# Multi-Focus Image Fusion Using DT-CWT, Curvelet Transform and NSCT

**T Bharathi[1], K Jhansi Rani[2]**

[1,2]Department of Electronics and Communication Engineering

Jawaharlal Nehru Technological University, Kakinada - 533003, Andhra Pradesh, India.

[1]bharathitulasi3@gmail.com, [2]jhansikaka@gmail.com

**Abstract: The method of combining images having different focus depths to get an image with full information is known as multi focus image fusion. For good enhancement and to get all the information in one image, different methods have been used before. To extract features accurately for multi focused image data, this paper involves new image fusion methods based on Dual Tree-Complex Wavelet Transform (DT-CWT), Curvelet transform and Nonsubsampled Contourlet transform (NSCT). The parts of the image set which are not in focus can be made available in a single image. Apart from this, good clarity and good contrast can also be obtained from fused image. From the results of statistical evaluation parameters demonstrated for the image pairs, the results of the used techniques can be found and are compared with each other.**

**Keywords:** Curvelet Transform, DTCWT, Image Fusion, Multi Focus, NSCT

## 1. INTRODUCTION

The procedure of combining images to get a single image by using a fusion rule is known as image fusion [1][2]. The usage of image fusion in current image processing systems is increasing, because of the increased number of applications and development of image acquisition techniques. There are many conventional image fusion algorithms. These can be classified as (i) Arithmetic combination and band ratio, such as Brovey and Synthetic Variable Ratio, (ii) projection and substitution methods, as Intensity-Hue-Saturation color fusion, and Principal Component Analysis fusion, and (iii) the wavelet fusion techniques [8].

Image fusion can be done using two main methods – Transform domain and spatial domain. Spatial domain methods lead to spectral distortion in the fused image. In later stages, the spectral distortion will become a drawback. Spectral distortion can be reduced by using transform domain methods for image fusion. The multi focus image analysis has its importance in digital photography. Previously the discrete wavelet transform (DWT) has been in use for fusion. But the discrete wavelet transform can retain only the horizontal and vertical features. NSCT is a multi scale and multi directional method which can be implemented in image fusion [6]. The filters in both the Pyramid and the directional filter banks are upsampled. This reduces the shift invariance problem, but a new problem arises in the form of aliasing effect. In order to retain features from different angles and to avoid aliasing, the curvelet transform is useful [3][4]. This method shows a better performance in enhancement and contrast of the fused image compared to other methods of fusion.

In this paper, a curvelet transform fusion is proposed to obtain appreciable clarity and the results are compared with DTCWT and NSCT. This paper is arranged as follows: Section 2 describes the dataset used, Section 3 describes the methodology for DTCWT, curvelet transform and NSCT, Section 4 discusses the results of the demonstrated parameters and spatial analysis of fused images and Section 5 concludes the paper.

## 2. IMAGE DATASET

The multi focus image data pairs involve different focus depths of the same image. The focus depth can be changed based on focal length, distance to object and aperture. This depth of field helps to see the features clearly on focused areas. But the remaining features in unfocused area remains blur. So the same image with different focus depths is considered for image fusion. The input test image pairs are shown in Fig. 4.

## 3. METHODOLOGY

### 3.1 DT-CWT fusion

The DT-CWT has two discrete wavelet transforms, separating the real and imaginary parts of transform into two trees. The real part of this complex wavelet is obtained as the difference of two separable wavelets and is oriented at -450 and +450. Four more oriented real wavelets in the direction of +750, -750, +150 and -150 can be obtained. The real oriented 2D dual tree transform is the real part of the complex dual tree wavelet Transform. The Imaginary part of complex 2D wavelet is similar to that of its real part oriented at -450. In this transform, there will be two wavelets in each direction and produce six such distinct directions. A perfect reconstruction is done as the filters are chosen from a perfectly reconstructed bi-orthogonal set. It is applied to images by using complex filtering in the two dimensions. The multi focus fused image offers good spatial fidelity compared to DWT techniques [7]. The methodology of DTCWT based image fusion is shown in Fig. 1.

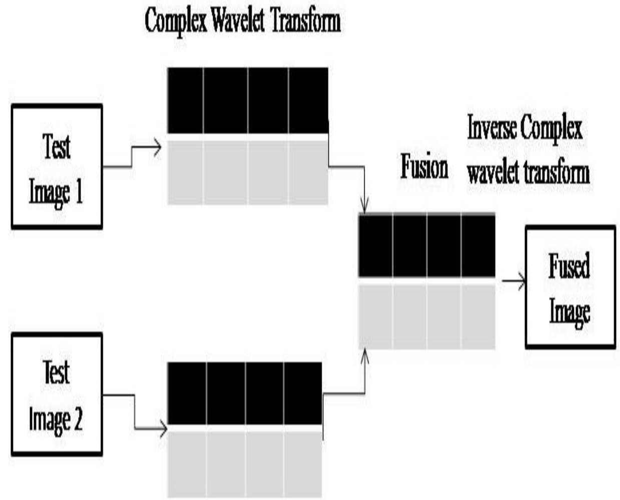



**Fig. 1** Architecture of Dual Tree Complex Wavelet Transform (DTCWT) Image Fusion

The test image 1 is a histogram matched with the test image 2. The complex wavelet transform is applied to test image 1 and test image 2 which are focused at different regions. In complex wavelet transform, two DWT with different filters are used. This decomposes the image into two approximations subbands and six detailed subbands. The two approximation subbands has the low frequency components which are filtered using two different opposite direction filter. The six detailed subbands have high frequency components, which are symmetrically opposite in direction. The approximation subbands are fused using averaging fusion rule and the detailed coefficients are fused using the maximum method. Now to get the fused image in the original form, the inverse complex wavelet transform is applied.

### 3.2 Curvelet Fusion

Curvelet transform is the most suitable technique for multi focus image fusion. The curvelet transform is the multi scale transform with directional elements. In this, with the variation of scale, the degree of localization with orientation varies. So it is like an extension of the wavelet transforms [5]. The use of the curvelet is to represent the curve as a superimposed function of variable lengths and widths. A second generation curvelet transform based on wrapping is used for image decomposition. The process of curvelet image fusion is shown in Fig. 2.

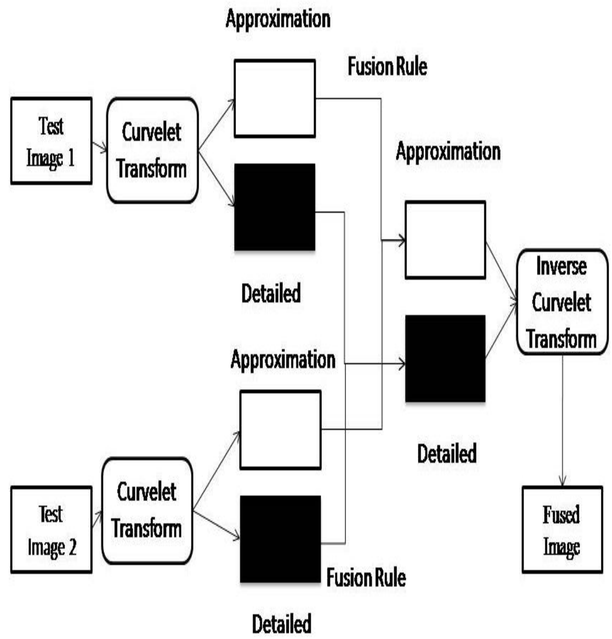



**Fig. 2** Architecture for Curvelet Image Fusion

The test image 1 of multi focus image set is resampled to the size of test image 2 using a bilinear interpolation technique. Curvelet transform is performed to both test image 1 and test image 2. Both the images are decomposed into the detailed and approximation coefficients. The coefficients of high frequency of the decomposed image are fused using a fusion rule called maximum method. The coefficients of low frequency of the decomposed image are fused using the minimum method. Inverse curvelet transform is performed to obtain the fused image.

### 3.3 NSCT Fusion

NSCT is multi-direction and multi-scale in nature in which the images can be divided into two stages. The two stages are nonsubsampled directional filter bank and nonsubsampled pyramid. At each level of pyramid decomposition, one low frequency image and one high frequency image can be produced with the help of multi scale property using two channel filter bank. The low frequency image is further decomposed into subsequent nonsubsampled pyramidal decomposition. It results in m+1 sub image, which consists of one low frequency image and m high frequency images having same size as that of the input image, where m denotes the number of levels of decomposition. The nonsubsampled direction filter bank is a form of two channel nonsubsampled filter bank with the directional filter bank. The direction decomposition is performed in n stages for high frequency image from nonsubsampled pyramid at each scale. It produces 2n directional subimages which have same size as that of the input image.

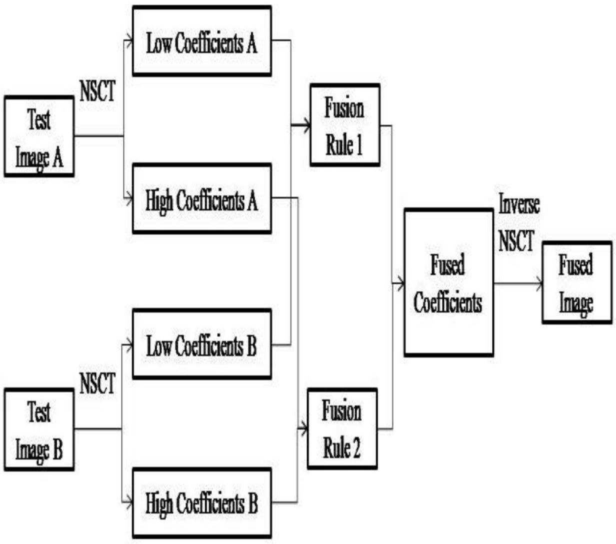


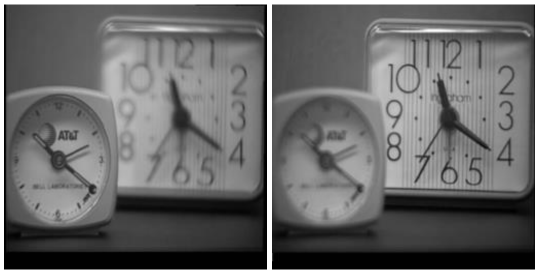

**Fig. 3** Architecture for NSCT Image Fusion

Firstly, NSCT is applied to the test image A and test image B to get low frequency and high frequency coefficients. The high frequency coefficients of image A and the high frequency coefficients of image B are fused with the help of a decision map for maximum value. Then the low frequency coefficients of image A and the low frequency coefficients of image B are fused by calculating the mean. Now, an inverse NSCT is applied on the fused low frequency and high frequency coefficients to get the fused image. The process of NSCT image fusion is shown in Fig. 3.

## 4. RESULTS AND DISCUSSION

The output of the fused images based on three methodologies is shown in fig. 5 and fig. 6.

**(a)** **(b)**



**(c)** **(d)**

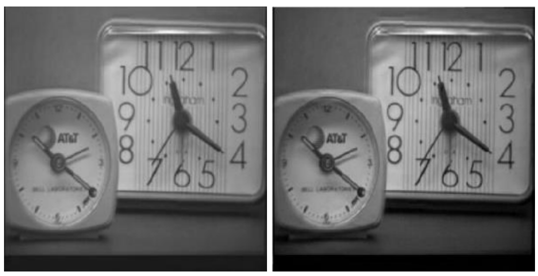
**Fig. 4 (a), (b)** Test image 1, Test image 2 of Image pair 1 and **(c), (d)** Test image 1, Test image 2 of Image pair 2.

**(a)** **(b)**

**(c)**

**Fig. 5 (a)** DTCWT Fusion, **(b)** Curvelet Fusion and **(c)** NSCT Fusion of Image pair 1

Based on visual and statistical parameters, the fused images are compared. It is observed that the fused images shows good clarity and contrast of multi focused images. The comparison of visual of images indicates that the curvelet image fusion shows good contrast and clarity of letters on plane with less amount of blur compared to that of other techniques.



**(a)** **(b)**

**(c)**

**Fig. 6 (a)** DTCWT Fusion, **(b)** Curvelet Fusion and **(c)** NSCT Fusion of Image pair 2

Also the contrast features present in the clock images are retained in a good manner and are highly visible in curvelet fused image compared to the other method's fused images. The correlation coefficient gives the measure of strength of the relationship between the original image and the fused image. The value of correlation coefficient is from 0 to 1. Entropy is used to calculate the amount of information present in an image. High entropy means high amount of information is being retained. RMS Error represents the amount of error between the fused image and the original image. The low value of RMSE represents better performance. Average Gradient describes the amount of visual information present in an image.

**Table 1:** Statistical Evaluation of image fusion of multi focus image pairs

| Statistical Parameter | Fusion Technique | Test image set 1 (planes) | Test image set 2 (clocks) |
|---|---|---|---|
| Correlation Coefficient | DTCWT | 0.9749 | 0.9787 |
| | Curvelet | **0.9800** | **0.9797** |
| | NSCT | 0.9799 | 0.9786 |
| Entropy | DTCWT | 0.0328 | 0.5183 |
| | Curvelet | **0.0390** | **0.6544** |
| | NSCT | 0.0202 | 0.4919 |
| RMS Error | DTCWT | 11.1339 | 10.7071 |
| | Curvelet | **9.8481** | **10.3915** |
| | NSCT | 9.8963 | 10.5382 |
| Average Gradient | DTCWT | 25.0064 | 62.4578 |
| | Curvelet | **35.7532** | **62.8775** |
| | NSCT | 35.0183 | 61.9511 |

From the results, the values of correlation coefficient for curvelet fused images are high compared to the other methods. This means the curvelet fused images retains information from original images effectively and there is a good relation between original test images and fused image. The values of entropy for curvelet fused images are also high compared to the other fused images. It means they have more information in comparison to other methods. The RMSE values are low for curvelet fused images when compared to DTCWT and NSCT fused images. The low value of RMSE is an indication of less amount of error is present between the original images and fused image. The high average gradient values of curvelet fused images shows that the more visual information is present in them.

## 5. CONCLUSION

With the help of statistical parameters considered for fused image evaluation, the performance of DTCWT, curvelet and NSCT is evaluated and compared. The high average gradient, entropy and correlation coefficient values shows that the visual information, contrast and clarity are good for the curvelet fused image. The low RMSE of curvelet fused image indicates that the data is concentrated around the line of best fit for fused image. Overall, the curvelet transform produced good results, compared to DTCWT and NSCT for the fusion of multi focus images.

## REFERENCES

[1] A. A. Goshtasby and S. Nikolov, "Image fusion: Advances in the state of the art," Information Fusion, Vol. 8, No. 2, pp. 114–118, Apr. 2007.

[2] Pohl et al. "Multi-sensor image fusion in remote sensing: concepts, methods and applications", International Journal of Remote sensing, Vol. 19, No.5, pp. 823-854, 1998.

[3] B. Y. Shutao Li, "Multifocus image fusion by combining curvelet and wavelet transform," Pattern Recognition Letters, ELSEVIER, No. 28, pp. 1295-1301, 2008.

[4] LucStarck, E J., Donoho, D L., "The curvelet transform for image denoising", IEEE Transactions on Image Processing, Vol.11, pp. 70-684, 2002.

[5] Ali, FE., Dokany, IM., Saad, AA., Samie, FEA., "Fusion of MR and CT images using the curvelet transform", pp. 1 – 8, 2008.

[6] Kurakula Sravya, Dr. P. Govardhan, Naresh Goud M, "Image fusion on multi focused images using NSCT", International Journal of Computer Science and Information Technologies, Vol. 5(4), pp. 5393-5396, 2014.

[7] Dr. S. Narayana Reddy, Y. S. Vaishnavi, "Performance comparision of different image fusion techniques for multi-focus and multi-modal images", International Journal of Science and Research (IJSR), Vol. 5, Issue 12, December 2016.

[8] A. A. Micheal, K. Vani, "Multi-sensor image fusion of the lunar image data using DT-CWT and curvelet transform," 4th International Conference on Electronics and Communication Systems (ICECS), pp. 49-53, Coimbatore, 2017.

[9] Xiao Zuzhang (2019), multi-focus-image-fusion-dataset (https://www.mathworks.com/matlabcentral/fileexchange/70109-multi-focus-image-fusion-dataset), MATLAB Central File Exchange.