrics. In the proposed work, the performance evaluation is accomplished using Entropy, Fusion Factor and standard deviation as fusion metrics. If entropy of fused image is higher than parent image then it indicates that the fused image contains more information [9] [11].

### (A) Entropy

Entropy of an image is considered as a measuring metric of the information content in the fused data. An increase in entropy of the fused image can be considered as overall increase in the amount of information. Hence the quality of the fused image can be assessed by observing the entropy of fused data and original data.

$$E = -\sum_{i=0}^{i-1} Pi \ \log_2 Pi \tag{4}$$

Where $l$ is the total number of grey levels and $P_i$ is the probability of occurrence of each intensity value.

*2) Fusion Factor:* F or the two input images say A, B and fused image F, the fusion factor can be given as

$$FF = M_{AF} + M_{BF} \tag{5}$$

Where MAF and MBF are mutual information among source images and the fused image. Higher values of fusion factor indicate better fusion results.

*3) Standard Deviation:* Standard deviation of i χ j image is given by

$$SD = \left( \frac{1}{i \chi j} \Sigma_1^i \, \Sigma_1^j \, (f(i,j) - \mu)^2 \right)^{1/2} \tag{6}$$

**Table I**
**Entropy Values for Bottle Images**

| *Image* | *Entropy values* |
|---|---|
| Source image 1 | 7.2507 |
| Source image 2 | 6.1115 |
| Wavelet Based PCA | 7.7424 |
| Wavelet Based GA | 7.5061 |

**Table II**
**Entropy Values for Transmission Lines Images**

| *Image* | *Entropy values* |
|---|---|
| Source image 1 | 7.5472 |
| Source image 2 | 6.5740 |
| Wavelet Based PCA | 7.7946 |
| Wavelet Based GA | 7.4812 |

**Table III**
**Entropy Values for Concealed Weapon Images**

| *Image* | *Entropy values* |
|---|---|
| Source image 1 | 7.5472 |
| Source image 2 | 6.5740 |
| Wavelet Based PCA | 7.7946 |
| Wavelet Based GA | 8.3031 |

## IV. RESULTS AND DISCUSSION

Simulations in this present work have been achieved on two different spectral images (Visual and IR). Once pre-processing is completed, the two input images are subjected to sub-band decomposition using daubechies wavelet family. The wavelet representation provides directional information whereas the Laplacian pyramid does not supply spatial orientation in the decomposition. Since the wavelet basis function can be chosen orthogonal, the information at each layer of the decomposition is unique [10] [12]. The suitable wavelet for decomposition is considered as db2 after performing several experiments. The choice of db2 variant not only contribute high values of fusion metrics but also consistent from the visual point of view. The results of fused images achieved using the proposed technique are shown in Fig., although the quantitative analysis of the same is given in table. Results shown in figures say that the proposed fused images have better visual characteristics than the individual images. In visible light images, we can't tell just by looking, whether the bottle contains cold water or hot water. But in Infrared image, we can tell whether the bottle is having cold water or hot water without physical contact. Infrared image is lagging in preserving the details other than bottle. So, it can be clearly seen that the fused image reserves the information from both the images. This is further supported by fusion metrics having high values. A greater value of standard deviation and entropy represents a good quality and increased information content of fused image; validates the effectiveness of the proposed fusion technique [13].

The Wavelet based proposed techniques have been compared with traditional image fusion techniques like select maximum, select minimum, select averaging methods. The achieved results represents the effectiveness of the proposed technique in visual representation as compared to select maximum, select

**Table III**
**Performance Comparison of Fused Images**

| *Fusion Approach* | *FF* | *SD* |
|---|---|---|
| Select Maximum | 1.6390 | 76.5128 |
| Select Minimum | 1.6582 | 76.4075 |
| Select Averaging | 2.2965 | 76.3596 |
| DWT Based PCA | 2.8698 | 76.5960 |
| DWT Based GA | 2.9268 | 76.7151 |

**Figure 1a: Visual Image**

**Figure 1b : IR Image**

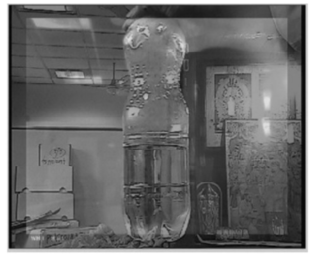

**Figure 1c : DWT based PCA fusion**

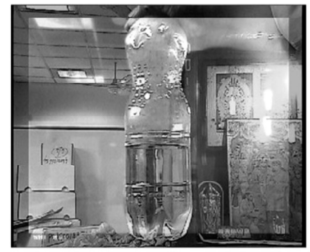

**Figure 1d: DWT based GA Fusion**

**Figure 2a: Visual Image**

**Figure 2b : IR Image**

**Figure 2c : DWT based PCA fusion**

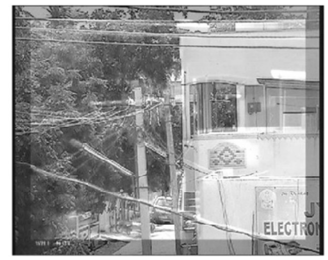

**Figure 2d: DWT based GA Fusion**

**Figure 3a: Visual Image**

**Figure 3b : IR Image**

**Figure 3c : DWT based PCA fusion**

**Figure 3d: DWT based GA Fusion**

minimum, select averaging methods. The fused image obtained from the proposed technique shows that the information from the original images are preserved as related to images obtained from other techniques. Further, the greater values of the fusion metrics shown in table III approve that the proposed fusion technique has better results than the other. In case of concealed weapon detection images, DWT based GA is effective and concealed feature (Gun) can be visualized.

## V. CONCLUSION

This paper presents a technique for image fusion applying PCA in wavelet domain. Feature enhancement property of PCA and the time and frequency conservancy property of wavelet make it suitable for all types of applications of image fusion. The fused image of the proposed technique is more refined in defining spectral and spatial information. Hence, it is providing the details of two different spectral images in one single image, validating the purpose of image fusion. Significant results applicable from visual point of view, likewise high values of the fusion metrics, have been achieved from the proposed fusion technique. Comparison results indicate a consistent increase in restoration of information and quality features in the achieved fused image; as interpreted by high value of fusion factor, in correlation to other fused images. Thus, the proposed fusion technique is more specific and can be more adequately used for all purposes than the other fusion methods. By visual analysis, we can observe that Wavelet based GA is more suitable for concealed weapon detection than other techniques.

## REFERENCES

[1] Shutao Li, Xudong Kang, Leyuan Fang, Jianwen Hu, Haitao Yin , “Pixel-level image fusion: A survey of the state of the art”, information Fusion, vol. 33, pp.100–112,2017.

[2] Sandhya Kumari Teku, S. Koteswara Rao, and I. Santhi Prabha, “Contrast Enhanced Low-light Visible and Infrared Image Fusion”, Defence Science Journal, Vol. 66, No. 3, pp. 266-271, , .May 2016

[3] Yong Yang,Dong Sun Park,Shuying Huang,and Nini Rao, “Medical Image Fusion via an EffectiveWavelet-Based Approach”, EURASIP Journal on Advances in Signal Processing, 2010

[4] Stefania Salvatore, Jorgen G. Bramness and Jo Røislien, “Exploring functional data analysis and wavelet principal component analysis onecstasy (MDMA) wastewater data”, , BMC Medical Research Methodology, July 2016.

[5] Comparison M.D. Nandeesh and Dr.M. Meenakshi, “Image Fusion Algorithms for Medical Images-A Comparison”, Bonfring International Journal of Advances in Image Processing, Vol. 5, No. 3, July 2015.

[6] *YANG* , *JING Zhong-liang*, *ZHAO Hai-tao*, J. Shanghai Jiaotong, “Review of Pixel-Level Image Fusion”, Univ. (Sci.), vol. 15, issue 1, pp.6-12, 2010.

[7] Mina Aminghafari, Nathalie Cheze, Jean-Michel Poggi, “multivariate denoising using wavelets and principal component analysis”, Computational Statistics & Data Analysis · Volume 50, Issue 9, , Pages 2381–2398 ,May 2006.

[8] M.Tamilarasi, K.S.Thara, “A Comparative Analysis of Image Fusion Techniques”, International Journal of Advanced Research Trends in Engineering and Technology, Vol. 3, Special Issue 1, March 2016

[9] Deepika.L , Mary Sindhuja.N.M, “Performance Analysis of Image Fusion Algorithms using HAAR Wavelet”, , IJCSMC, Vol. 3, Issue. 1, pg.487 – 494, January 2014.

[10] HAI-HUI WANG, “A New Multiwavelet-Based Approach to Image Fusion”, Journal of Mathematical Imaging and Vision, vol. 21, pp. 177–192, 2004.

[11] D. Bhavana, V. Rajesh and K. Kishore Kumar, “Implementation of Plateau Histogram Equalization Technique on Thermal images”, Indian Journal of Science and Technology. 2016 Aug; 9(32).

[12] D. Bhavana, V. Rajesh and D. Ravi Tej, “ Scene based two-point nonuniformity correction of thermal images”, International Journal of Engineering and Technology.2013 Apr-May. 5(2).

[13] D. Bhavana, V. Rajesh, “A New Pixel Level Image Fusion Method based on Genetic Algorithm”, . Indian Journal of Science and Technology, Volume 9, Issue 45, December 2016.