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An Efficient Approach for Image Fusion Using Filtering Method

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ABSTRACT: Image fusion technique combines details from multiple images of a scene into a single image. The output image is of good quality and suitable for different kinds of applications. The proposed method divides an image into two layers a base layer and a detail layer. Base layer shows high intensity variations and detail layer shows low intensity variations. This method utilizes a guided filtering technique which helps to perform base and detail layer fusion. The proposed method works well for different kind of images.

KEYWORDS: Image fusion, Weight map construction, Entropy, Correlation coefficient, Mutual Information.

I. INTRODUCTION

Image Fusion technique aims in combining two images of a scene together. The fused image produced will be high in quality. It represents every object from both images very accurately. The fused image produced can provide more detailed information about the scene. It is very useful for human and machine perception. The accuracy of feature extraction algorithms can be enhanced by fusing multi-spectral remote sensing images. The multi-exposure image fusion can be used for digital photography. A perfect image fusion method must have some properties. It must protect useful information of different images. Second, it must not produce noise. Third, it must perform well under imperfect conditions like noise. So many image fusion methods are available. Most of these methods protect the needed information of different images. These methods cause colour distortions and noise because spatial consistency is not very well considered in these methods. Fusion approaches based on optimization methods can solve this problem. These methods will estimate spatially smooth and edge aligned weights by using energy function and then perform fusion of source images by using constructing weight maps of pixel values. But optimization methods may cause inefficiency because they will over smooth the fused image.

To solve the problem mentioned above a new fusion method based on guided filtering is introduced in this paper. It can solve all the problems mentioned above. This method uses a fast decomposition method. It is done with the help of an average filter. Pixel saliency and spatial consistency are joined together by using a weight construction method. Proposed system does not depend on optimization methods. It uses a guided filtering technique. Guided filter is a type of edge preserving filter which won't produce ringing artefacts.

II. RELATED WORK

As the image fusion has shown its importance in variety of applications like medical imaging, remote sensing, navigation, etc. a tremendous work has been proposed. Considering the domain of image processing, the image fusion can be classified as spatial image fusion and transform based image fusion. The transform based image fusion have been proposed such as discrete wavelet transform based image fusion, discrete cosine transform based image fusion, stationary wavelet based transform fusion, etc. The transform based image fusion techniques are famous methods but show the complexity of processing like lacking translation invariance, insufficient edge preservation. While spatial image fusion techniques shows the ease of operation but fail to use spatial properties. The spatial image fusion techniques have been proposed like averaging fusion, maximum selection based image fusion, principal component analysis (PCA) based image fusion, intensity hue saturation (IHS) based image fusion, etc. The image fusion using

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generalised random walks, Markov random fields are able to use the spatial content to the full potential using global optimising approach. But these methods required more looping actions. Also global optimising approach fails to control smoothing of weights.

So the guided filter based image fusion adds up the features as follows:

1. Instead of decomposing image into multiple components, the image is separated into two components only by simple processing like average filter.
2. The guided filter is local linear approach of filtering which makes full use of spatial context. Also, varying the value of the parameters desired fusion results can be achieved.

III. GUIDED FILTERING METHOD

Assuming, G and P be the guidance image and input image respectively. Also, the output of the filter can be denoted by O_i. For each pixel i, the guided filter final output is local linear transform of the guidance image for window ω_k which is centred at pixel k.

$$O_i = a_i G_i + b_k \qquad (1)$$

Where, the coefficients a_k and b_k are considered to be constant in window ω_k .The cost function in window ω_k is given to find coefficients a_k and b_k as follows:

$$E(a_k, b_k) = \sum_{i\in\omega_k} ((a_k G_i + b_k - P_i)^2 + \varepsilon {a_k}^2) \qquad (2)$$

Where, ε controls the value of a_k , which is also known as the blur degree. The solution of the cost function considering it as linear regression model can be given by,

$$a_k = \frac{\frac{1}{|\omega|}\sum_{i\in\omega_k} G_i P_i - \mu_k \overline{P}_k}{{\sigma_k}^2 + \varepsilon} \qquad (3)$$

$$b_k = \overline{P}_k - a_k \mu_k \qquad (4)$$

Where, μ_k and ${\sigma_k}^2$ are the mean and variance of G in ω_k , |ω| gives the number of pixels in ω_k ,

$$P_k = \frac{1}{|\omega|}\sum_{i\in\omega_k} P_i \text{, is the mean of P in } \omega_k \text{ .}$$

Considering, all possible windows for the image, the output is given as,

$$O_i = \frac{1}{|\omega|}\sum_{k|i\in\omega_k} (a_k G_i + b_k) \qquad (5)$$

The average of the values for O_i is considered as its value might be different for different windows overlapping.

Assuming, $\sum_{k|i\in\omega_k} a_k = \sum_{k\in\omega_i} a_k$ a k the symmetry of the window, rewrite above equation as

$$O_i = \overline{a}_i G_i + \overline{b}_i \qquad (6)$$

Where, $\overline{a}_i$ and $\overline{b}_i$ are the average of coefficients for all possible windows overlapping.

The edge detection significantly depends on ε. If the edge is present in I which represent the structure of the guidance image, the edge is transferred to the output image. For the flat region of the guidance image the output image will be

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average of input in ω_k . The structure of G i.e. for the edges present in the G, the output also shows edge. Above explanation regarding gray scale or single channel can be extended to colour image by applying the filter separately to each channel.

IV. IMPLEMENTATION

The proposed system consists of 3 stages. Those are two scale image decomposition, weight map construction and two scale image reconstructions. During the first stage source image is divided in to base and detail layers. Weight maps of source images are constructed in the second stage. Guided filtering is applied in this stage. The output of this stage is processed during reconstruction of images in the final stage.

Among these stages second stage is the most important as the guided filtering process is done at this stage. So it consumes much time than any other module. However we can reduce this delay by modifying the filtering parameters. Window size is one such parameter which has a good effect on processing speed. If the window size taken is so big then processing delay will be high. So an appropriate window size is necessary. Also the computing time of guided filter is very less. The figure shows different stages of image processing. An average filter is used here to average the number of pixels in the source images. Then fusion of Base and Detail layers is performed using guided filtering technique.

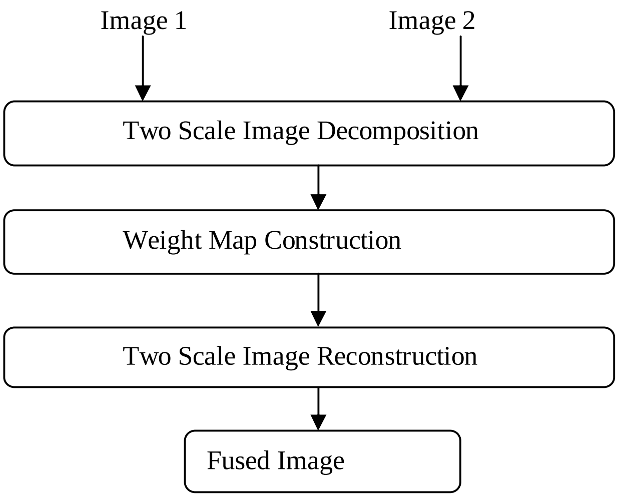

Fig 1: Block diagram of guided filtering method

3.1 DECOMPOSITION OF IMAGE

Decomposition of source images is done at this stage. An average filter can be used for this job. The input image is divided in to base and detail layers.

$$B_n = I_n * Z \qquad (7)$$

$$D_n = I_n - B_n \qquad (8)$$

Where, B_n and D_n represents the base layer and represents the detail layer. F is used to represent the average filter. Base layer holds high intensity pixels and Detail layer holds low intensity pixels.

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B. CREATING WEIGHT MAPS

This is one of the important steps in Image Fusion process. Here a weight map is constructed for both base and detail layers. Laplacian filters are used for this job. The weight map is created in the following way.

$$H_n = I_n * L \tag{9}$$

$$S_n = |H_n| * g_{r_g,\sigma_g} \tag{10}$$

L represents a 3*3 laplacian filter. The output of laplacian filter is a highpass image H_n. Saliency maps are constructed using the average values of the high pass image. A Gaussian filter G is used to process the high pass image. The weight maps produced are usually noisy and their alignment may not meet with object boundaries. It will produce noise to the fused image. Applying spatial consistency is the best way to solve this problem. Spatial consistency indicates that if two neighbour pixels have equal brightness, they may have equal weights.

$$P_n^k = \begin{cases} 1 & \text{If } S_n^k = \max(S_1^k, S_2^k, ...S_n^k) \\ 0 & \text{Otherwise} \end{cases} \tag{11}$$

Fusion approach based on spatial consistency will generate an energy function. Weight maps are produced from this energy function. Fusion of base layer employs large filter size and large blur degree. In order to perform detail layer fusion small filter size is suitable.

$$W_n^B = G_{r_1,\varepsilon_1}(P_n, I_n) \tag{12}$$

$$W_n^D = G_{r_2,\varepsilon_2}(P_n, I_n) \tag{13}$$

Here W_n^B represents weight map of base layer and W_n^D represents weight map of detail layer, I_n represents the source image.

C. GUIDED IMAGE FILTERING

Guided filtering method is also known as edge preserving filtering. While using other kinds of filters the edges of output image looks blurred which will affect the quality. Guided filters are known for their edge preserving qualities. Guided filter takes less time to process an image. In most of the filters selection of filter size directly affects the processing time. So, more the filter size more will be the time to produce fusion. Guided filtering can be used for both colour and colourless images. In colour images there will be red, green, and blue channels. In order to create fusion of colour images these three channels must be filtered separately.

Guided filter imagine that the filtering output is a linear transformation of the guidance image. Guided filtering is done on each colour layer of this image to get the filtered image. The guided filter will blur the image details while preserving the strong edges of the image. After filtering, noisy pixels are avoided and the edges in the image are corrected with object boundaries. The pixels with same colours in the image may have equal values in the filtering process.

D. IMAGE RECONSTRUCTION

A Two-step image reconstruction process is happening here. Base layer and detail layers of input images are fused in the first step. Weighted averaging method is used for that.

$$\bar{B} = \sum_{n=1}^{N} W_n^B B_n \tag{14}$$

$$\bar{D} = \sum_{n=1}^{N} W_n^D D_n \tag{15}$$

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Then fusion of fused base layer and fused detail layer is performed. Thus we will get the final image which contains needed information's from both source images.

$$F = \overline{B} + \overline{D} \tag{16}$$

V. IMAGE QUALITY METRICS

Correlation Coefficient:

It defines the similarity structures between the input and fused image. The higher value of correlation means that more information is preserved. The correlation coefficient is defined by

$$cc = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(a_{ij} \times b_{ij}\right)}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(a_{ij}\right)^{2}} \tag{17}$$

a_{ij} - Difference between input image and its overall mean, b_{ij} - difference between fused image and its overall mean.

Entropy:

Entropy is used to calculate the amount of information. Higher value of entropy indicates that the information increases and the fusion performances are improved.

$$E = -\sum_{i=0}^{l-1} p_i \log_2 p_i \tag{18}$$

Where, P is the probability of the two adjacent pixels.

Fusion Mutual Information:

FMI measures how well the original information is preserved in the fused image.

$$Q_{MI} = 2\left[\frac{MI(A,F)}{H(A)+H(F)} + \frac{MI(B,F)}{H(B)+H(F)}\right] \tag{19}$$

$$MI(A,F) = H(A) + H(B) - H(A,F) \tag{20}$$

Where, $H(A)$, $H(B)$ and $H(F)$ are entropy of A, B and F,

$MI(A,F)$ is the mutual information between source and fused image,

$H(A,F)$ is the joint entropy between A and F,

$MI(B,F)$ is similar to $MI(A,F)$.

VI. SIMULATION RESULTS

Experiments were performed on different kinds of images such as satellite images, multifocal images, medical images etc. These images are subjected to different techniques including our guided filtering technique in MATLAB. Then the results are compared.

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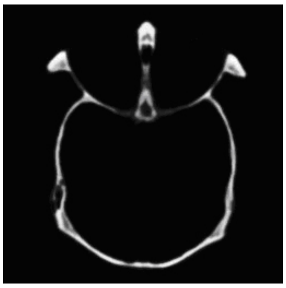
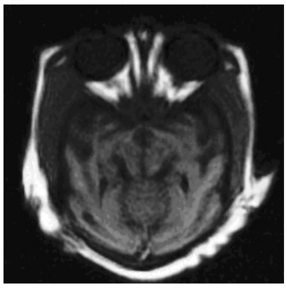
Guided filtering performs well on every image. It preserves most of the useful information in source images, protects the edges and produces a fused image of fine quality. Other methods failed to preserve the edges of the input images. By using the MATLAB, parameters like Entropy, Standard deviation, Correlation coefficient, FMI are compared for Averaging method, Wavelet transform method, Principal Components Analysis and Guided filtering method.

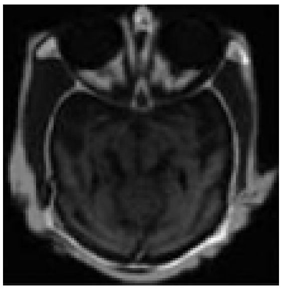


a. CT image of brain

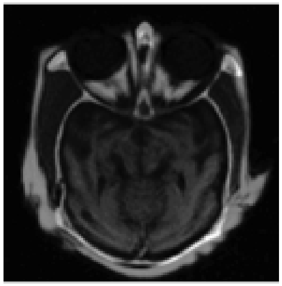


b. MRI image of brain

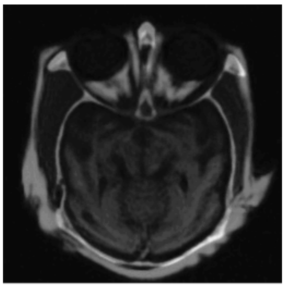
Fig 2: Input images



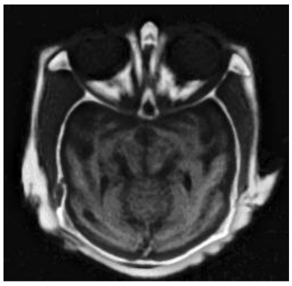
c. Average method



d. PCA method



e. DWT method



f. Guided filter method

Fig 3: Fused image results of average, PCA, DWT and Guided filter methods

The image quality of the guided filter can be seen by visual perception. Compared to the remaining methods, proposed method gives a very good image quality as it can preserve the edges by not over smoothing the image. The quality metric assessment of the above compared methods is shown in the table below. From the table we can see that guided method has high FMI, correlation coefficient, entropy and standard deviation. From these metric values we can say that guided filtering method can preserve more information compared to Average, PCA, DWT methods.

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METHODS	ENTROPY	STANDARD DEVIATION	CORRELATION COEFFICIENT	FMI
AVERAGE	4.8185	34.8184	0.4781	0.508
PCA	5.7230	30.2069	0.8524	0.619
DWT	6.4711	29.9770	0.5679	0.597
GUIDED	6.5429	56.4641	0.8706	0.714

Table: Simulation results of different fusion methods

VII. CONCLUSION

An advanced approach for image fusion is presented in this paper. Experimental results show that the proposed method for image fusion works well for different kinds of images. Among the above mentioned fusion methods, wavelet based fusion extracts spatial details from high resolution bands. So the colour distortion can be reduced to a certain extent, but the fused image appears similar to a high pass filtered image, the colour appears not to be smoothly integrated into the spatial features. The proposed filter method can improve the fusion results, reduces the ringing or aliasing effects to some extents and make the whole image smoother.

The fusion result of Wavelet Transform based fusion method loses more spectrum information. Relatively, the final image of our fusion algorithm is more natural and it is more advantageous to further implement on image segmentation and recognition.

VIII. ACKNOWLEDGEMENT

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