Multi-focus Image Fusion using Digital Negative

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ABSTRACT
The aim of image fusion is to combine appropriate information from two or more source images into one single image such that the single image is more informative than source images. Digital negative which is one of the spatial domain image enhancement techniques,enhances white or gray detail on dark regions, especially, when black areas are dominant in size.. Considering this, a method of image fusion is proposed, specifically for multi-focus images.Each of these images are fused with digital negative of each other for getting augmentation in white or gray detail on dark regions.Act of this method is evaluated with the help of fusion appraisal parameters like RMSE, PSNR, Mean Intensity value Mutual Information etc.

Keywords
Image Fusion , Multi-focus Image, Digital negative, Image Enhancement

1. INTRODUCTION
As the name implies the image fusion is a technique used in image processing for combining information from multiple images of the same scene, which are acquired either by different means or at different times. Those images may differ in their spatial as well as spectral characteristics also.It is often not possible to get an image that contains all appropriate objects in focus. One way to overcome this problem is image fusion, in which one can acquire a series of pictures with different focus settings and fuse them to produce an image with extended depth of field which helps in different applications like clinical diagnosis. Image fusion techniques can improve the quality and increase the application of these data.Image fusion is widely used in image enhancement. Image enhancement.improves the visual quality of an image. The negative transformation is one of the spatial domain image enhancement techniques, which is suitable for enhancing white or gray detail embedded in dark regions of an image, especially when the black area are dominant in size.This paper proposed a method of fusion of an image and a negative transformed image.The images which are considered here are of the same object but with different focusing areas.Performance evaluation is done based on different statistical parameters like RMSE,PSNR,mutual information etc.

2. RELATED WORK
Depending upon the domain Image fusion can be broadly classified into two types:- First is spatial domainin which direct processing of pixels in an image is done. Spatial domain filtering is normally used for smoothing and sharpening of images. Specifically filters are used for sharpening the edges from an image.In this method spatial distortions might get introduced.Simple average, Select maximum, HIS transform, Brovey transform and PCA are the examples of this domain. Two methods of image fusion based on histogram equalization are used for image fusion are given in [6].Another type is frequency domain in which source images are transformed into frequency domain and processing is done on it. Wavelets transform, Laplacian pyramids, Morphological pyramids, gradient pyramids , Discrete wavelet transform ,Discrete stationary wavelet transform are the examples of this domain . IHS transform and Brovey transform has restricted number of bands which can overcome in PCA method. [1][2][4][13][14][15]. Image fusion can also be performed roughly at four different stages: signal level, pixel level, feature level, and decision level [4]. The pixel level image fusion and feature level image fusion methods are compared in [7]using soft computing techniques that makes the intelligent decisions for improving fusion accuracy.Image enhancement is used for improving visual quality of images. A literature review shows that various image fusion techniques are used for image enhancement[4]. Different fusion methods are used for image enhancement also. A literature review state that Various techniques of image enhancement. A lot of work has been done in image fusion of multi focus images. By taking weighted average of pixels efficient fusion of muti- focus images in wavelet domain is proposed in [2].Image fusion can be used for various applications likebiomterics,3-D people tracking , fusion of EEG-MEG images, Gender classification, Contrast enhancement etc.[3][9][10][13].

3. IMAGE FUSION TECHNIQUES:-
The simple method of image fusion is Simple Average, Inwhichthe value of the pixel P (i, j) of each image is taken and added. This sum is then divided by 2 to obtain the average. The average value is assigned to the matching pixel of the output image.InSelect Maximummethod algorithm selects the in-focus regions from each input image by choosing the maximum value for each pixel, resulting in highly focused output. Principal Component Analysis (PCA) is a statistical technique which transforms a number of correlated variables into a number of uncorrelated variables. While IHS transform is very simple method and basically used for sharpening the image.The Brovey transformation was developed to avoid the disadvantages of the multiplicative method. This method is based on calculating ratios which sharpen the MS image.The following equation represents BT :

$$F_{k(i,j)} = \frac{M_{k(i,j)} \times P_{(i,j)}}{\sum_k M_{k(i,j)}} \qquad (1)$$

The HPF method is used to obtain the enhanced spatial resolution multispectral image in which high- resolution images converted into transform domain by using Fourier transform.The fusion algorithm can be represented as in equation (2),

$$F_k(i,j) = M_k(i,j) + HPF(i,j) \qquad (2)$$

Where F_k is the fusion value of the band k pixel(I,j), M_k is the value of multi-spectral of band k pixel(I,j),

The Laplacian pyramid fusion consists of an iterative process of calculating the Gaussian and Laplacian pyramids of each source image.While a gradient pyramid is obtained by applying a set of 4 directional gradient filters (horizontal, vertical, and 2 diagonal) to the Gaussian pyramid at each level. In the DWT-based fusion method, the source images are first transformed by DWT to their corresponding wavelet coefficient images at each scale level. Corresponding approximation coefficients and detail coefficients of the source images at each level are then fused, respectively, based on a certain fusion rule.The Discrete Wavelet Transform is a translation-varianttransform. The way to restore the translation invariance is to usesome slightly different DWT, called Stationary WaveletTransform (SWT). It does so by suppressing the down-samplingstep of the decimated algorithm and instead up-sampling thefilters by inserting zeros between the filter coefficients.Stationary Wavelet Transform (SWT) is similar to Discrete Wavelet Transform (DWT) butthe only process of down-sampling is suppressedthat means the SWT is translation-invariant. The 2-DSWT decomposition scheme is illustrated in Fig. 1

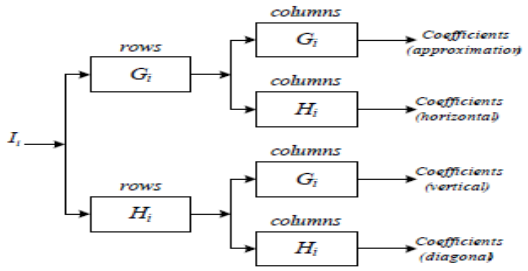

Fig. 1 SWT decomposition scheme

Where Ii, Gi, Hi are a source image, low-pass filter and high-pass filter, respectively.

4. PROPOSED METHOD

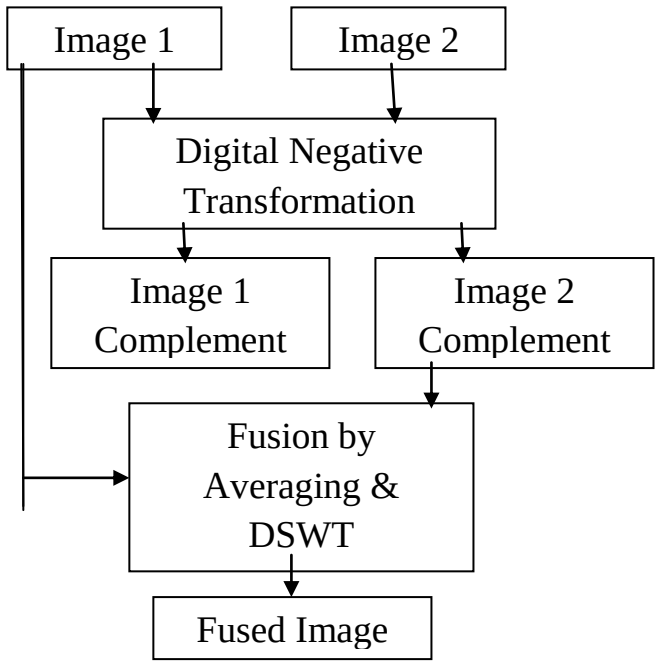

Fig. 2Proposed Image Fusion Scheme

As shown in Fig. 2 as per proposed method, consider two images namely Image 1 and Image 2 of the same objects but with different focusing details. Before performing the fusion complement each image using digital negative transformation. Perform the fusion of any of the original source images with complement of other one. As shown in Fig.2 fusion of Image 1 is done with complement of Image 2. Perform the fusion of Image 2 and complement of Image 1 also. For fusing the two images two techniques namely Averaging and DSWT are used.Evaluate the performance of the fused images,by calculating different performance evaluation parameters which are explained in next section.

4.1 Performance Evaluation Parameters:-

Literature survey shows that evaluating the performance of a fused image is a confront as in most of the applications ground truth is not available.To make the comprehensive study, here severalstandard evaluation parameters are considered which are as follows:-

1. *Root Mean Square Error(RMSE):-*

. This is defined as follows

$$\mathrm{RMSE} = \sqrt{\frac{1}{m \times n}\sum_{i=1}^{m}\sum_{j=1}^{n}[R(i,j) - F(i,j)]^2} \quad (3)$$

where R(i,j) and F(i,j) are reference and fused images, respectively.

2. *Peak signal to noise ratio (PSNR) :-*

.The PSNR can be evaluated as

$$\mathrm{PSNR} = 20\log_{10}\left[\frac{L \times L}{\frac{1}{m \times n}\sum_{i=1}^{m}\sum_{j=1}^{n}[R(i,j) - F(i,j)]^2}\right] \quad (4)$$

3. *Average PixelIntensity (μ) or mean (F):-*

It can be given as

$$\mu = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} F(i,j))}{m \times n} \quad (5)$$

4. *Mutual Information (MI)*

It can be given for source image and fused image as below

$$I_{FA}(f;a) = \sum_{f,a} P_{FA}(f,a) log_2 \frac{P_{FA}(f,a)}{P_F(f)P_A(a)} \quad (6)$$

$$I_{FB}(f;b) = \sum_{f,a} P_{FB}(f,b) log_2 \frac{P_{FA}(f,b)}{P_F(f)P_A(b)} \quad (7)$$

It is defined as,

$$MI_F^{AB} = I_{FA}(f;a) + I_{FB}(f;b) \quad (8)$$

5. *Fusion Symmetry (FS):-*

It indicates how much symmetric the fused image is with respect to source images

$$FS = 2 - \left| \frac{MI_{FA}}{MI_{FA} + MI_{FB}} - 0.5 \right| \quad \textbf{(9)}$$

5. SIMULATION RESULTS

The above mentioned algorithm is implemented for three different sets of multi-focus colour imagesAeroplane, Leg and Book. Implementation is done in MATLAB 7.11.Fusion of images is performed by namely simple average method and by Single level stationary wavelet transfor method.The two source images are of the same objects but with different portions highlighted i.e. focused. In one image dark region is dominant and light regions are not highlighted. While in second image the region which is dominant in first is highlighted. Hence when fusion of first image is done with digital negative (complement) of second, light regions from original source image are observed to be highlighted.The source images, their complemented versions and the resultant fused images are shown in Fig. 3, Fig. 4 and Fig. 5 respectively.Their quantitative fusion parameters are calculated for each image and are listed in Table 1, Table2 and Table 3 respectivelyFrom the table it can be observed that in the first fusion case (i.e. Image1 fused with complement of Image 2) ,best possible performance is observed using DSWT method than simple averaging method. i.e value of RMSE and FS are observed to be less while PSNR, MI are observed to be more.

6. CONCLUSION

The paper proposes a novel method of image fusion using only the spatial properties of a single image. Using the digitaldigital negative of colour images, two different fusion techniques, averaging and DSWT are implemented.The evaluation parameters in Table I, II and III suggest that in the first fusion case (i.e. Image1 fused with complement of Image 2)Values of PSNR, MI & average pixel intensity are observed to be higher as expected while RMSE and FS values are lower in comparison. From the results it can be concluded that, for multi-focus images for highlighting the light areas from dominant dark back grounddigital negative fusion technique gives improved results.As a part of future work, more multi-focus images have to be included along with more number of evaluation parameters for effectively getting comprehensive results. This method can prove advantageous for fusion of all types of images including hyper spectral and infrared images.

Table 1 Quantitative Performance of Aeroplane Images

Parameter	Aeroplane1 + Complement of Aeroplane2		Aeroplane 2 + Complement of Aeroplane1	
	Average	DSWT	Average	DSWT
RMSE	83.5317	69.9138	84.3668	69.6069
PSNR	19.2695	29.7383	18.6094	29.7192
MI	5.5357	5.5681	5.3498	5.5680
Avg. Intensity	116.5146	127.5019	116.5777	127.4981
FS	1.4862	1.4657	1.4864	1.4655

Parameter	Leg1 + Complement of Leg2		Leg2 + Complement of Leg1	
	Average	DSWT	Average	DSWT
RMSE	69.1597	58.3920	70.1148	58.5964
PSNR	19.2695	30.5013	18.6094	30.4861
MI	6.2107	6.2437	6.1673	6.1991
Avg Intensity	113.8494	127.1450	113.1399	127.8554
FS	1.4804	1.4775	1.4802	1.4777

Table 2 Quantitative Performance of Leg Images

Table 3 Quantitative Performance of Book Image

Parameter	Book1 + Complement of Book2		Book 2 + Complement of Book1	
	Average	DSWT	Average	DSWT
RMSE	98.7673	82.3882	102.1076	82.3396
PSNR	17.8144	29.0087	16.1441	29.0061
MI	5.3277	5.4216	5.3266	5.3599
Avg. Intensity	101.5351	127.6850	101.1884	127.3374
FS	1.4801	1.4710	1.4770	1.4738

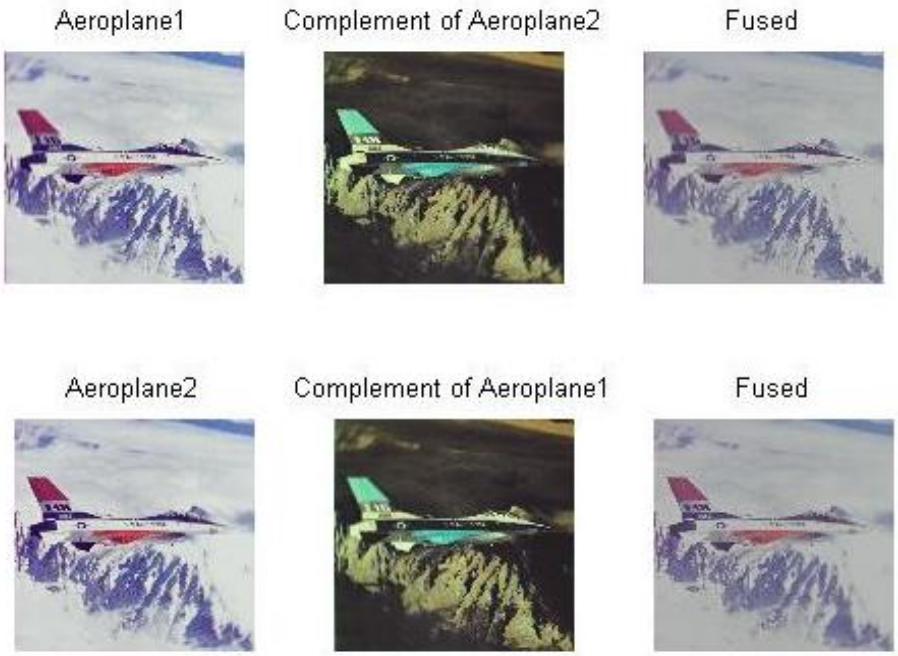

Fig. 3 Image Fusion for two sets of Aeroplane images

Fig. 4 Image Fusion for two sets of Leg images

Fig. 5 Image Fusion for two sets of Book Images

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