A Multi Focus Image Fusion Method Based On Curvelet Transform

J. Arivazhagan[1], Dr. R. Bhavani[2], Dr. R. Priya[3]
[1, 2, 3] Department of Computer Science and Engineering
[1, 2, 3] Annamalai University

Abstract- *Image fusion is the process of integration of two or more source images into a single fused image. The resultant fused image is used to retain the important features of the source images. Color image fusion is the process of integrating one or more color images to enhance clarity of the image. The application of color image fusion simplifies object identification and helps in better cognition. In the existing system, image fusion is done on gray scale images by using Discrete wavelet Transform (DWT) and Discrete Cosine Hormonic wavelet transform (DCHWT) techniques. In the proposed system, image fusion is done on color images by using the Curvelet Transform (CT). Curvelet technique is a multi-scale and multi-directional decomposition technique. The performance assessment of the proposed method was conducted on Lytro multi-focus image dataset. Experiments are conducted to show the effectiveness of the proposed system over existing system.*

Keywords- DWT-Discrete Wavelet Transform, Discrete Cosine Hormonic wavelet transform (DCHWT), Curvelet Transform (CT), Lytro multifocus image.

I. INTRODUCTION

Image fusion has become a widely used tool for increasing the interpretation quality of images in various applications like getting an 'all-in-focus' image from a given set of multi- focus images or multispectral image based applications such as medical diagnosis, surveillance, and remote sensing. The main objective of any image fusion application is to retain all the important visual information found in the input images without introducing any artifacts. In general, advantage of data fusion is the increased dimensionality of the data space which in turn can increase the quality of the deduced information and reduce the ambiguity and vulnerability of the system.

Image fusion can be applied in robot vision, image classification, concealed weapon detection and detection of tumors in medical images. The fusion of images is performed on images acquired from different instrument modalities. In this paper, the images are decomposed using multi-resolution transform based techniques and the method of pixel averaging or maximum selection rule is applied for fusion.

II. LITERATURE REVIEW

Subitha.V, Jenicka.S.et.al (2013) presented color image fusion. Color image fusion is the process of integrating one or more color images to enhance clarity of the image. The application of color image fusion simplifies object identification and helps in better cognition. Wei Huang, Zhongliang Jing.et.al (2007) proposed a method to assess focus measures according to focus measures' capability of distinguishing focused image blocks from defocused image blocks. Several focus measures were studied in this paper as the measures of image clarity, in the field of multi-focus image fusion. Mamta Sharma, Sarika Khandelwal.et.al (2016) proposed a scheme to convert the image data from spatial domain to transform domain. Decompose the transform data into four parts that is LL, LH, HL, HH part. This decomposition Process again applies in LL part at two levels. After this three level decomposition we combine the input image data by applying average method using DCT and get fused data.

Mamatha M., Padmavathi N.B.et.al (2016) proposed a image fuion technique. Medical image fusion is a method in which the information from many images of the same picture are registered and combined into single fused image, which provides more information, compared to each single source image and it provides more reliable result for the observers. R. Bhavani, et.al (2017) proposed multi focus image fusion and DWT based fusion technique is used. A coefficients based selection algorithm is presented. Source images are decomposed by DWT, two different window-based fusion rules are separately applied to combine the low frequency and high frequency coefficients. The coefficients in the frequency domain with maximum sharpness focus measure are selected as coefficients of the fused image, and a maximum neighbouring energy based fusion scheme is proposed to select high frequency sub-bands coefficients.

III. SYSTEM DESIGN AND IMPLEMENTATION

The proposed work consist of three modules, they are

I. Separate RGB bands
II. Curvelet transform
III. Image Fusion

1. Block Diagram

This proposed system was implemented by MATLAB software. Block diagram of the proposed approach is given in Figure 1.

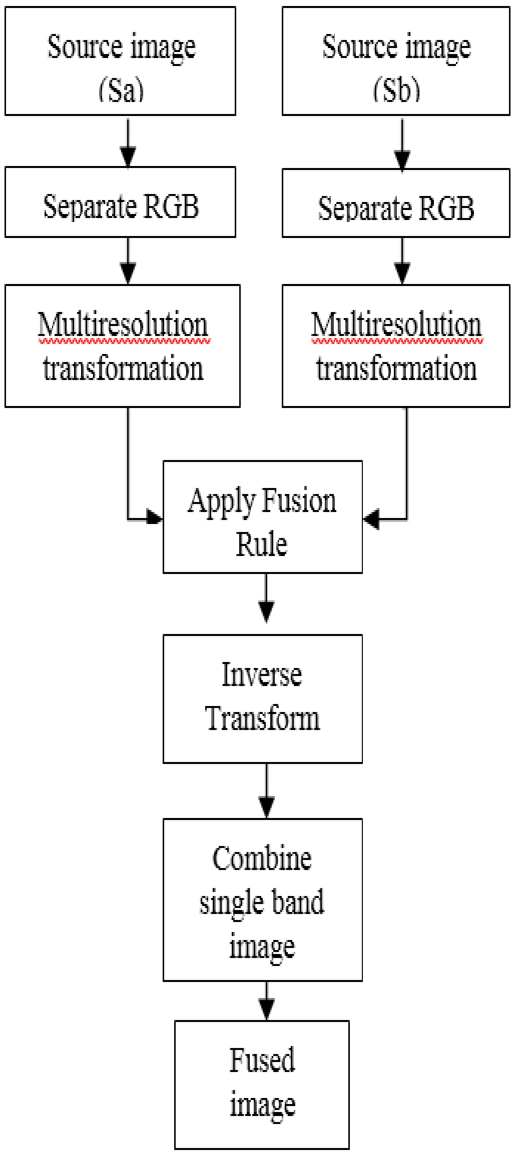

Figure 1. Block diagram

The RGB bands of source images are separated as the pre-processing step. Then the multi-resolution curvelet transform is applied to the spectral bands. The third step explains the fusion of curvelet coefficients using fusion rule. Finally inverse transform is performed to obtain the fused image.

2. Modules Description

Separation of RGB bands

Color digital images are made of pixels, and pixels are made of combinations of primary colors represented by a series of code. An RGB image has three channels: red, green, and blue. The red channel provides the contrast map i.e. contrast information of the image. The green channel contains the most detail of the image while blue channel is responsible for the noise parameter. Red, green and blue bands of a sample image are shown in Figure 2.

Figure 2. RGB separation

Separation of RGB bands is done as the pre-processing step for reducing the complexity and increase the speed of computation. Since the green channel contains most of the information, it is used for further processing.

Curvelet Transform

Curvelet transform is also a multi-resolution decomposition technique. The 2D-FFT is applied on images to obtain the Fourier samples. The Fourier samples are wrapped around the origin. Finally the image is reconstructed by performing the inverse FFT transform.
The Curvelet Transform includes four stages:

- Sub-band decomposition
- Smooth partitioning
- Renormalization
- Ridgelet analysis

Curvelet Transform is a new multi-scale representation most suitable for objects with curves. The curvelet transform open us the possibility to analyse an image with different block sizes, but with a single transform. The idea is to first decompose the image into a set of wavelet bands, and to analyze each band by the ridgelet transform. The block size can be changed at each level scale.

Curvelet transform is a directional multi-scale transform with frame elements indexed by scale and location parameters. Curvelet transform is a multi-scale pyramid with many directions and positions at each length scale, and needle-shaped elements at fine scales.

The first generation curvelet transform originally developed in the continuous domain is through multi-scale filtering, followed by a block Ridgelet transform on each band pass image. The ridgelet transform has limited directional features; it only works for line singularities while the curvelet has superior directional representations. Due to its computational complexity and high redundancy this technique is seldom used for image compression but find application in image denoising, image fusion etc.

In order to reduce the computational complexity of the first generation curvelet transform, second generation curvelet transform was introduced. Second generation wavelets was defined directly via frequency partitioning without using the ridgelet transform. It uses the scaling law in its construction .That is why we can decompose an image at different scales and angles to represent more curvilinear objects and have better edge representations.

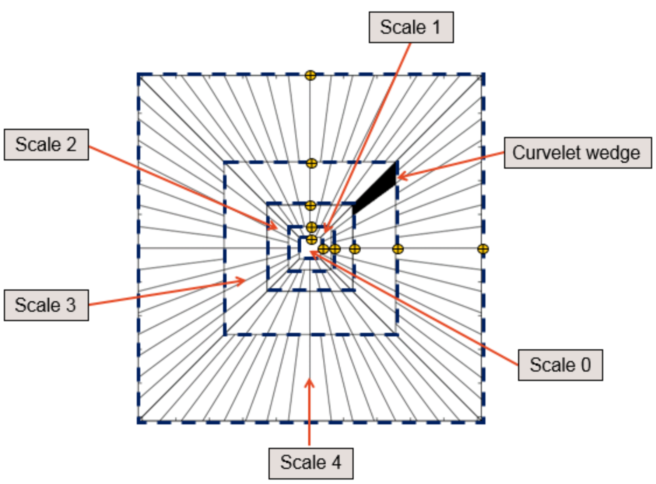

Figure 3. Decomposition of the curvelet transform

Figure 3 shows the default curvelet tiling. 5-scale decomposition is shown. Each scale is divided into $16 \times 2^{(j-1)/2}$ wedges, where j is the scale number. Scale locations are denoted by yellow markers.

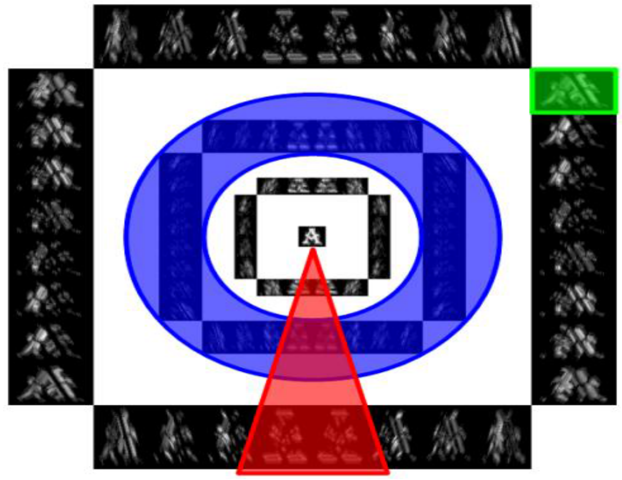

Figure 4. curvelet transform framework

Figure 4 shows the framework of curvelets. In the middle, the sub-sampled image which corresponds to the mean is visible. The rings of this illustration refer to the different scales of the decomposition. Throughout all scales, slices indicated by the red triangle unify similar directions. For each scale, and each direction, several locations for the structures are possible that are captured by the single images. It is obvious that the main structures of the original image still can be recognized in the coefficient images. However, each single image indicated by the green rectangular highlights special parts of the original image according to scale and direction.

Fast Discrete Curvelet Transform:

`There are two simpler digital versions of second generation curvelet transform. They are

1. FDCT via USFFT
2. FDCT via Frequency wrapping

The first FDCT is based on unequally-spaced fast Fourier transforms (USFFT) and the second FDCT is based on the frequency wrapping Fourier samples. These two techniques handle the translation step with different choice of spatial grid. The FDCT using wrapping method is faster than usfft. So, in this work wrapping method is used. The algorithm of FDCT via wrapping is as follows:

Step 1:Take FFT of the Image.
Step2: Divide FFT into collection of Digital Tiles.
Step 3: For each tile

- Translate the tile to the origin
- Wrap the parallelogram shaped support of the tile
- around a rectangle centered at the origin.
- Take the inverse FFT of the wrapped support.

- Add the curvelet array to the collection of curvelet
- coefficients.

Figure 5 shows the decomposition of curvelet transform for sample image at scale=5.

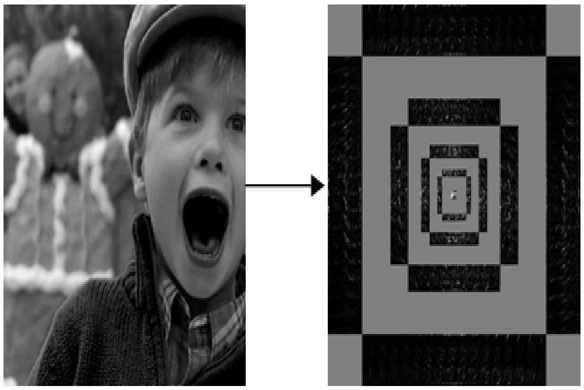

Figure 5. Representation of sample image in curvelet domain

3. Coefficients Organization

The original source images were decomposed into frequency domain by using fast discrete curvelet transform. According to the rules of decomposition, we can get the scale number (nscales =log2n - 3, where [m, n] = size (image). After decomposition, the original image was divided into three levels: Coarse, Detail and Fine. The low-frequency coefficients were assigned to Coarse, which is the most inner level. The high-frequency coefficients were assigned to Fine, which is the outermost level. The middle-frequency coefficients were assigned to Detail. From the viewpoint of statistics, the characteristics of curvelet coefficients can be summarized as follows:

1) Most image energy is compacted into the lowest sub-band. The rest energy was spread over other sub-bands, reducing from low frequency to high frequency.
2) The maximum value of coefficients focused on the first level.
3) The minimum value of coefficients focused on the last level.
4) With the increasing number of scale, coefficients include more zero.

Fusion Rule

The trivial image fusion techniques are as follows:

Average Method:

In Average method, the resultant image is obtained by averaging every corresponding pixel in the input source images.

Select Maximum/Minimum Method:

This is a selection process where, for every corresponding pixel in the input source images, the pixel with maximum/minimum intensity is selected, respectively, and is put in as the resultant pixel of the fused image.

Since most of the energy is confined at the coarse level, the fusion rule of Select Maximum method is used for this level of coefficients. The other level coefficients are fused using Average method.

The final fused image obtained using both average and selected maximum method is shown in Figure 6.

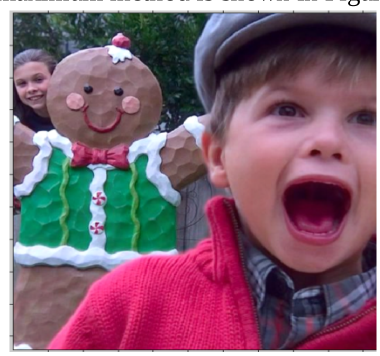

Figure 6. Final fused image

IV. RESULTS AND DISCUSSIONS

Here we measure six parameters for image quality metrics. In this report we use Curvelet transform technique for image fusion. By using this technique we measure six parameters for coloured image. Theoretically, for parameters: API, SD, AG, Entropy and Correlation higher the value better is the quality of the fused image, whereas for FS, lower the value better is the quality.

1. **Average Pixel Intensity (API) or mean (F):** An index of contrast.

$$API = Mean(A)$$

2. Average Gradient (AG): A measure of sharpness and clarity degree.

$$AG = \frac{Y_{Q-}\ Y_P}{X_{Q-}\ X_P}$$

3. Standard Deviation (SD): This is the square root of the variance, which reflects the spread in the data.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

4. Entropy (H): An index to evaluate the information quantity in an image.

$$Entropy = -\sum i \; P_i(\log_2 P_i$$

5. Fusion Symmetry (FS) or Information Symmetry: An indication of how much symmetric the fused image is with respect to source images.

$$FS = 2 - abs\left(\left[\frac{MIF}{MIA+MIB}\right] - 0.5\right)$$

Where,
MIF- Mutual information of fused image
MIA- Mutual information of source image A
MIB- Mutual information of source image B

6. Normalized Correlation (CORR): A measure of relevance of fused image to source images.

$$d_c(y_1, y_2) = \frac{y_1 \; y_2}{|y_1 \,||y_2\,|}$$

Table 1. Result of multi focus image using proposed Curvelet based Fusion method

Color Images	API	SD	AG	Entropy	Correlation	FS
Boy	118.0940	69.2293	8.8268	7.8961	0.9899	1.9889
Bottle	80.3616	63.2618	15.3366	7.4670	0.9633	1.9911
Tree	103.9199	54.0076	24.5301	7.6250	0.9675	1.8656
Man	134.2534	64.2952	8.3179	7.6224	0.9913	1.9835
Dog	136.2096	54.7060	13.2449	7.6899	0.9709	1.9103

Table 2. Comparison of proposed color image fusion method with gray scale image

Images	Gray Scale image			Color Image		
	API	SD	AG	API	SD	AG
Boy	93.1836	47.7429	7.9115	118.0940	69.2293	8.8268
Bottle	94.1271	60.6161	14.7331	80.3616	63.2618	15.3366
Tree	100.4807	49.9783	22.6520	103.9199	54.0076	24.5301
Man	116.8454	58.8421	7.5187	134.2534	64.2952	8.3179
Dog	129.7557	45.9919	11.6498	136.2096	54.7060	13.2449

Table 4.2 shows the comparison results of existing and proposed fusion techniques. The parameter API is 118.0940 for boy image in the proposed system while it is 93.1836 in existing system. The results prove that the proposed fusion method shows better performances than existing system.

V. CONCLUSION

In this work, single multi-resolution method is applied with novelty to integrate the color images of the same scene taken at different focus. The color image fusion process uses different multi-resolution methods to explore the complementary characteristics of two source images. The first step is to separate the color bands from the source image and then green band is selected for applying curvelet transformation. In second step, the curvelet coefficients are obtained using fast discrete curvelet transform via wrapping method. Finally, the coefficients are fused to form the final fused image using fusion rule. From the experiments, it is evident that performance of the proposed fusion method is better than the existing multi-resolution method.

REFERENCES

[1] Subitha.V and Jenicka.S, 'Efficient Image Fusion in Color Images Using Multi-resolution Transform Techniques', International Journal of Advanced Research in Computer and Communication Engineering, Vol. 2, Issue 7, pp.2589-2594, 2013.

[2] Wei Huang and Zhongliang Jing, 'Evaluation of focus measures in multi-focus image fusion', Pattern Recognition Letters 28, Elsevier, pp. 493-500, 2007.

[3] Mamta Sharma and Sarika Khandelwal, 'Image Fusion on Coloured and Gray Scale Multi Focus Images by using Hybrid DWT-DCT', International Journal of Computer Applications, Volume 152 – No.9, pp. 0975 – 8887, 2016.

[4] Mamatha M., Padmavathi N.B, 'Fusion of Medical Images Using Transform Techniques', International Journal of Technical Research and Applications, Volume 4, Issue 3, pp 155-158, 2016.

[5] Myungjin Choi, Rae Young Kim, Myeong-Ryong NAM, and Hong Oh Kim, 'The Curvelet Transform For Image Fusion', IEEE, 2004.

[6] Shriniwas T. Budhewar, 'Wavelet and Curvelet Transform based Image Fusion Algorithm', International Journal of Computer Science and Information

Technologies, Vol. 5 (3), pp. 3703-3707, 2014.

[7] Wang Xin and Li Yingfang, 'A New Method for Multi-Focus Image Fusion Using Countourlet Transform', International Conference on Transportation, Mechanical, and Electrical Engineering (TMEE), 2011.

[8] Di Guo, JingwenYan, XiaoboQu, 'High quality multi-focus image fusion using self-similarity and depth information', Optics Communications, Elsevier, pp. 138-144, 2015.

[9] Changhong Chen, Peng Geng, Kai Lu, 'Multifocus Image Fusion Based on Multiwavelet and DFB', Chemical Engineering Transactions, Vol 46, pp. 277-282, 2015.

[10] Sweta Mehta, Bijith Marakarkandy, 'CT And MRI Image Fusion Using Curvelet Transform', Journal Of Information, Knowledge And Research In Electronics And Communication Engineering Volume – 02, Issue - 02, pp. 848-852, 2012.

[11] Peng Geng , Min Huang , Shuaiqi Liu , Jun Feng, Peina Bao, 'Multifocus image fusion method of Ripplet transform based on cycle spinning', Multimed Tools Appl, Springer, 2014.

[12] Ying Li, Xing Xu, Ben-Du Bai, Yan-Ning Zhang, 'Remote Sensing Image Fusion Based On Fast Discrete Curvelet Transform', Proceedings of the Seventh International Conference on Machine Learning and Cybernetics, Kunming, 2008.

[13] Barkha Panda , 'Image Fusion Using Combination of Wavelet And Curvelet Fusion', International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 5, Issue 8, August 2016.

[14] Lei Tang and Zong-gui Zhao, 'Multiresolution Image Fusion Based on the Wavelet-based Contourlet Transform', International Journal of Engineering Research and Application, 2008.

[15] Qiang Fu, Fenghua Ren, Legeng Chen, Zhexin Xiao, 'Multi-focus image fusion algorithms research based on Curvelet transform', Third International Conference on Genetic and Evolutionary Computing , 2009.

[16] R. Bhavani, R. Priya, J. Arivazhagan, 'A multi focus image fusion method based on discrete wavelet transform' in proceedings of International conference on Advanced Research in Engineering and Applied Science (ICAREAS'17), March 22-24, 2017 Vandavasi, India, pp: 68 to 74.