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Image Fusion Using Cross Bilateral Filter

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ABSTRACT

Image fusion is a sub-field of image processing in which more than one images are fused to create an image where all the objects are in focus. Image fusion is of significant importance due to its application in medical science, forensic and defense departments. It is proposed to fuse source images by weighted average using the weights computed from the detail images that are extracted from the source images using cross bilateral filter. The performance of the proposed method has been verified on several pairs of multi-sensor and multi-focus images, and compared with the existing methods like wavelet transform, and guided filtering techniques, visually and quantitatively. It is found that, none of the methods have shown consistence performance for all the performance metrics. But as compared to them, the proposed method has shown good performance in most of the cases. In this, propose a fast and effective image fusion method to merging multiple images. Experimental results demonstrate the proposed method is well efficient than several existing methods.
Keywords : Image Fusion, Wavelet Transform, Guided Filter, Cross Bilateral Filter

I. INTRODUCTION

Optical lenses, particularly those with long focal lengths, suffer from the problem of limited depth of field. Due to that, the image obtained by the lenses will not be in focus everywhere, i.e., if one object in the scene is in focus, another one will be out of focus. A possible way to overcome this problem is by image fusion, in which several pictures with different focus points are combined to form a single image. This fused image will contain all relevant objects in focus. The term fusion means in general an approach to extraction of information acquired in several domains.

In computer vision, image fusion is the process of combining the relevant information from two or more images into a single image. The resulting image will have more information than the input images. Image fusion has been used in many application areas like remote sensing, astronomy, medical imaging (Evaluation of CT, MRI, and/or PET images), military, security, and surveillance areas etc.

Image fusion is a process of combining images, obtained by sensors of different wavelengths simultaneously viewing of the same scene, to form a composite image. The composite image is formed to improve image content and to make it easier for the user to detect, recognize, and identify targets. There are several techniques are available to generate a fused image. Selecting the appropriate method plays a major role in getting the desired fused image.

In this paper, a study is made on various fused algorithms like Wavelet Transform, Guided Image Filtering and Cross Bilateral Filtering each is implemented in MATLAB R2013a and each technique is compared in terms of its quality parameters.

The rest of the paper organized as section 2 describes the various existing fusion techniques, section 3 describes proposed technique, section 4 describes results and discussions and section 5 describes the conclusion and future scope.

II. METHODS AND MATERIAL

Existing Fusion Techniques

In this section discuss the various existing fusion techniques such as wavelet transform and guided filter based image fusion methods.

Wavelet Based Image Fusion

The wavelet transform is use to detect local features in a signal process. It also used for decomposition of two dimensional (2D) signals such as 2D gray-scale image signals for multiresolution analysis.

General process of image fusion using DWT

Step 1. Implement Discrete Wavelet Transform on both the source images to create wavelet lower decomposition.
Step 2. Fuse each decomposition level by using different fusion rule like simple average, simple maximum, simple minimum, etc.
Step 3. Carry Inverse Discrete Wavelet Transform on fused decomposed level, for reconstruction of final fused image I.

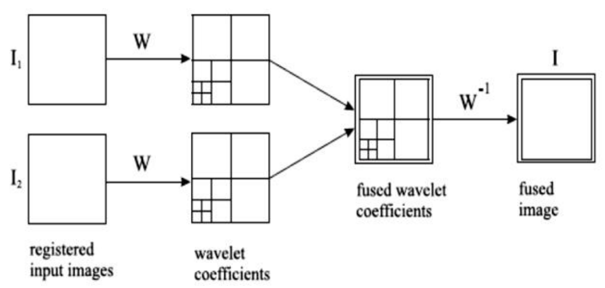


Figure 1: Wavelet based image fusion

Guided Filter Based Image Fusion

As shown in Figure 2, the source images are first decomposed into two-scale representations by average filtering. The base layer of each source image is obtained as follows: Bn = In * Z.

Where In is the nth source image, Z is the average filter, and the size of the average filter is conventionally set to 31×31. Once the base layer is obtained, the detail layer can be easily obtained by subtracting the base layer from the source image. Dn = In − Bn. The two-scale decomposition step aims at separating each source image into a base layer containing the large-scale variations in intensity and a detail layer containing the small scale details.

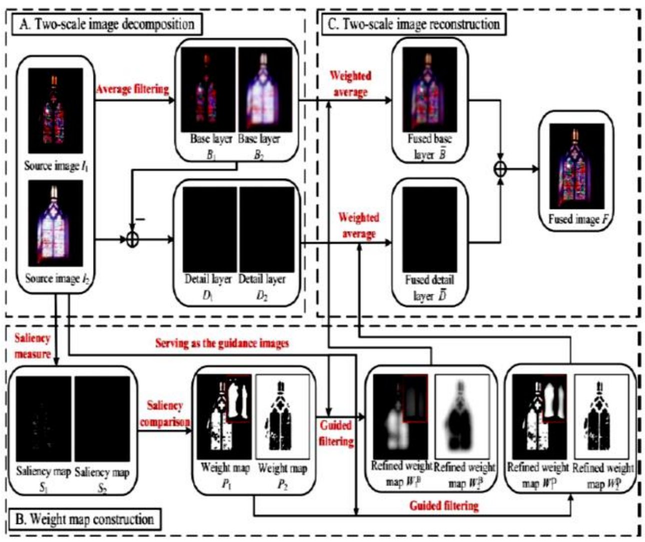


Figure 2: Guided filter based image fusion

Weight Map Construction with Guided Filtering

In this section, an interesting alternative to optimization based methods is proposed. Guided image filtering is performed on each weight map Pn with the corresponding source image In serving as the guidance image.

Wn^B=Gr1, α1 (Pn, In)
Wn^D=Gr2, α2 (Pn, In)

Where r1, α1, r2, and α2are the parameters of the guided filter, Wn^B and Wn^D n are the resulting weight maps of the base and detail layers. Finally, the values of the N weight maps are normalized such that they sum to one at each pixel k.

Two-Scale Image Reconstruction

Two-scale image reconstruction consists of the following two steps. First, the base and detail layers of different source images are fused together by weighted averaging. Then, the fused image F is obtained by combining the fused base layer B and the fused detail layer D

$$F = B + D.$$

Proposed Image Fusion Technique

The proposed image fusion algorithm directly fuses two source images of a same scene using weighted average. The proposed method differs from other weighted methods terms of weight computation and the domain of weighted average. Here, the weights are computed by measuring the strength of details in a detail image obtained by subtracting CBF output from original image. The weights thus computed are multiplied directly with the original source images followed by weight normalization. The block diagram of the proposed scheme is show in Fig. 1 for two source images A and B.

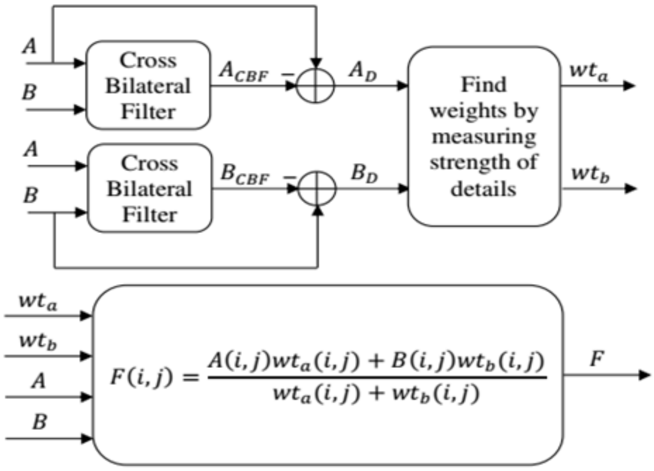


Figure. 3. Proposed Image Fusion Framework

Cross Bilateral Filter (CBF)

Bilateral filtering is a local, nonlinear and non-iterative technique which combines a classical low-pass filter with an edge-stopping function that attenuates the filter kernel when the intensity difference between pixels is large. As both gray level similarities and geometric

$$A_F(p) = \frac{1}{W}\sum_{q\in S} G_{\sigma_s}(\|p-q\|)\ G_{\sigma_r}(|A(p)-A(q)|)\ A(q)$$

closeness of the neighboring pixels are considered, 20 image while preserving edges using neighboring pixels. Mathematically, for an image A, the BF output at a pixel location 'p' is calculated as follows

Where $G_{\sigma_s}(\|p-q\|) = e^{-\frac{\|p-q\|^2}{2\sigma_S^2}}$ is a geometric closeness function $G_{\sigma_r}(|A(p)-A(q)|) = e^{-\frac{|A(p)-A(q)|^2}{2\sigma_r^2}}$ is a gray level similarity/ edge-stopping function $W = \sum_{q\in S} G_{\sigma_s}(\|p-q\|)\ G_{\sigma_r}(|A(p)-A(q)|)$ is a normalization constant $\|p-q\|$ is the Euclidean distance between p and q.

S is a spatial neighborhood of p.

$$B_{CBF}(p) = \frac{1}{W}\sum_{q\in S} G_{\sigma_s}(\|p-q\|)\ G_{\sigma_r}(|A(p)-A(q)|)\ B(q)$$

CBF considers both gray level similarities and geometric closeness of neighboring pixels in

$$W = \sum_{q\in S} G_{\sigma_s}(\|p-q\|)\ G_{\sigma_r}(|A(p)-A(q)|)$$

image A to shape the filter kernel and filters the image B. CBF output of image B at a pixel location p is calculated as Where $G_{\sigma_r}(|A(p)-A(q)|) = e^{-\frac{|A(p)-A(q)|^2}{2\sigma_r^2}}$ is a gray level similarity/ edge-stopping function is a normalization constant.

The detail image, obtained by subtracting CBF output from the respective original image, for image A and B is given by $A_D = A - A_{CBF}$ and $B_D = B - B_{CBF}$ respectively. In multifocus images, unfocused area in image A will be focused in image B and the application of CBF on image B will blur the focused area more compared to that of unfocused area in image B. This is because; the unfocused area in image A anyway looks blurred with almost similar gray values in that area thereby making the filter kernel close to Gaussian. Now the idea is to capture most of the focused area details in detail image B_D such that these details can be used to find the weights for image fusion using weighted average. This is because, as the information in A is absent, the gray levels in that region has similar values thereby making the kernel as Gaussian.

Quality Assessments

In this section discuss various image quality measurements to find out the quality of fused images.

There are different quantitative measures which are used to evaluate the performance of the fusion techniques. We used four measures Average Pixel Intensity (API), Standard Deviation (SD), Average Gradient (AG) and Spatial Frequency (SF)

Average Pixel Intensity (API)

Average Pixel Intensity (API) or Mean measures an index of contrast and is given

$$API = \bar{F} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} f(i,j)}{mn} \quad (1)$$

Where f (i,j) is pixel intensity at (i,j) and m*n is the size of the image

Standard Deviation

This metric is more efficient in the absence of noise. It measures the contrast in the fused image. An image with high contrast would have a high standard deviation.

$$SD = \sqrt{\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(f(i,j)-\bar{F})^2}{mn}} \qquad (2)$$

Average Gradient (AG)

Average Gradient (AG) measures a degree of clarity and sharpness, and is given by

$$AG = \frac{\sum_i\sum_j\left(\left(f(i,j)-f(i+1,j)\right)^2+\left(f(i,j)-f(i,j+1)\right)^2\right)^{1/2}}{mn} \qquad (3)$$

Spatial Frequency (SF)

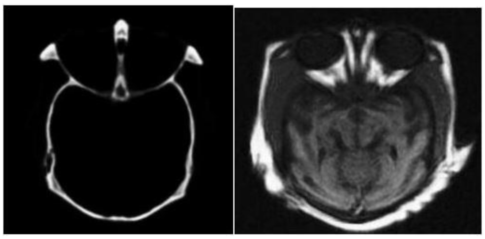
Spatial Frequency (SF) measures the overall information level in the regions (activity level) of an image and is computed as

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

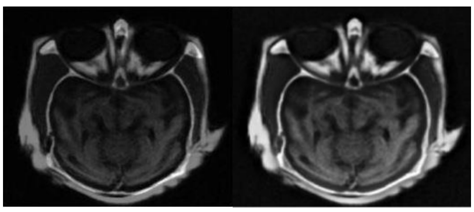
Where $,RF = \sqrt{\frac{\sum_i\sum_j\left(f(i,j)-f(i,j-1)\right)^2}{mn}}$

$$CF = \sqrt{\frac{\sum_i\sum_j\left(f(i,j)-f(i-1,j)\right)^2}{mn}}$$

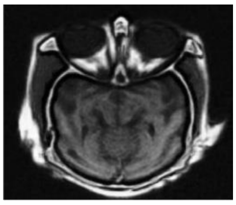
III. RESULTS AND DISCUSSION



(a) (b)



(c) (d)



(e)

Figure 4: (a),(b): Input images (c) Wavelet transform (d) Guided Filter (e) CBF

(a) (b)

(c) (d)

(e)

Figure 5: (a),(b): Input images (c) Wavelet transform (d) Guided Filter (e) CBF

(a) (b)

(c) (d)

(e)

Figure 6: (a),(b): Input images (c) Wavelet transform (d) Guided Filter (e) CBF

Table 1 : Quality Assesments of various Fusion Methods

Source image name	Quality Mertic	Fusion Technique		
		WVT	GF	CBF
Med256	API	0.1243	50.7287	54.7351
	SD	0.1466	55.4783	57.6902
	AG	0.0231	9.5527	11.0334
	SF	0.0432	17.4649	19.8160
OFFICE 256	API	0.3253	80.9559	81.3517
	SD	0.2402	67.6002	66.8859
	AG	0.0355	13.1000	13.2674
	SF	0.07570	24.8526	24.6667
GUN	API	0.1975	5.6200	6.3412
	SD	0.1773	4.6152	5.5260
	AG	0.1144	3.8696	3.9668
	SF	0.1406	4.7168	4.8476
UHR	API	0.4152	96.8758	95.9638
	SD	0.2157	49.8681	50.0407
	AG	0.0417	12.9397	12.2429
	SF	0.607	19.8690	18.8249

Figure 4, 5, 6 represents the image fusions of various fusing methods for multimodal and multiexpouser images. From table 1 we can say that the proposed method is superior than other existing techniques like wavelet filter and guided filter in terms of quality parameters like API, SD, AG and SF.

IV. CONCLUSION AND FUTURE SCOPE

In this work, it was proposed to use detail images extracted from the source images by cross bilateral filter for the computation of weights. These weights, thus computed by measuring the strength of horizontal and vertical details, are used to fuse the source images directly. Several pairs of images are used to assess the performance of the proposed method. The proposed method provides good performance compared to other traditional algorithms in terms of API, AG, SD and SF.

Furthermore, the proposed method is computationally efficient, making it quite qualified for real applications. At last, how to improve the performance of the proposed method by adaptively choosing the parameters of the cross bilateral filter can be further researched.

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