Multiresolution Edge Fusion using SWT and SFM

Somkait Udomhunsakul, Pradab Yamsang, Suwut Tumthong and Pusit Borwonwatanadelok

Abstract— **In this paper, we propose a multiresolution edge fusion method based on Stationary Wavelet Transform (SWT) and Spatial Frequency Measurement (SFM). Our proposed method, Stationary Wavelet Transform (SWT) is firstly applied with the original image to get the edge image information both in level 1 and level 2. Next, both edge images are fused to get a complete edge image using Spatial Frequency Measurement, which is compared with a few simple fusion methods. In addition, we also apply our method to be used for edge detection in noisy original image. From the experiments, we found that our proposed method provides a complete edge image evaluated by the correlation value.**

Index Terms—**Multiresolution, Egde Fusion, SWT, SFM**

I. Introduction

THE edge detection has been essential topic research in digital image processing field [1], which is referred to a process to identify and locate sharp discontinuities in an image. The discontinuities are abrupt in pixel intensity which characterizes boundaries of objects in a scene. The classical edge detection methods are involved in convolution the image with an edge detection operator. At present, there are an extremely large number of edge detection operators available, each designed to be sensitive to certain types of edges. In general, edge detectors can perform well on uncorrupted image but are highly sensitive to noise. Edge detection is difficult to locate in noisy image, since both the noise and the edges contain high-frequency content. Traditionally, the basic algorithms of edge detection, Sobel Operator, Robert Operator and Prewitt Operator have a major drawback of being very sensitive to noise [2]. In addition, the Laplacian method that searches for zero crossings in the second derivative of the image to find edges are give satisfactory results in the slightly noisy images. In the case of noisy images, it may produce false edges caused by discontinuities in gray level due to noise. In order to fulfill the reliability requirement of edge detection, a great diversity of operators has been devised with differences in their mathematical and algorithmic properties.

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When an image is examined for intensity variations, several scales generally are of interest. The detection of certain feature in an image is optimal at a certain scale. This scale depends on the characteristic scale contained in the object to be detected. Therefore, it is necessary to perform and combine information of edge detection at multiple scales. Recently, Wavelet Transform is a useful transform that can be used to get multiresolution detail information.

In this research, we present a multiresolution edge detection using Stationary Wavelet Transform (SWT) where edge images are fused to get a complete edge image using Spatial Frequency Measurement, which is compared with a few simple fusion methods. In fusion process, we adopt to use a different block sizes, 4×4, 8×8, 16×16 and 32×32 [5], [6], [7]. In addition, we also apply our method to be used for edge detection in noisy images. From the experimental results, we found that our proposed method provides a complete edge image and outperforms other edge detection method such as Sobel Operator, Laplacian Operator and Wavelet based image fusion method. The performance of edge detection results are evaluated by the correlation value [8].

The rest of this paper is organized as follow. Section II and III, the edge detection methodology and proposed approach are described. Finally, experimental results and conclusion are presented in section IV and V, respectively.

II. Edge Detection Methodology

A. Stationary Wavelet Transform

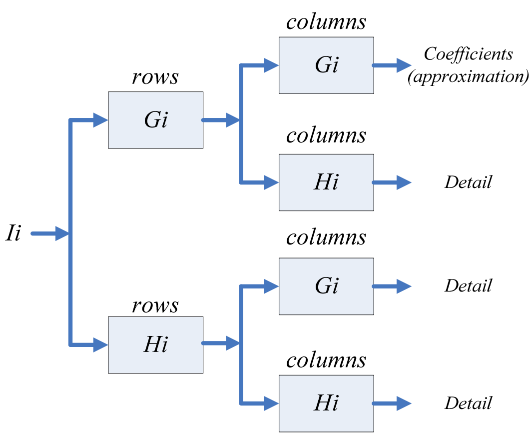

Fig. 1. SWT decomposition scheme.

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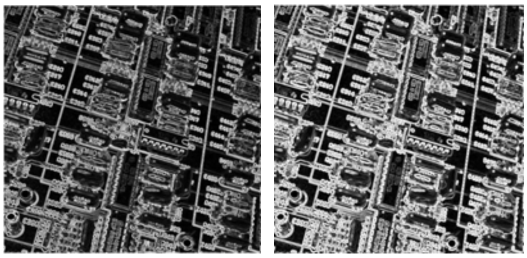
The 2D Stationary Wavelet Transform (SWT) is based on the idea of no decimation [3],[4]. It applies the Discrete Wavelet Transform (DWT) and omits both down-sampling in the forward and up-sampling in the inverse transform. More precisely, it applies the transform at each point of the image and saves the detail coefficients and uses the low frequency information at each level. The Stationary Wavelet Transform decomposition scheme is illustrated in Figure 1 where I_i, G_i, H_i are a source image, low-pass filter and high-pass filter, respectively. Figure 2 shows the detail results after applying SWT to an image using SWT at 1 to 4 levels.

(a) (b)



(c) (d)

Fig. 2. Detail image subbands on Stationary Wavelet Transform (SWT): (a) SWT level 1, (b) SWT level 2, (c) SWT level 3, (d) SWT level 4.

B. Spatial Frequency Measurement (SFM)

Spatial Frequency Measurement (SFM) is a method to measure the overall activity level in an image. For an M×N image block F, with gray value I (i, j) at position (i, j), the spatial frequency measurement is defined as [6],[7],

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

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

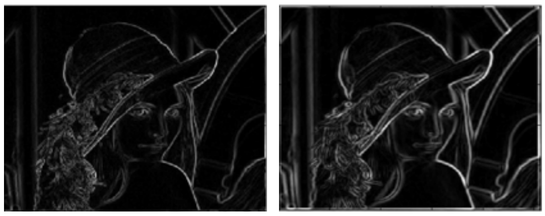
$$SFM = \sqrt{(RF)^2 + (CF)^2} \quad (3)$$

where RF is row frequency and CF is column frequency, $I(i,j)$ denotes the samples of image. M and N are numbers of pixels in horizontal and vertical directions, respectively. The large value of SFM means that image contain components in high frequency area.

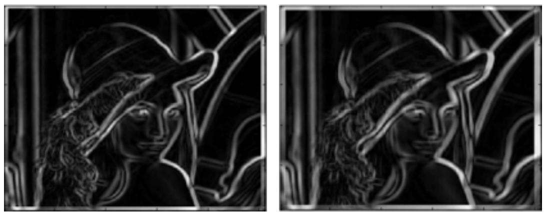
(a) (b)

(c) (d)

Fig. 3. Original and blurred image versions with moving average filter: (a) Original image (b) 3×3 mask (c) 5×5 mask (d) 7×7 mask.



(a) (b)



(c) (d)

Fig. 4. Edge image results of Fig. 3(a), (b), (c) and (d) using SWT level 1

TABLE I
SPATIAL FREQUENCY MEASUREMENT OF FIG. 4.

Figures	(4a)	(4b)	(4c)	(4d)
SFM	17.2092	8.8989	4.8925	3.1995

Figure 3 (a) shows an original image. Images 3 (b)-(d) show the degraded image versions after blurring with a moving average filter using mask size 3×3, 5×5, 7×7. Figure 4(a) to 4(d) show the edge image results using SWT at level 1, applied to images in figure 3. As can be seen from table I, when the images get more blurred, the SFM values are decreased consequently. These demonstrate that the spatial frequent measurement can be used to reflect the clarity of an edge image.

III. PROPOSED APPROACH

A. Edge Image Fusion Scheme

Figure 5 shows the edge image fusion scheme of our proposed approach.

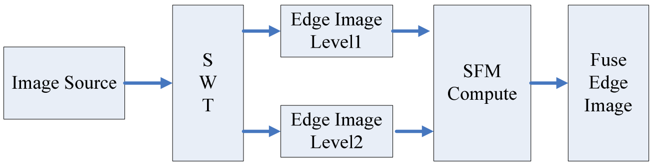


Fig. 5. Proposed edge image fusion scheme.

The algorithm of edge image fusion consists of the following steps.

A) Decompose an image using SWT at two level including level 1 and level 2

B) Partition the coefficients of edge images in to blocks of size M×N. Denote the i_{th} coefficients blocks from each edge image 1 and edge image 2 with GA_i and GB_i, respectively

C) Compute the Spatial Frequency Measurement (SFM) using equation 3 of two corresponding blocks GA_i and GB_i, the simple rule for construct the i_{th} fused coefficient block GF_i is given by,

$$GF_i = \begin{cases} GA_i & SFGA_i > SFGB_i \\ GB_i & SFGA_i < SFGB_i \\ \dfrac{GA_i + GB_i}{2}, & otherwise \end{cases}$$

where GF_i is fused coefficient blocks and $SFGA_i$, $SFGB_i$ are Spatial Frequency Measurement values of GA_i and GB_i, respectively.

B. Correlation Measurement

Correlation measurement is a measurement that is used to find out the closely correlation between edge image and original image. If the correlation measurement value is high or get the maximum result, it can be concluded that the edge image is completely sharp edge image. The correlation measurement is defined as,

$$corr(A,B) = \frac{\sum_{j=1}^{npix}(A_j - \overline{A})(B_j - \overline{B})}{\sqrt{\sum_{j=1}^{npix}(A_j - \overline{A})^2 \sum_{j=1}^{npix}(B_j - \overline{B})^2}} \quad (4)$$

where A is original image and B is the edge image.

TABLE II.
CORRELATION VALUES OF FIG. 3.

Figures	(3a,3a)	(3a,3b)	(3a,3c)	(3a,3d)
Correlation Values	1	0.4145	0.1676	0.0807

Figure 3 (a) shows an original image. Figure 3 (b)-(d) show the images are used to find the correlation values compared with the original image. In Table II, the correlate measurement value is high, it can be seen that image is completely sharp image when compared with the original images. These demonstrate that the correlation value can be used to reflect the clarity of an edge image.

IV. EXPERIMENTAL RESULTS

A. Effect of block sizes for fusion process

Table III shows the correlation values obtained from our proposed approach using different block sizes (4×4, 8×8, 16×16, 32×32) to compute the SFM of the edge image results obtained from the Stationary Wavelet Transform level 1 and level 2. The original images, figure 7, are contaminated with Gaussian noise at the SNR=30. We demonstrate that the best correlation values and suitable block size are depended on the overall activity level of each original image (SFM values).

TABLE III.
CORRELATION VALUE WITH DIFFERENT BLOCK SIZES

Mask sizes / Images	Mask size 4×4	Mask size 8×8	Mask size 16×16	Mask size 32×32
Lenna	0.0713	0.0760	0.0773	**0.0768**
Man	**0.0306**	0.0248	0.0237	0.0264
Plane	0.0322	0.0345	**0.0360**	0.0356
Hand	0.0475	0.0521	**0.0525**	0.0503
Cat	0.1528	0.1538	0.1571	**0.1588**
Face	**0.0433**	0.0340	0.0405	0.0319
DJ	0.0201	0.0225	**0.0231**	0.0220
Flower	**0.0183**	0.0125	0.0126	0.0145

B. Comparison with other methods

In this section, the different Signal to Noise Ratio (30, 40 and 50) of Guassian noise are used. The experimental results are shown in Table IV, V and VI. As can be seen, our proposed edge fusion scheme using Stationary Wavelet Transform (SWT) and Spatial Frequency Measurement (SFM) provides completely sharp edge results, figure 6, and outperforms other simple edge detection methods in term of correlation values.

V. CONCLUSION

In this paper, a method of multiresolution edge image fusion is proposed. It is based on the use of Spatial Frequency Measurement (SFM) and Stationary Wavelet Transform (SWT), compared with some simple edge detection methods. From the experiments, we evaluate the performance results of our proposed method using the correlation values and found that our proposed fusion method provides complete edge results. In addition, our proposed method can be applied to other features in the noisy image source.

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TABLE IV.
CORRELATION VALUE S WITH GUASSIAN NOISE, SNR = 30

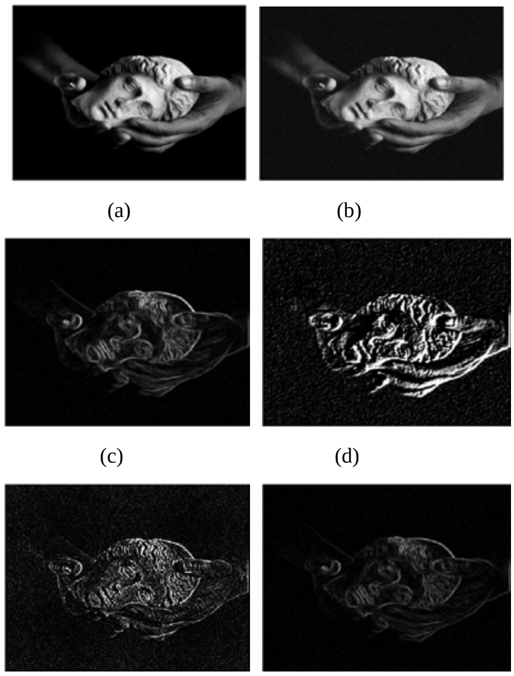
Methods / Images	SWT Fusion	Sobel Operator	LOG	Wavelet based Image Fusion
Lenna	**0.0768**	0.0572	0.0404	0.0693
Man	**0.0376**	0.0303	0.0306	0.0359
Plane	**0.0360**	0.0267	0.0283	0.0315
Hand	**0.0952**	0.0725	0.0569	0.0831
Cat	**0.1588**	0.1402	0.1416	0.1499
Face	**0.0433**	0.0224	0.0212	0.0404
DJ	**0.0231**	0.0197	0.0229	0.0208
Flower	**0.0183**	0.0131	0.0121	0.0172

TABLE V.
CORRELATION VALUE S WITH GUASSIAN NOISE, SNR = 40

Methods / Images	SWT Fusion	Sobel Operator	LOG	Wavelet based Image Fusion
Lenna	**0.0773**	0.0581	0.0412	0.0702
Man	**0.0383**	0.0374	0.0318	0.0362
Plane	**0.0375**	0.0288	0.0286	0.0327
Hand	**0.1043**	0.0742	0.0576	0.0838
Cat	**0.1594**	0.1413	0.1421	0.1503
Face	**0.0454**	0.0258	0.0218	0.0413
DJ	**0.0276**	0.0203	0.0231	0.0217
Flower	**0. 0191**	0.0138	0.0128	0.0174

TABLE VI.
CORRELATION VALUE S WITH GUASSIAN NOISE, SNR = 50

Methods / Images	SWT Fusion	Sobel Operator	LOG	Wavelet based Image Fusion
Lenna	**0.0786**	0.0586	0.0423	0.0706
Man	**0.0391**	0.0379	0.0324	0.0373
Plane	**0.0384**	0.0293	0.0298	0.0336
Hand	**0.1048**	0.0751	0.0587	0.0841
Cat	**0.1602**	0.1420	0.1435	0.1516
Face	**0.0461**	0.0268	0.0234	0.0419
DJ	**0.0285**	0.0216	0.0238	0.0223
Flower	**0.0208**	0.0143	0.0139	0.0182



(a) (b) (c) (d) (e) (f)

Fig. 6. Edge image fusion with Guassian noise at SNR=30
(a) Original image (b) Noisy image (c) SWT fusion (d) Sobel Operator
(e) LOG, (f) Wavelet Based Image Fusion

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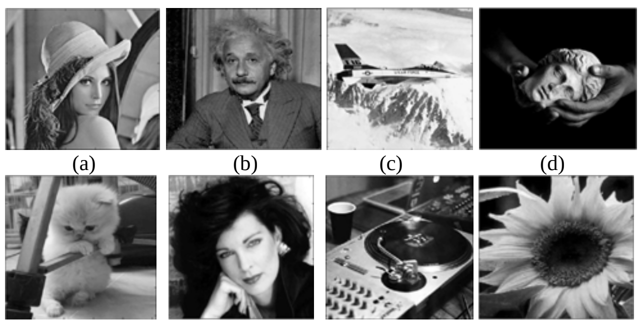

(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 7. Original images.

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