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Multi Focus Image Fusion Based on Spatial Frequency and Contrast Based Analysis under Stationary Wavelet Transform Domain

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Abstract—Due to the limited depth of focus of cameras a scene can sometimes not be described accurately on the basis of a single image. Multiple Images have to be fused together to get a clear description. In this paper we use stationary wavelet transform with contrast analysis and spatial frequency to perform multi focus image fusion. The existing Discrete Cosine Transform (DCT) method and other wavelet transforms suffer from problems like blocking or ringing artifacts or computational complexity. The performance of the system is evaluated on the basis of the various parameters like Peak signal to noise ratio, minimum mean square error, entropy and correlation coefficient. The results over a number of Joint Photographic Experts Group (JPEG) images show improvement over the existing method of spatial frequency and average based DCT image fusion and Non-subsampled Contourlet Transform (NSCT).

Index Terms— Contrast Analysis, Image fusion, Spatial Frequency, Stationary Wavelet Transform.

1 INTRODUCTION

A multi focus fused image helps in obtaining a more detailed and accurate description of a scene as compared to the contributing source images and is therefore very widely used in wireless visual sensor networks. A number of methods have been used to perform image fusion like wavelet transform, Principal Component Analysis (PCA), Discrete Wavelet Transform (DWT), Shift Invariant Wavelet Transform (SIDWT), DCT based on average or DCT based on spatial frequency, Non-subsampled Contourlet Transform (NSCT) etc. All these methods can broadly be divided into two domains, either the spatial domain or the transform domain. The methods in spatial domain deal with the pixel level but they produce spectral distortion in the fused image. The methods under the transform domain first convert the image into frequency domain and the operations are performed using various transform like Fourier transforms etc [1]. The methods like DWT suffer from shift-variance or computational inefficiency. DCT offers fast computation but is mostly used when we do not require very high quality or accuracy in the final fused image.

The proposed model performs image fusion in frequency domain and uses Stationary wavelet transform to perform the required multi scale decomposition. The obtained image is decomposed into structural and textural components. When the image is reconstructed from the frequency domain, the edge textural details are preserved as the process does not down-sample the image when it is transformed into frequency domain. The problems faced in DCT or DWT based fusion, like blocking or ringing artifacts are reduced by the proposed method. Maximum spatial frequency is used to choose the low frequency sub band coefficients that are to be fused. The high frequency coefficients to be fused are selected on the basis of maximum contrast value generated using the standard method for contrast evaluation. The final fused image is reconstructed by applying Inverse stationary wavelet transform on the two fused frequency sub bands obtained by contrast and spatial frequency method.

The rest of the paper has been oraganized in a way that Section II describes the existing work that has already been performed the field of image fusion. Section III deals with the basic concepts used in the proposed method and contains the detailed explanation of the proposed methodology with a block diagram. Section IV consists of results followed by conclusion in section V

2. LITERATURE SURVEY

Image fusion is being performed since a long time in both the spatial as well as the transform domain. The methods can be based on pixel values or wavelet based, but they perform the same task, i.e. Image fusion. A few such wavelet, DCT and spatial frequency based methods have been reviewed in this section.

H.Li et.al proposed a technique Multi-sensor image fusion using the wavelet transform [2]. Earlier fusion methods like the laplacian pyramid suffered from instability during reconstruction of fused image if the source images had regions where the images are very different. This problem was resolved using Wavelet transform due to its compactness and directional ability to extract information of interest. The images were decomposed into levels and sub bands and a fused image is obtained using a binary decision map. Inverse transform is applied and a maximum selection rule is applied to select dominant features in the fused image. A consistency verification step is used and results show improvement over direct averaging method and laplacian method. The drawback is that the algorithm allows fusion of images only from two sensors and can be extended to include more.

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B. K. Shreyamsha Kumar et.al presented a Multiresolution DCT decomposition for multi-focus image fusion [3] and according to this method a number of source images are fused in multiresolution pyramid domain on various scales even if they have overlapping areas in order to make the fused image more robust as against single resolution. Each 8X8 DCT block is viewed as a depth-3 tree of coefficients. The resulting 10 sub bands are fused using existing methods like pixel significance using multiresolution decomposition or wavelet transform etc. the results revealed improvement over various parameters like mean, spatial frequency, entropy, mutual information etc. This improvement was additional to the advantage of reduced complexity as compared to the wavelet domain. The use of faster algorithms can improve the computational capacity further.

O. Rockinger used a shift-invariant wavelet transform for fusion of images. There was an improvement over the existing DWT method by introducing temporal stability and the obtained fused sequence is highly consistent [4]. The shift invariant extension of DWT is obtained by decomposing the input sequence into a shift invariant wavelet representation and by calculating the transform for all possible shifts of input image. The result showed improvement over several exiting methods like DWT, laplacian method etc.

Q. Zhang and B.L. Guo used the non-subsampled contourlet transform. This new approach presents a technique of image fusion which offers advantages like shift-invariance, good multi resolution and high directionality [5]. NSCT is a combination of two sift invariant parts. The non-sampling pyramid which helps in achieving good multiscale resolution which is achieved by eliminating the up and down sampling in laplacian pyramid and then upscaling the filters as per need. The second is the Non-subsampled directional filter bank which provides directionality. The results show great improvement in PSNR, entropy etc.

Liu Cao et.al found a new method for image fusion in DCT domain and was based on spatial frequency. In this approach the DCT blocks with maximum contrast are selected for further processing [6]. The spatial frequencies of these blocks are calculated and the ones with the highest value are subjected to consistency verification in order to maintain the quality of the produced output image. The results over numerous JPEG images show extreme improvement in SSIM and RMSE as compared to general DCT methods like DCT average, DCT contrast or DCT variance etc.

M. B. A. Haghighat et.al proposed a real time fusion of images for visual sensor networks. This method was a variance based DCT domain image fusion, with consistency verification [7]. Results show improved SSIM over the existing methods. The blocks of source images are divided into DCT blocks, their variance is calculated and the blocks with the greater variances correspond to form fused image. It reduced the complexity for real time applications and also improved visual clarity of output images.

S. Li and B. Yang used region segmentation and spatial frequency for fusing multi-focus images [8]. A simple average method is used to fuse the source images and the intermediate image is partitioned using normalized cut method. The source images are partitioned on the basis of this result and are finally fused on the basis of their spatial frequencies. This method provides improved results because it reduces drawbacks like noise sensitivity, effect of motion and blurring effect.

3. PROPOSED METHOD

3.1 Stationary Wavelet Transform

Discrete wavelet transform is time-variant and suffers from poor directionality [9]. In order to get rid of this translation variation, we have to use an un-decimated approach called Stationary wavelet transform. Instead of down-sampling the filter coefficients, we up-sample the filter by inserting zeros between the filter coefficients. Such algorithms are applied on rows first, followed by columns. The four images obtained (three detail and one approximation) are of the same size as the original image, although the resolution is halved. The decomposition of image in SWT domain is as shown in Fig.1

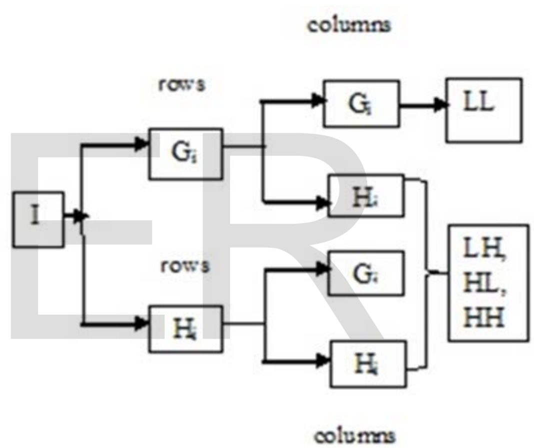

Fig.1 SWT decomposition

where LL is the approximation subband and LH, HL and HH are the detail subbands.

3.2 Spatial Frequency (SF)

The overall active level of an image is measured using spatial frequency [10]. If a block of image F of size MXN has a gray value F(m,n) at position (m, n), then the value of Spatial frequency, SF is given by

$$SF = \sqrt{RF^2 + CF^2} \tag{1}$$

where RF and CF are row and column frequency respectively.

$$RF = \sqrt{1/MN \sum_{m=0}^{M-1}\sum_{n=1}^{N-1}\left(F(m,n) - F(m,n-1)\right)^2} \tag{2}$$

$$CF = \sqrt{1/MN \sum_{m=1}^{M-1}\sum_{n=0}^{N-1}\left(F(m,n) - F(m-1,n)\right)^2} \tag{3}$$

It is seen that the value of spatial frequency decreases as an image becomes more blur. In other words, it also gives the degree of clarity of an image.

3.3 Contrast Analysis

Instead of intensity value of a pixel the visual systems of humans is highly sensitive to intensity contrast [11]. Contrast measures the difference in intensity of one pixel to the neighboring pixel at any given point.

A series of steps are followed in calculating the value of contrast. First of all the value of mean is calculated for the low frequency coefficient. Then the maximum values for the three decomposed sub bands (LH, HL and HH) are calculated.

Contrast value = Mean / Maximum value of the visible sub band (4)

Contrast values of source images for the various sub bands is found by the following set of equations.

AL_M=mean(mean(LL(i-1:i+1,j-1:j+1))) (5)

AL_H=max(max(LH(i-1:i+1,j-1:j+1))) (6)

AL_V=max(max(HL(i-1:i+1,j-1:j+1))) (7)

AL_D=max(max(HH(i-1:i+1,j-1:j+1))) (8)

Con_A_H(i-1,j-1)=AL_H/AL_M (9)

Con_A_V(i-1,j-1)=AL_V /AL_M (10)

Con_A_D(i-1,j-1)=AL_D /AL_M (11)

where i and j are the pixel positions in the matrix of image,

LL is the approximation subband and LH, HL and HH are the detail subbands;

AL_M=Value of mean for the detail subband LL;

AL_H, AL_V and AL_D are the maximum values for the LH, HL and HH subbands respectively;

Con_A_H, Con_A_V and Con_A_D are the contrast values for LH, HL and HH sub bands.

3.4 Algorithm for Proposed Method

The step by step process for the proposed method is shown with the help of a block diagram in Fig.2

STEP1. Select the left and right focus images that are to be fused and apply SWT on them and obtain four subbands (three detail and one approximation sub band).

STEP2. Calculate contrast on the obtained high frequency coefficients by equations (4) to (11).

Here we get three images for input image1 and three images for input image2. We have to select the higher value of LH, HL and HH from the two images. This completes the contrast process.

STEP3. Apply spatial frequency on the low frequency components and choose the one with the highest value. Evaluate using equations (1), (2) and (3).

STEP4. Perform inverse SWT on the fused components to obtain the fused image.

STEP5. Evaluate the performance of the proposed method and compare it with the existing spatial frequency and average based DCT and NSCT method using suitable parameters like RMSE, Entropy, PSNR and Correlation coefficient.

4. PARAMETRIC EVALUATION AND RESULTS

The proposed method is applied on two sets of images. The first group addressed as group1 contains images with left and right focus and the second group known as group2 consists of CT and MRI images. A number of performance parameters have been calculated after applying the method on a number of JPEG images. Then the average of all the values has been included in the tables.

The various parameters are:
1. RMSE (Root Mean Square Error)
2. Entropy
3. PSNR (Peak Signal to Noise Ratio)
4. Correlation Coefficient

We have also evaluated the same parameters for Non-Subsampled Contourlet Transform (NSCT) in order to achieve a comparison [12]. The results of DCT based image fusion are directly being used used in the table1 and table2 for a few parameters [6], [11].

The images for group1 on which the process of image fusion were applied are shown in Fig.3 to Fig.7

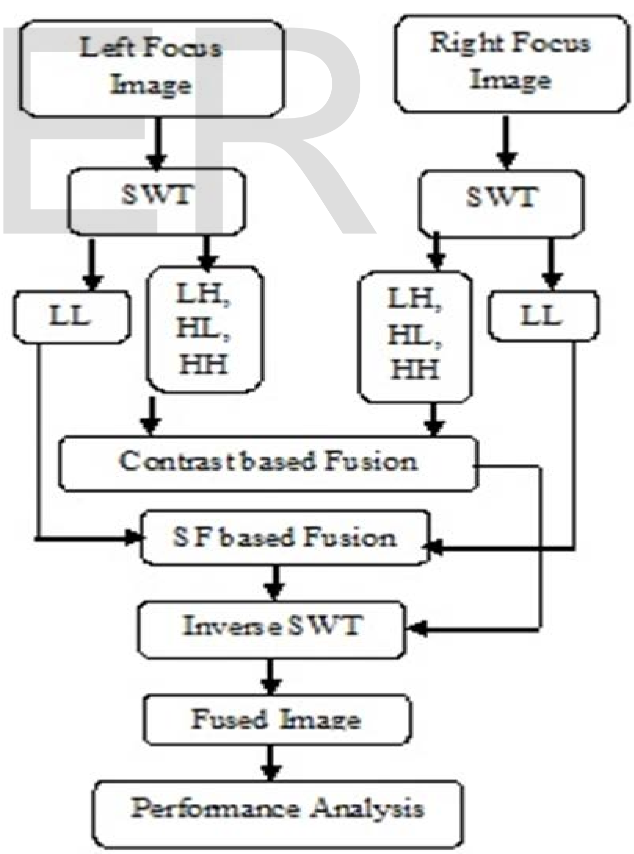

Fig.2 Block diagram for proposed method

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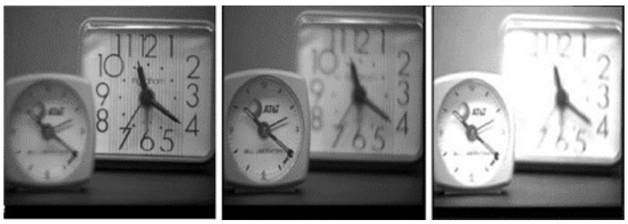
(a) (b) (c)

Fig.3 (a) Source image with focus on left, (b) Source image with focus on right and (c) Final image after fusion

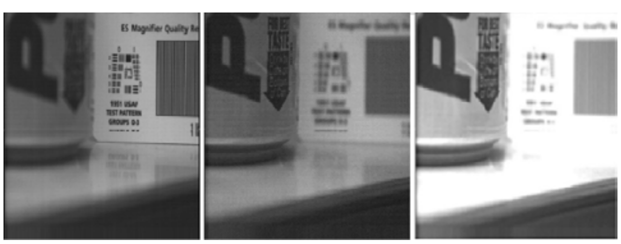


(a) (b) (c)

Fig.4 (a) Source image with focus on left, (b) Source image with focus on right and (c) Final image after fusion

(a) (b) (c)

Fig.5 (a) Source image with focus on left, (b) Source image with focus on right and (c) Final image after fusion



(a) (b) (c)

Fig.6 (a) Source image with focus on left, (b) Source image with focus on right and (c) Final image after fusion

(a) (b) (c)

Fig.7 (a) Source image with focus on left, (b) Source image with focus on right and (c) Final image after fusion

When the images in the first group are subjected to the algorithm, we observe that the value of RMSE for DCT (4.037) and NSCT (11.2573) is more than our proposed method (0.1598). The low value of RMSE in Fig.8, shows that our method is better than the other two methods.

Entropy represents the information content in an image. So a higher value of entropy indicates a better fusion technique. The experiment on the first set of images as shown in Fig.9 states that the value of entropy is highest for our proposed method 5.8118, followed by a value of 4.3051 for NSCT and the least value for DCT i.e. 0.7949.

Peak signal to noise ratio indicates the level of strength of a signal in presence of noise and should be high for a better performance. According to Fig.10, the value for PSNR is least for NSCT 37.2015, followed by DCT 38.3281, and the highest value is for our method 56.3274

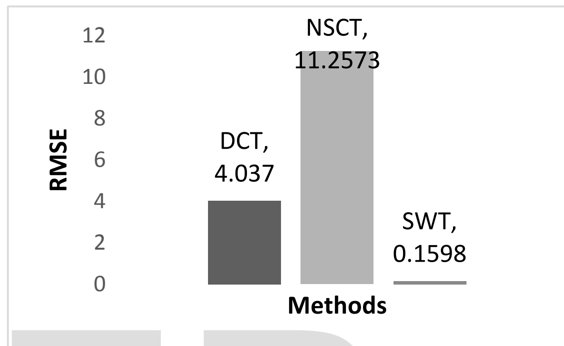


Fig.8 RMSE graph for group1 images

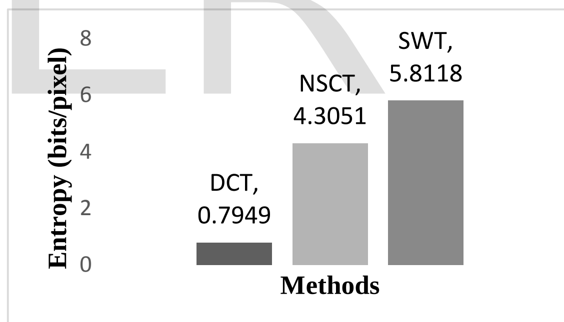


Fig.9 Entropy graph for group1 images

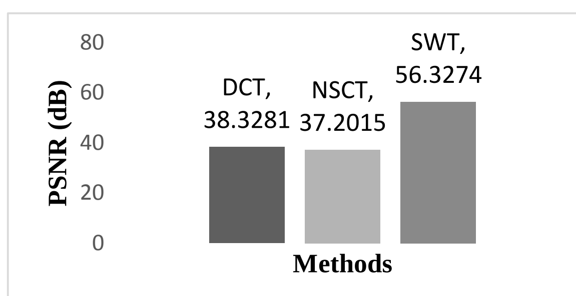


Fig.10 PSNR graph for group1 images

Correlation Coefficient indicates the degree of similarity or dissimilarity between the images. It starts to decrease from one in case of dissimilarity. As shown in Fig.11, the value is

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least for NSCT 0.8547, increases for DCT at 0.8867 and is highest for SWT based method, 0.8943

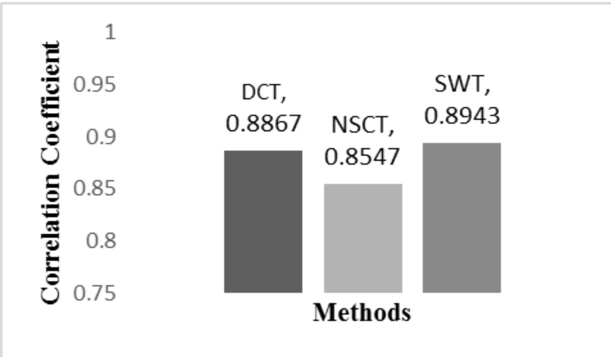
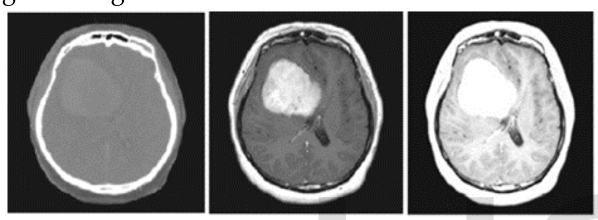


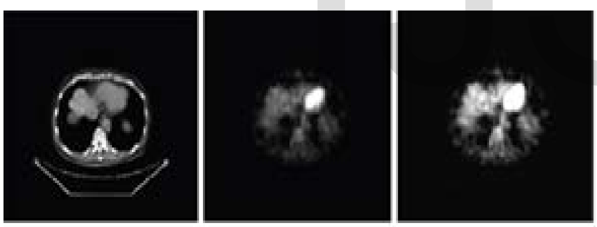
Fig.11 Correlation Coefficient for group1 images

The second set of experiments was performed on group2 images comprising of CT and MRI images shown in Fig. 12 to Fig.15 and similar results were obtained.



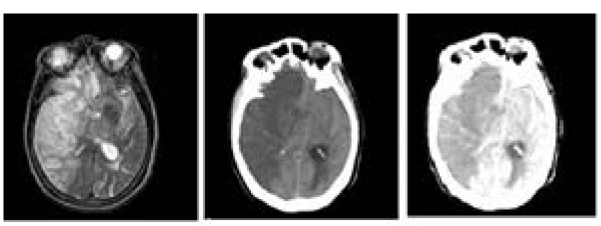
(a) b) (c)

Fig.12 (a) CT of input image (b) MRI of input image (c) Final fused image



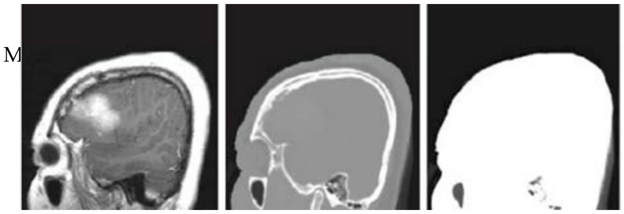
(a) (b) (c)

Fig.13 (a) CT of input image (b) MRI of input image (c) Final fused image



(a) (b) (c)

Fig.14 (a) CT of input image (b) MRI of input image (c) Final fused image



(a) (b) (c)

Fig.15 (a) CT of input image (b) MRI of input image (c) Final fused image

The Root Mean Square error as per Fig. 16 indicates that for DCT, RMSE is 4.037, gets reduced for NSCT and is 2.2845 and is the least for our method and has a value of 0.1487.

The value for entropy is highest for SWT based approach 2.8576 and is smaller for NSCT method 1.91495 and is smallest for DCT and is at 0.7949 and is plotted in Fig. 17

The Peak signal to Noise Ratio shows a better fusion process with its higher value and it is observed in Fig.18 that the best result is obtained for our SWT based approach for which the value is 61.1714, is less for DCT 38.3281and is least for NSCT at 32.8328.

The value of correlation coefficient is shown in Fig. 19 also keeps on decreasing from SWT based method to DCTand is least for NSCT have the values 0.9673, 0.8867 and 0.8747 respectively.

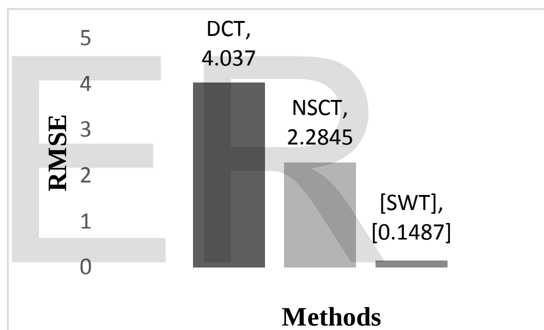


Fig.16 RMSE graph for group2 images

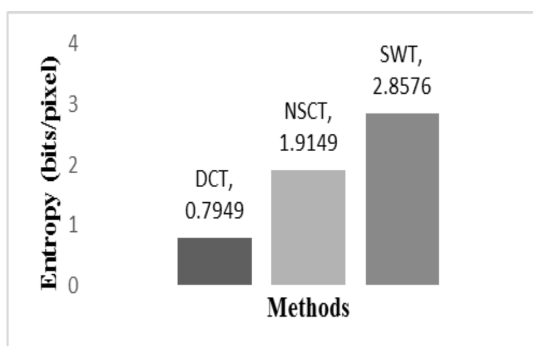


Fig.17 Entropy graph for group2 images

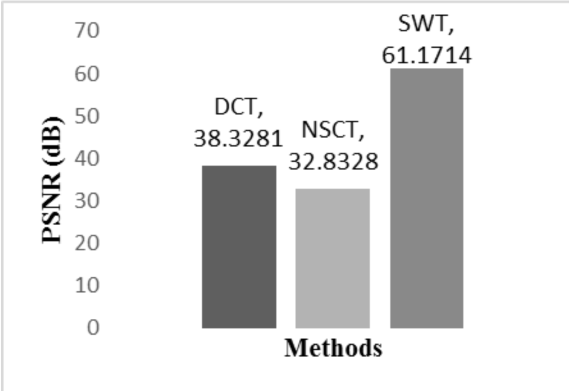


Fig.18 PSNR graph for group2 images

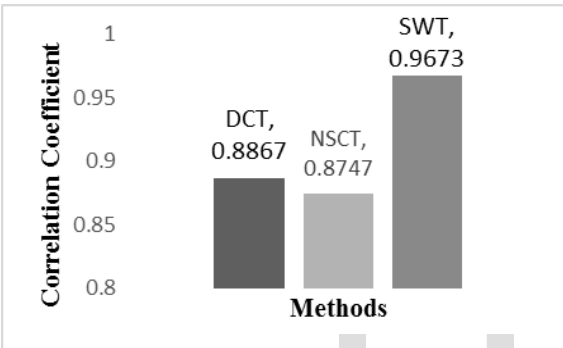


Fig.19 Correlation Coefficient for group2 images

Table1: Values for group1 images (Left and Right Focus)

	RMSE	Entropy (bits/pixel)	PSNR (dB)	CC
DCT [6],[11]	4.037	0.7949	38.3281	0.8867
NSCT	11.2573	4.3051	37.2015	0.8547
SWT (proposed method)	0.1598	5.8118	56.3274	0.8943

Table2: Values for group2 images (CT and MRI)

	RMSE	Entropy (bits/pixel)	PSNR (dB)	CC
DCT [6],[11]	4.037	0.7949	38.3281	0.8867
NSCT	2.2845	1.9149	32.8328	0.8747
SWT (proposed method)	0.1487	2.8576	61.1714	0.9673

5. CONCLUSION AND FUTURE SCOPE

In this paper, we present image fusion based on stationary wavelet transform using contrast analysis and spatial frequency. Experimental results on two group of JPEG images show improvement in terms of RMSE, PSNR, Entropy and correlation Coefficient. The proposed method outperforms the existing DCT, NSCT methods for left and right focus images as well as MRI and CT images and can therefore be successfully used in biomedical applications, etc.

The proposed method takes a longer time to execute and is a bit complex to implement. Instead of using different method for fusion, same methods with higher accuracy and efficiency can be used and instead of SWT, hybrid transforms can also be used.

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