

Wavelet Coefficient Fusion Method -Based Image Denoising

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Abstract: In this study, new manner for removing noise from image using wavelet fusion method. The main aim of this research is restaurant the image based on peak signal to noise ratio measure. The key idea is compared each sub band for different levels of wavelet based on PSNR value. Initially apply discreet wavelet transform with 2level decomposition on the set of images .Then perform denoising wavelet techniques that achieved by threshold value for detail coefficient and compare it with wavelet coefficients for detail sub band. After that select sub band that has less noise from each image, sub band that contain high PSNR measure is the optimal. Finally apply IDWT process to convert the result image from frequency domain to spatial domain. The outcomes of the work exposed that the number of levels increases, PSNR of image decrease. In this study was chosen two level of decomposition to guarantee choosing several sub band for fusion process but the increasing in number of levels of wavelet will lose the essential information of image, therefore level 1 is better than level 2.

Key words: Discrete wavelet transform, noise image, denoising wavelet, image fusion, level decomposition

INTRODUCTION

Discrete wavelet transform: DWT is one of the image fusion methods that use to reveal local features during a signal process. The first discrete wavelet transform is haar wavelet that invented in 1910. The discrete wavelet transform has become a tool very helpful for fusion and used in many applications like image denoising, image compression, Speech recogni+tion and fractal recognition. Tawfiq and colleagues. DWT decomposes the original images into set of sub band with level K, called LL (approximation coefficients), LH (vertical Details), HL (horizontal details) and HH (diagonal details). The approximation coefficients of each level are the input of the next level. Discrete wavelet transform tends to pick out the distinguished features of an image, this scheme produce well results. The LL1 sub band is decomposed to find out the next approximation level. The finding DWT of image by passing it a set of filters. In the beginning, it passed through a low pass filter and result approximation coefficients, in this time it decomposed using a high-pass filter and result the detail coefficients. The approximation coefficient and detail coefficient can be calculated according to the following equation:

$$a(r, c) = \sum_k x(r, k)g(c - k) \quad (1)$$

$$d(r, c) = \sum_k x(r, k)h(c - k) \quad (2)$$

where, h and g represent the high pass filter and low pass filter respectively. Figure 1 shows the global structure of 2D DWT (Richard, 2003).

Denoising wavelet: unfortunately a signal or an image is corrupted by noise from through transmission or acquisition (Scott, 2011). The goal of image denoising is removing noise and preserving useful information. Wavelet thresholding is non-linear technique, each coefficient is compared with threshold, if the threshold value is smaller than coefficient, then it is kept otherwise represent to zero. Xie *et al.* (2002) There are two thresholding methods in wavelet denoising image, hard and soft thresholding. In the hard thresholding if its coefficient is smaller than determined threshold, it will represent to zero (kill) otherwise it will retain unchanged, or shrink in the absolute value in the soft thresholding. The types of utilized thresholds are calculated according to the following equation:

$$T_B = \sigma^2 / \sigma_s \quad (3)$$

$$\sigma_s = \sqrt{\max(\sigma n^2 - \sigma^2), 0} \quad (4)$$

$$\sigma n^2 = \frac{1}{m^2} \sum_{x,y=1}^m n^2 \quad (5)$$

$$\sigma n^2 = \frac{1}{m^2} \sum_{x,y=1}^m (x, y)^2 \quad (6)$$

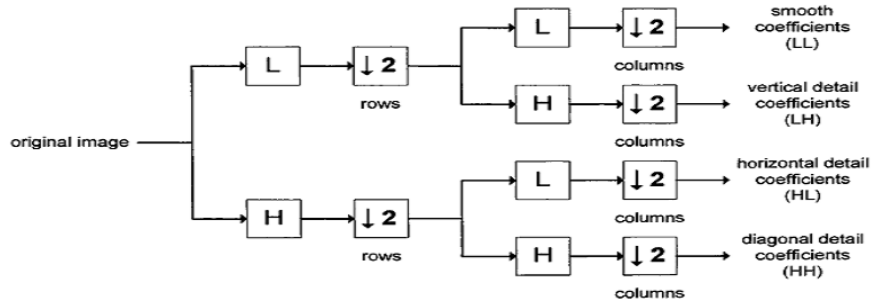


Fig. 1: 2D discrete wavelet transform

$$T = \sigma_s \sqrt{2 \log m} \quad (7)$$

where, T_B is the Bayes threshold, σ^2 is the noise variance, σ_s is signal variance without noise, m is the dimension of image, T is universal threshold and σn^2 is the noise variance of sub band for corrupted image.

Image fusion: It is the process of blending relevant information from more than one image original into a single image that is more informative than any of the sources images. The key goal of fusion is improvement original images and providing a result image with more useful information than original image. In our research study has been fused the optimal sub bands from set of images that has less noise than other sub bands for other images in order that getting on the optimal image (Heba, 2013).

Types of noise in digital images: There are different types of noise in image processing are salt and pepper, Gaussian, Poisson and speckle that will be explained as shown in below.

Impulsive noise: It was named salt and pepper noise (spike noise). This type of it is typically found in images. It contains white and black pixels. This type consists of two parts are bright and dark. Bright parts contain dark pixels while dark parts contain bright pixels. It happens when bit errors that transmitted through analog to digital converter and dead pixels will consist of it. Anutam and Rajni (2014)

Amplifier noise (Gaussian noise): The Gaussian noise follows additive noise, this noise is independent at each pixel. Blue channel gives more noise from other channels (red and green) because in color cameras blue color can be more amplifier from others (Anutam and Rajni, 2014).

Poisson noise: Poisson noise can be also called shot noise is one of types of electronic noise that occurs when

the limited number of molecules that transport power, like electrons in an electronic circuits or photons in an optical system. Farooque and Rohankar (2013) Speckle Noise: It follows multiplicative noise. This type of noise is a granular noise that more popular found in radar, laser and SAR images. This type of noise increases the mean grey level of a local region. It causes the difficulties for image analysis in SAR images. This type of noise results from coherent processing of backscattered signals from several targets. The origin of it was referred to random intervention between the coherent outputs (Anutam and Rajni, 2014; Suman, 2014).

MATERIALS AND METHODS

The proposed method as illustrated in Fig. 2 that contains many of steps.

Input set of images: the images can be used in this study are noise images that gained by appending noise to the original images. These images will be converted to 2D array with size $M \times N$. These images are of same size and same scene but capturing under different condition.

Apply two level decomposition wavelet transform for each image: Perform wavelet transform on each image with two level. Haar family is used in this study. DWT decomposes an image into various sub bands based on local frequency content. The DWT coefficients are calculated by using low pass filter and high pass filters and down sampling process on both rows and columns according to Eq. 1 and 2.

Extract coefficient feature for each sub band of DWT: By performing DWT on the images will extracts from the wavelet coefficients decomposition the vertical, horizontal and diagonal detail coefficients for each level.

Calculate thresholds for detail sub band: This step has been calculated the threshold for each sub band according to Eq. 3 and 6.

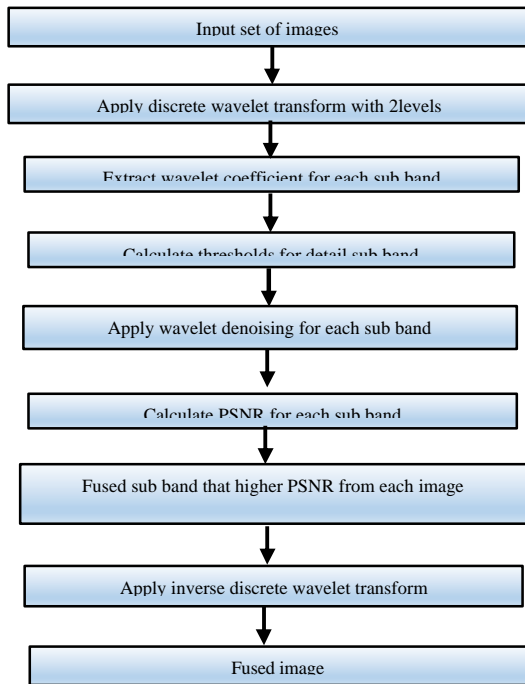


Fig. 2: Block diagram of the proposed method

Apply denoising wavelet for each image: In this step is selected bayes and universal thresholds with hard and soft thresholding to calculate threshold value for detail sub band and compared with wavelet coefficient according to the equation 7 and 8. The comparison process was performed by using Peak Signal to Noise Ratio (PSNR). The image that has the highest PSNR is better. The soft and hard thresholding computed from the following equations respectively.

$$\tilde{x}[n] = \begin{cases} Y[n] - T & Y[n] \geq T \\ Y[n] + T & Y[n] \leq -T \\ 0 & |Y[n]| < T \end{cases} \quad (8)$$

$$\tilde{x}[n] = \begin{cases} Y[n] & \text{if } |Y[n]| \geq T \\ 0 & \text{otherwise} \end{cases} \quad (9)$$

Wavelet denoising consists of three steps:

DWT stage: Apply DWT on images to obtain the approximation and detail coefficients.

Denoising stage: Compare the detail coefficient with threshold value. All the detail coefficients have less than the threshold are represented to zero.

IDWT stage: Perform inverse DWT to reconstruct an image and get the denoised image (Chin *et al.*, 2013).

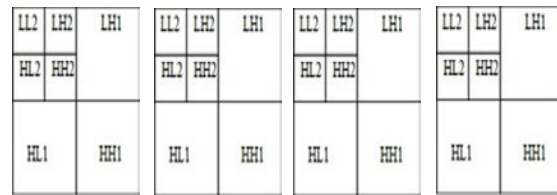


Fig. 3: PSNR for sub band

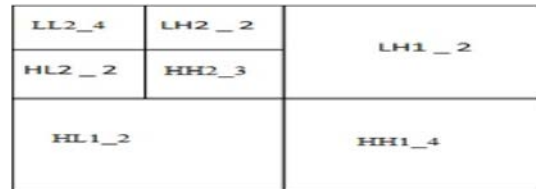


Fig. 4: Fusion process

Calculate PSNR for each sub band: The selecting process of optimal sub band is performed by using Peak Signal to Noise Ratio (PSNR). The image that has the highest PSNR is the better for selecting it.

For example they have four original images and they compute PSNR for sub band LH1: Now calculate sum PSNR for each image as follow show in fig. 3:

- as PSNR_LH1 between (image 1 and image 2) = 10
- as PSNR_LH1 between (image 1 and image 3) = 20
- as PSNR_LH1 between (image 1 and image 4) = 30
- as PSNR_LH1 between (image 2 and image 3) = 40
- as PSNR_LH1 between (image 2 and image 4) = 50
- as PSNR_LH1 between (image 3 and image 4) = 60

Image 1 = 10+20+30=60

Image 2 = 10+40+60= 110

Image 3 = 20+40+60=120

Image 4 = 30+50+60= 140

The higher PSNR is 140

The image 4 is better for selecting sub band LH1

Fusion process: By applying DWT on the images and performing denoising wavelet using thresholding techniques will get on image that sub bands have less noise from input images. In this step is selected suitable sub band from each the image after compare it with other sub band contrast to the image of another image according to PSNR value , sub band that gives large value is optimal sub band. The resulting image is the product combining optimal sub bands that has higher PSNR for each image (in frequency domain). For example the resulted image after PSNR are computed for each sub band in Fig.4:

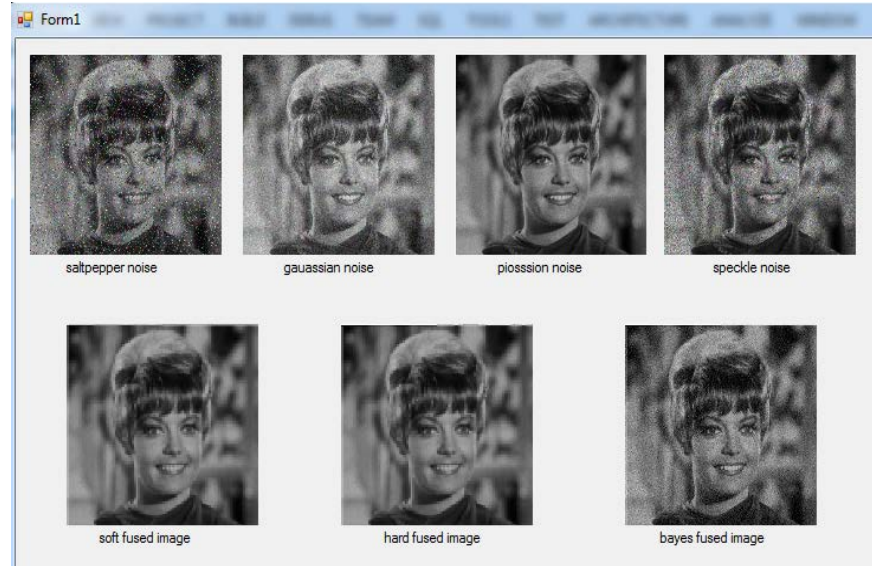


Fig. 5: The original images and fused images

Table 1: Results PSNR of sub band for each thresholding of noisy images (400×400)

Sub bands of images	Peak signal to noise ratio		
	Soft universal thresholding	Hard universal thresholding	Soft Bayes thresholding
LH2 of image 1 and 2	50.994	25.791	16.171
LH2 of image 1 and 3	33.546	22.278	16.138
LH2 of image 1 and 4	51.736	26.173	15.789
LH2 of image 2 and 3	33.582	23.897	20.098
LH2 of image 2 and 4	55.136	29.896	19.310
LH2 of image 3 and 4	33.596	23.609	18.940
HL2 of image 1 and 2	28.803	24.659	19.216
HL2 of image 1 and 3	31.312	25.625	20.164
HL2 of image 1 and 4	27.298	22.695	18.023
HL2 of image 2 and 3	39.118	35.006	25.624
HL2 of image 2 and 4	34.076	24.954	20.130
HL2 of image 3 and 4	32.676	25.053	21.183
HH2 of image 1 and 2	48.130	40.440	17.225
HH2 of image 1 and 3	53.884	38.210	18.298
HH2 of image 1 and 4	48.130	40.085	16.642
HH2 of image 2 and 3	53.884	37.959	22.397
HH2 of image 2 and 4	48.130	38.967	18.803
HH2 of image 3 and 4	53.884	37.270	20.713
HH2 of image 1 and 2	48.130	48.130	55.408
LH1 of image 1 and 3	47.132	43.063	43.623
LH1 of image 1 and 4	48.130	48.130	60.765
LH1 of image 2 and 3	47.132	43.063	43.710
LH1 of image 2 and 4	48.130	48.130	59.173
LH1 of image 3 and 4	47.132	43.063	59.173
LH1 of image 1 and 2	37.632	26.973	43.215
HL1 of image 1 and 3	30.674	25.557	16.613
HL1 of image 1 and 4	35.514	22.333	17.518
HL1 of image 2 and 3	34.887	37.856	15.493
HL1 of image 2 and 4	36.847	24.829	22.340
HL1 of image 3 and 4	31.943	24.787	17.800
HL1 of image 1 and 2	79.831	37.339	19.306
HH1 of image 1 and 3	55.367	36.766	16.755
HH1 of image 1 and 4	79.390	36.473	18.021
HH1 of image 2 and 3	55.383	45.848	16.255
HH1 of image 2 and 4	89.551	43.899	22.368
HH1 of image 3 and 4	55.381	41.755	20.639

Table 2: Sum PSNR of sub band for each thresholding of noisy images (400*400)

No. of levels	Images	Sub band	Soft Universal thresholding	Hard Universal thresholding	Soft Bayes thresholding	
1	1	LH	143.394	139.324	129.797	
		HL	103.821	74.864	49.625	
		HH	214.589	110.579	51.032	
	2	2	LH	143.394	139.324	138.291
			HL	109.367	89.659	56.754
			HH	224.765	127.087	57.708
		3	LH	141.398	129.189	130.549
			HL	97.504	88.201	59.166
			HH	166.132	124.370	61.029
2	4	LH	143.394	139.324	133.154	
		HL	104.305	71.950	52.599	
		HH	224.323	122.127	57.478	
	1	1	LH	136.276	74.243	48.098
			HL	87.414	72.980	57.404
			HH	150.146	118.735	52.166
		2	LH	139.713	79.585	55.579
			HL	101.997	84.619	54.971
			HH	150.146	117.366	50.426
3	2	LH	100.725	69.785	55.177	
		HL	93.107	85.685	60.973	
		HH	161.653	113.440	60.409	
	4	LH	140.468	79.679	54.041	
		HL	94.051	71.703	50.337	
		HH	150.146	116.323	56.159	

Apply inverse discrete wavelet transform: After performing previous step will implement (IDWT) on the resulted image with using low and high pass filter to reconstruct the image and transform back to the spatial domain.

Fused Image: Finally after performing the previous steps, in the step will be acquired on single image that result from merging optimal sub bands form each image.

RESULTS AND DISCUSSION

In this study the experiments are performed on 4 images as given in Fig. 5. Figure 5 is applied discrete wavelet transform on each original noisy image with two level decomposition. Soft and hard thresholding have been applied with using universal and bayes thresholds. Fusion process utilised PSNR as metric to determine the optimal sub bands that has less noise. Inverse discrete wavelet transform has been applied on the fused image to convert to the spatial domain. The following results of this work as shown in Table 1 and Table 2 displays PSNR values for different thresholds with soft and hard thresholding of between images. The image that has value higher of PSNR is the better for selecting it. Through the results of Table 2 show the PSNR of level 1 is higher from level 2. The increasing number of levels will lose the essential information of image.

CONCLUSION

This study presents removing noise from images using wavelet fusion method. Through the outcomes of this work we notice that PSNR value was decreased as number of levels was increased. This work reduces noise

at different resolution levels. This work concludes PSNR value of level one is higher from PSNR of level two. Also the results show that soft thresholding give value large of PSNR than hard thresholding.

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