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Multi-Focus Image Fusion Using SFM and Wavelet Packet

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***Abstract*—**In this paper, a multi-focus image fusion method using Spatial Frequency Measurements (SFM) and Wavelet Packet was proposed. The proposed fusion approach, firstly, the two fused images were transformed and decomposed into sixteen subbands using Wavelet packet. Next, each subband was partitioned into sub-blocks and each block was identified the clearer regions by using the Spatial Frequency Measurement (SFM). Finally, the recovered fused image was reconstructed by performing the Inverse Wavelet Transform. From the experimental results, it was found that the proposed method outperformed the traditional SFM based methods in terms of objective and subjective assessments.

***Keywords*—**Multi-focus image fusion, Wavelet Packet, Spatial Frequency Measurement.

I. Introduction

NOWADAYS, the image fusion has become an essential sub-topic in digital image processing research area. The main objective of image fusion is to combine information from two or more source images of the same scene to obtain an image with completely information. The simplest image fusion technique is to compute the average pixel-by-pixel gray level value of the source images [1]. However, this technique leads to undesirable side effects such as contrast reduction. In the past two decades, a variety of image fusion methods were introduced such as Laplacian pyramid [2], Contrast pyramid [3], Ratio pyramid [4], and Discrete Wavelet Transform (DWT) [5], [6]. In DWT based method, the basic idea of this method is to perform decompositions on each source image then combine all these decompositions to obtain composite representation, from which the fused image can be recovered by finding inverse transform. This method had been proved to be an effective method [7]. However this method is not translation–invariant because of down-sampling process. If there is a movement of the object in the source images, the performance of this method will deteriorate.

In this paper, a multi-focus image fusion approach based on Wavelet Packet Transform [8] and Spatial Frequency Measurement was proposed. Wavelet Packet represents a multiresolution decomposition and comprise the entire family of subband coded (tree) decompositions. The proposed method, two fused images are firstly decomposed into sixteen subbands using Wavelet Packet. In fusion process, the Spatial Frequency Measurement [1] is adopted. The recovered fused image is reconstructed by performing the Inverse Wavelet Packet Transform.

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The paper is organized as follows. Section II provides the detail of Wavelet packet decomposition. In Section III, the spatial frequency measurement (SFM) is adopted and expressed [1]. In Section IV, the quality of image fusion assessment is described. In Section V, the methodology of proposed approach was provided. Moreover, Section VI gave some experimental results to demonstrate the effectiveness of the proposed method compared with the performance of other existing methods applied on a number of tested images. Finally, concluding remarks are given in Section VII.

II. Wavelet Packet Transform

Wavelet Packet represents a multiresolution decomposition and comprise the entire family of subband coded (tree) decompositions. Whereas in the wavelet case the composition is applied recursively to the coarse scale approximations only leading to the well known pyramidal wavelet decompositions, in the Wavelet packet (WP) decomposition the recursive procedure is applied to all the coarse scale approximations and detail signals, which leads to a complete wavelet tree and more flexibility in frequency resolution [8].

III. Spatial Frequency Measurement

Spatial Frequency Measurement (SFM) is used to measure the overall activity level of an image [1]. The SFM can be used to represent the clarity of an image, defined as follows,

$$RF = \sqrt{\frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=2}^{N}\left[I(i,j) - I(i,j-1)\right]^2} \tag{1}$$

$$CF = \sqrt{\frac{1}{M \times N}\sum_{j=1}^{N}\sum_{i=2}^{M}\left[I(i,j) - I(i-1,j)\right]^2} \tag{2}$$

$$SF = \sqrt{RF^2 + CF^2} \tag{3}$$

where *RF and CF* represented frequency in row and column spatial frequency of an image, respectively.

IV. Fused Image Quality Assessments

The goal of image fusion is to achieve the best possible quality for fusion process. No single quality measurement method had gained universal acceptance, however, two measurement methods have dominated the assessment of image quality, which are computable objective distortion measure and subjective quality as measured by visually evaluation. In this paper, the objective performance evaluation is measured using Peak Signal to Noise Ratio, (PSNR) and edge measurement to evaluate the quality of fused image. The PSNR is defined as follow [9],

$$PSNR(dB) = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (4)$$

and MSE is Mean Square Error (MSE), defined as,

$$MSE = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\left(x(m,n) - \hat{x}(m,n)\right)^2 \quad (5)$$

where $x(m,n)$ and $\hat{x}(m,n)$ are the original and fused images. The higher values of PSNR refer to the better image fused quality.

$$Edge = \frac{1}{M \times N}\sum_{m=1}^{M}\sum_{n=1}^{N}\left(Q_R(m,n) - Q_F(m,n)\right)^2 \quad (6)$$

where $Q_R(m,n)$ and $Q_F(m,n)$ are the edge gradients of the $x(m,n)$ and $\hat{x}(m,n)$ using Sobel operator. Smaller the values of Edge measurement mean the better image quality.

V. Methodology

Fig. 1 shows the proposed approach of the multi-focus image fusion scheme. The proposed fusion procedure consists of the following steps.

A) Decompose the two source images using Wavelet Packet Transform at one level resulting in sixteen subbands

B) Partition the coefficients from each subbands into blocks of size 4x4 and denote the ith coefficients blocks from each subband of image1 and image2 by ωA_i^s and ωB_i^s , respectively

where S = each sixteen subband

C) Compute the spatial frequency values of each blocks ωA_i^s and ωB_i^s using (3)

D) Compare the spatial frequency values of two corresponding blocks ωA_i^s and ωB_i^s, the simple rule for construct the ith fused coefficient block ωF_i^s is given by

$$\omega F_i^s = \begin{cases} \omega A_i^s, & SF\omega A_i^s > SF\omega B_i^s \\ \omega B_i^s, & SF\omega A_i^s < SF\omega B_i^s \\ \dfrac{\omega A_i^s + \omega B_i^s}{2}, & otherwise \end{cases} \quad (7)$$

where ωF_i^s is fused coefficient blocks and $SF\omega A_i^s, SF\omega B_i^s$ are spatial frequency value of ωA_i^s and ωB_i^s block , respectively.

E) Verify and correct on the fusion result obtained in step D using a majority filter with a 3×3 window, if center block comes from image1 but the neighbor of its surrounding block are from image2, then this center block will be changed to be from Image 2, and vice versa

F) Finally, the fused image is reconstructed by performing the inverse Wavelet Packet Transform on the results, obtained from Step E.

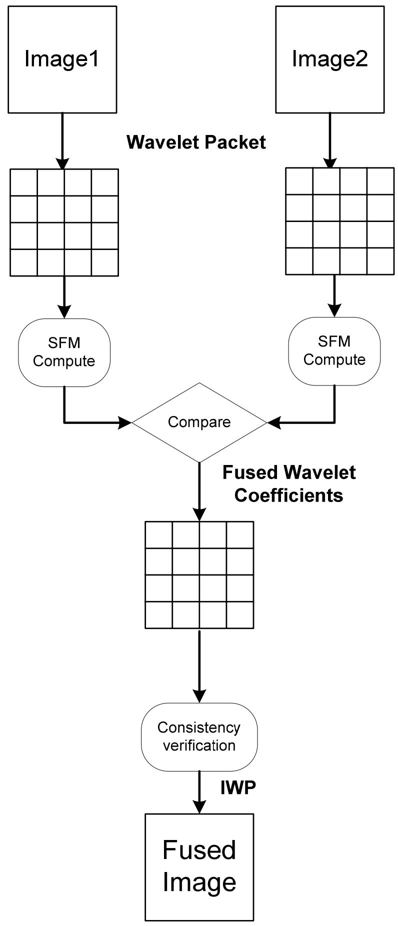

Fig. 1 Block diagram of proposed approach

VI. Experiments

Original eight gray scale images of different sizes were used in these experiments shown in Fig. 2. The sizes of images are 640x480, 256x256 and 512x512 pixels. In addition, each original image was equally blurred on the left and right hand sides using Moving Average Filter size 3x3. Also, two fusion processes using SFM and proposed approach as described in Section V were used, using the block size 4x4 and Daubichies Wavelet filter at order 4 (Db4). For objective assessment, the qualities of fused image results were evaluated using PSNR and edge measurements as illustrated in Table I. From Table I, it can be seen that the proposed method were slightly better than conventional method. For subjective assessment, the original image Fig. 3 (a), and fused image results obtaining from both methods were zoomed in the area of books (on the book shelf) as shown in Fig. 3. As can be seen, the traditional SFM method was contained blocking artifact, Fig. 3 (c), and looked more blur than the proposed method, Fig. 3 (d). In addition, it was suffered from uneven gray level compared to the original images. Then, the proposed method outperforms SFM based method.

VII. Conclusion

In this paper, a method of multi-focus image fusion was proposed. It was based on the use of Wavelet Packet Transform and Spatial Frequency Measurement. The proposed method had an advantage over SFM based methods. Therefore, the proposed approach leads to an effective method for multi-focus image fusion. However, this research only considered in intensity image fusion. In the future works, the effects of color information or chrominance components to fused image will be studied in order to get the best quality for color image fusion.

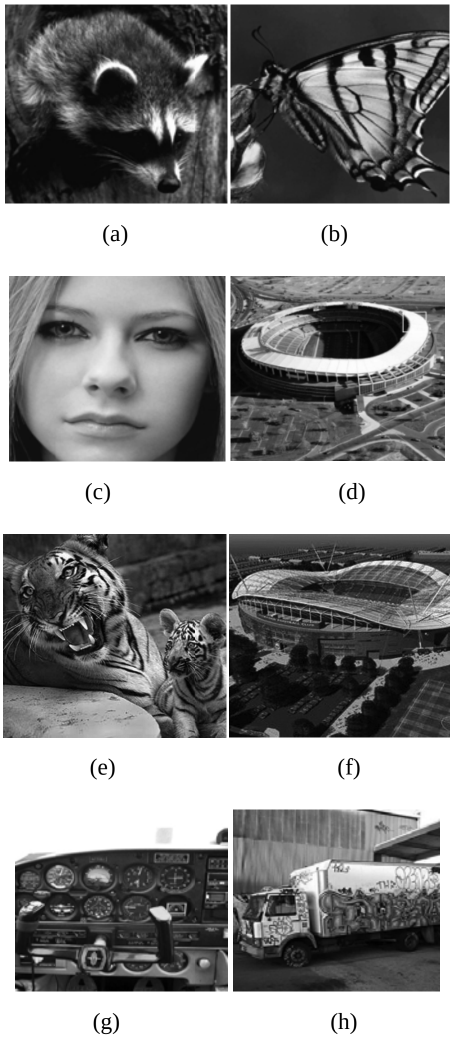

Fig. 2 Eight tested images for multi-focus image fusion

TABLE I
Units for Magnetic Properties

Figures/Methods	PSNR	Edge measurement
a		
SFM	39.5519	0.7824
Proposed method	41.8527	0.5249
b		
SFM	37.6913	0.9875
Proposed method	40.5352	0.7995
c		
SFM	45.0992	0.4567
Proposed method	46.8280	0.0889
d		
SFM	34.3237	1.8201
Proposed method	37.1088	1.4880
e		
SFM	31.5363	2.6257
Proposed method	34.4353	2.1022
f		
SFM	30.6459	3.3891
Proposed method	33.0276	3.0215
g		
SFM	30.3671	4.4928
Proposed method	32.5435	4.0444
h		
SFM	31.3217	4.5823
Proposed method	33.2440	3.6690

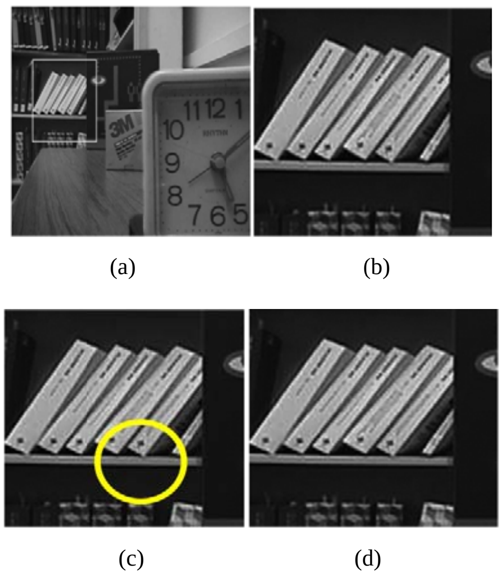

Fig. 3 Local zooming image results (a) original tested image (b) original zooming (c) SFM method zooming (d) proposed method zooming

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