Image Fusion Using Direction Wavelet Approach and Performance Evaluation of Multiple Source Images

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Abstract—**Image fusion is the approach to get one composite output image from number of variety of input images. We can fuse images which are out of focus, here images of different focal length are considered as input whereas output image is expected to be clear and visible. There are various types of sensors available today having wide variety of focal length and hence they generate images in which some objects are clear some are not. Again multi-sensor devices provide huge data to analyze and interpret. So we require some sort of mechanism to fuse all this data into single one. Therefore there is a basic requirement of certain image fusion algorithm which will perform the desired task and gives some accurate and reliable information about the scene. In the research work a method is developed to perform the fusion of multiple images to get a single image which is more informative, reliable and accurate. The proposed method is based on complex wavelet transform with the combination of direction wavelet decomposition method. The method is good at direction selectivity, also perfect reconstruction which is very important aspect for fusion of images. The final fused image is enhanced in such a way that it is useful for interpretation and analysis and assists to come up with certain decision about the scene.**

Keywords-* *Image fusion of Multi-focus images; Directionapproach method; PCA method; Weighted Average method.

I. INTRODUCTION

In the field of image processing there are various areas and applications such as image improvement and enhancement, restoration of images, image classification, noise removal from the images, objects/image classification and so on. One of the most important applications is fusion of images that are captured from single sensor or multi-sensors.

Now a days Image fusion becomes one of the popular method which takes multiple images may be from single sensor or multiple sensors as inputs and produces a single fused output image. It is required that the fusion is performed to get the reliable and accurate information which is not available using single sensor image [1]. For multi-focus images it is the basic requirement from fusion that all objects should be in focus. Low cost and accuracy is the major two demands from the fusion process.

Further, image fusion takes information from source images that are impossible to perceive with single sensor and fuse it. The implemented method works on two basic properties one is perfect reconstruction and another is yields good directional selectivity results in good fusion results than other classical methods.

The paper is arranged as: Section II focus on research method used for image fusion. Section III gives results tested on various set of input images, performance calculation of fusion method using various evaluation parameters Section IV proceeds with the result analysis and comparison of proposed method with other methods, and Conclusion is given in Section V.

II. RESEARCH METHODOLOGY FOR IMAGE FUSION

The method used in the research work is the combination of complex wavelets with the perfect reconstruction property with less redundancy. The direction wavelet is used as it is good in image edge information collection. Edge information plays important role while reconstruction of objects that are not clearly visible in the set of images. The method first divides the image into various components like R, G, and B component planes. Then work separately on each plane. Anisotropic wavelet decomposition is used which is a multi-direction wavelet decomposition method with perfect reconstruction and unique advantage in the performance of image edge information generation.

The steps of proposed method are given below:

Step 1: Read the two multi focus images. Here we can also input Low resolution Multispectral image I1 and High resolution panchromatic image I2.

Step 2: Preprocessing: In this step wiener filter of kernel 7 x 7 is applied to remove noise from the images. Noisy image leads to incorrect assumption during fusion process.

Step 3: Separation of images into RGB component plane: Divide the images into R component plane, G component plane, and B component plane. In total now there are three planes of image I1 and three planes of image I2.

Step 4: Decomposition step: Apply the decomposition method to R, G & B component images of I1 separately. Similarly apply to R, G, & B planes of I2. For decomposition continuous

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wavelet transforms with the properties of direction anisotropic wavelet transform is applied. Here we have assumed 16 directions of decomposition with 4 layers.

Angles are varying in the range of 0 to (2*Pi-Pi/8) in the step of Pi/8.

So the range of angles we get is 0, 22.5, 45, 67.5, 90, 112.5, 135, 157.5, 180, 202.5, 225, 247.5, 270, 292.5, 315, and 337.5.

Step 5: Fuse the component images: here fuse the R-R component image of I1 and I2, G-G component image of I1 and I2, B-B component images of I1and I2 separately. To perform this fusion we have calculated matching parameter which will check matching factor of both the sub-bands of images I1 & I2, and high coefficient edge information of sub-bands. Using these values we have generated a threshold value.

- If the sub-band images are not similar then the threshold is considered as high coefficient edge information of I1 or I2 whichever is larger.
- If the sub-band images are similar then the threshold is considered as mixture of high coefficient edge details of source images. Weights applied to them.

The respective component planes are then fused.

Step 6: The component planes are respectively fused together i.e. R, G, and B of the source images.

Step 7: The step is the inverse reconstruction to obtain the final output fused image.

The paper shows the comparison of implemented method with the methods namely PCA, Weighted Average. The implemented method is based on wavelet decomposition theory with the combination of complex wavelet transform with direction based anisotropic wavelet approach.

PCA: The method uses arbitrary band during the fusion process. With the limitation is that in spatial domain fusion may produce spectral information is degradation [2][5].

Weighted Average fusion: It is the easiest method of image fusion. It reduces noise present in the source image. But also suppresses some features of images. The main problem of the method is that it produces low contrast composite fused image with some 'washed – out' appearance [4][5].

Proposed method maintains and improves spatial information of the images at the same time it also cares about the spectral information of source images while performing fusion. Colour distortion which is the main issue during fusion, is also minimized and spatial degradation is also at the lower side.

III. Performance Evaluation Of Proposed Method

Image fusion is categorize depending upon type and number of sensors involved in capturing of images; such as multi-view image fusion where same object or scene is captured from different view angle, multi-modal image fusion here images from different model are available for fusion, and multi-focus image fusion where images are not in focus completely. Here Multi-focus images are considered for fusion. Fusion is performed on multi-focus images to get the output fused image with all objects of the image in focus and clear. If the fusion is good it will help for perception [3][4].

The proposed work is tested on set of images. Sample test image data are given in following Fig.1 and Fig.2. Fig.1 gives fusion of two input grey images using weighted average fusion method, fusion using PCA and fusion using proposed method. Fig.1 (a) source image I, (b) source image II, (c) fused image f1 using implemented method. Fig.2 is another sample of multi-focus set of colour image, (a) source image III, (b) source image IV, (c) fused image f2 using implemented method.

(a) (b) (c)

Figure 1. Example of Multi focus images (a) Source image I (b) Source image II (c) fused image f1 using proposed method

(a) (b) (c)

Figure 2. Example of Multi focus image fusion: (a) Source image III (b) Source image IV (c) fused image f2 using proposed method.

The performance of implemented method is checked with the help of evaluation metrics as correlation, quality index, measure of structural similarity, multi-scale measure of structural similarity and peak signal to noise ratio.

Table I gives values of these metrics for fig.1 sample image data and it is also calculated for weighted average and PCA fusion method and given in the same table i.e. table I. The methods are compared on the basis of these parameters.

TABLE I. Evaluation Parameters Of Weighted Average, PCA, And Proposed method

Evaluation Metrics	**Fusion Method**		
	Weighted Average	***PCA***	***Proposed Method***
CORR	0.9964	0.9964	0.9992
QI	0.540725	0.552525	0.77265
SSIM	0.895775	0.896675	0.969025
MSSIM	0.9435	0.9437	0.981925

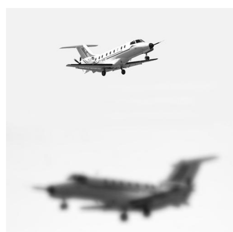
Evaluation Metrics	Fusion Method		
	Weighted Average	***PCA***	***Proposed Method***
PSNR	35.20728	35.2143	38.44055

From the above table if we simply compare the values it is very much clear that the proposed method outperforms better than the other two methods evaluated in the table. The discussion, analysis and comparison of these evaluation metrics are given in the next section.

IV. Result and Discussion on Evaluation Metrics

The section analyzes and compares the proposed method with the other two methods viz. weighted average and PCA. One of the sample results is given the Fig. 3 and analysis is done on the basis of evaluation parameters given in Table I.

(a) Source Image I



(b) Source Image II

(c) Fusion using weighted average

(d) Fusion using PCA method

(e) Fused using Proposed method

(f) Reference Image

Figure 3. Image fusion (a) source image I (b) source image II (c) fusion using weighted average (d) fusion using PCA (e) fusion using proposed method (f) reference image. of Multi focus image fusion: (a) Source image III (b) Source image IV (c) fused image f2 using proposed method.

The research work is evaluated on the basis of some parameters. The parameter is defined below to understand their contribution in performance checking. The method is also compared with the two methods. Quality of fused image is proved to be better compare to two methods on the values of metrics we have used. The parameters used are given below;

Correlation: The correlation coefficient [7], CORR, checks how much similar the original image and output fused image. It checks for small size structural similarity. Its value ranges from -1 to +1. Value near to +1 is the indication of high similarity else near to −1 is the indication of high dissimilarity. Fig.4 below gives the comparative values for the CORR metrics for the methods discussed in the paper.

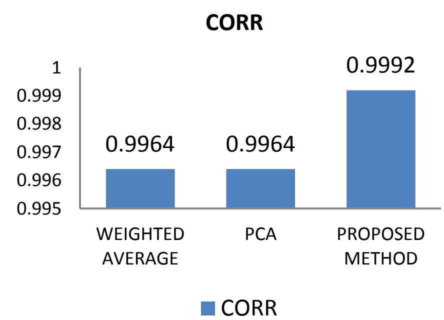


Fig. 4. Correlation CORR values for the image given in Fig.3

Quality Index: The parameter QI [11] computes how much salient features of original image is present in fused image. It varies from 0 to 1. Value 1 is the indication of full information content in the fused image. Fig.5 below gives the comparative values for the QI metrics for the methods discussed in the paper.

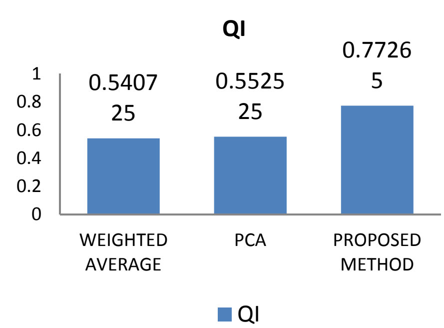


Fig. 5. QI values for the image given in Fig.3

Structural Similarity Index Measure: SSIM measures the similarity between original and output fused image [8]. It gives the prediction of image quality. Higher value shows similarity between reference and fused image.

Fig. 6 below gives the comparative values for the SSIM metrics for the methods discussed in the paper.

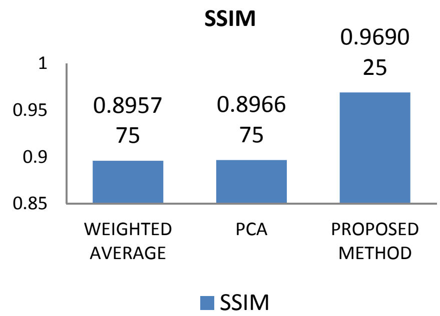


Fig. 6. SSIM values for the image given in Fig.3

MSSIM (Multi-scale SSIM): It is more advanced form of SSIM conduct over multiple- scale through a process of multiple stages of sub –sampling [12]. Higher value is good for result. Fig. 7 below gives the comparative values for the MSSIM metrics for the methods discussed in the paper.

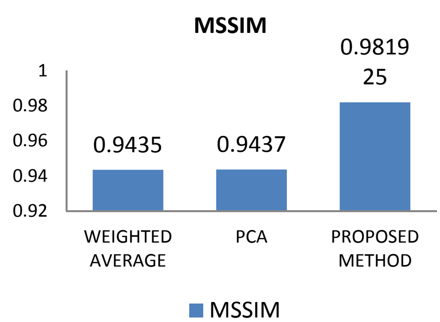


Fig. 7. MSSIM values for the image given in Fig.3

Peak Signal to Noise Ratio: PSNR is the ratio of original/ fused image by the noise content. Higher value of the parameter PSNR is demanded, high value proves the performance of the algorithm [9]. Fig. 8 below gives the comparative values for the PSNR metrics for the methods discussed in the paper.

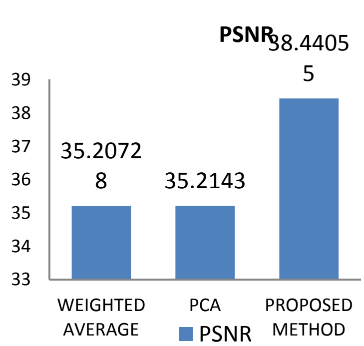


Fig. 8. PSNR values for the image given in Fig.3

CORR is the parameters which checks correlation between original image and final output image also gives small scale structures similarity, the proposed method have 0.9992 value for this parameter which is closer to +1 indicates proposed method gives more structural information compare to other two methods weighted average and PCA which posses lower values.

Next parameter is QI; value of proposed method for this is 0.77265 larger than other two methods (i.e. 0.540725 & 0.552525) which indicate more information of salient features are transformed into final fused output.

SSIM is the similarity checking parameter between reference and final fused image. If we simply compare the values of SSIM for the three methods we come to conclusion that the implemented method gives higher value indicating good performance, as the values are 0.969025, 0.895775, and 0.896675 for implemented method, weighted average and PCA respectively.

Similar to SSIM, MSSIM for implemented method posses 0.981925 shows better performance in fusion of the images. Again compare the value of MSSIM with weighted average (0.9435), and PCA (0.9437) method for fusion.

From the above statistics it is proved that the implemented method outperforms better under the reference of the evaluation metrics.

V. CONCLUSION

The fused image improves or enhanced the spectral and spatial resolution. The implemented work uses the complementary and redundant details of source images in the output image. From the evaluation metrics computed for PCA and weighted average method it is clear that implemented method performs better. Proposed method gives higher value for the parameter CORR than the other method (as shown in Table 1), indicates higher similarity between fused image and the reference image. Value of proposed method for QI parameter is larger than other methods which indicate more information of salient features are transformed into final fused output. If we simply compare the values of SSIM given in Table 1 for the other fusion methods and proposed method we come to conclusion that the implemented method gives higher value for the parameter SSIM indicating good performance of the proposed algorithm. Similar to SSIM, MSSIM for implemented method possesses higher value shows better performance in fusion of the images using proposed method. Higher value of PSNR proves the performance of the algorithm, it is calculated for image given in Fig. 3 and values are presented in Table 1, proposed method posses higher value for PSNR proves its performance over other methods.

As PCA method ignores the spectral information while performing fusion [6], whereas weighted average method blurs the fusion result; these are not accepted as best methods for fusion. The proposed method is good at extracting edge details to enhance the final fused image. The implemented method also possesses property of perfect reconstruction which yields good fusion result compare to classical fusion method.

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