Noise removal from medical image using fusion technique based on DWT coefficient

A H Russell
College of Arts, University of Babylon, Iraq
E- mail : rhjssaa@yahoo.com

Abstract. This paper introduces new manner for removing noise from medical images using wavelet transform based on fusion technique. The main goal of this research is restaurant the medical image based on peak signal to noise ratio value. This paper contains of three key stages are discrete wavelet transform, denoising wavelet and fusion technique. The new idea is compared each sub band of wavelet with other sub band depend on PSNR value and is selected the higher value of measure. First, perform 2 level of discreet wavelet transform on the noisy medical images. Then, perform denoising wavelet techniques (soft and hard thresholding) that achieved by threshold value for detail coefficient and compared it with wavelet coefficients for detail sub band. Second, select sub band that contains the higher peak signal to noise ratio value that has less amount of noise from each image and it is merged to form the fused image. Finally, perform inverse discrete wavelet transform to convert the output image (fused image) from frequency domain to spatial domain. The outcomes of the work showed that soft thresholding is better than hard thresholding based on higher PSNR value. The fusion process gives better results than wavelet denoising technique.

Keywords: Denoising Wavelet, Discrete Wavelet Transform, Image Fusion, Medical Image, Noisy Image, PSNR.

1. Introduction

Image enhancement is an important part of image processing and computer vision. Image enhancement is the process of improving the quality of image and content of information before processing. In general, images are degraded from through noise, contrast and blur. Noise is removed by using filters in spatial domain and wavelet denoising in frequency domain. Contrast is enhanced by using histogram equalization. Blur can be removed by using blind Deconvolution, wiener filter and inverse filtering. In this work will explain about noise removal in frequency domain based on denoising wavelet.

2. Discrete wavelet transform

Discrete wavelet transform is one of the image fusion techniques. DWT is used in many applications like image denoising, image compression, speech recognition and fractal recognition [1].
The input image is applied by dwt to produce approximation coefficients and detail coefficients. The approximation coefficients of each level are the input of the next level. The LL1 sub band is decomposed to find the next approximation level [2].

DWT of an image is found by passing it on low pass and high pass filters. The low pass filter creates approximation coefficients while the high pass filter creates the detail coefficients. The approximation coefficient and detail coefficient can be computed according to the equations (1, 2):

\[
a(r,c) = \sum_k x(r,k) l(c-k)
\]

\[
d(r,c) = \sum_k x(r,k) h(c-k)
\]

Where \(x\) represents the original image, \(l\) and \(h\) represent the low pass and high pass filters respectively. Figure 1 represents the structure of 2D discrete wavelet transform [3].

![Discrete wavelet transform of two-level decomposition](image)

Figure 1. Discrete wavelet transform of two-level decomposition [3].

### 3. Denoising wavelet

An image is degraded by noise from transmission or acquisition. Image denoising is the process of eliminating noise from images and preserving useful information. Wavelet denoising is a noise removal process by using wavelet method.

There are two types of thresholding methods in wavelet denoising: soft and hard thresholding. Wavelet denoising is performed via comparing coefficients with a threshold [4].

If its wavelet coefficient is smaller than the threshold, it will be represented as zero (in the hard thresholding), while it will remain unchanged (in the soft thresholding). The threshold value is calculated according to the equation (3):

\[
T = \sigma \sqrt{2\log(n \times m)}
\]

Where \(T\) is the universal threshold, \(\sigma\) is the noise standard deviation, and \(n\) and \(m\) are the dimensions of the image [5].

There are various kinds of noise in image processing: Gaussian, Poisson, salt & pepper, and speckle noise. Gaussian noise follows additive noise. In color cameras, blue color is more amplified from red and green colors, so this reason blue channel is more noise from red and green channels. Poisson noise is one of the kinds of electronic noise that happens once the limited number of electrons in an electronic circuit. Salt and pepper noise is more popularly found in the images.
Speckle noise is multiplicative noise that found in laser, radar and SAR images (see Figure 2) [6].

4. Image Fusion
Image fusion is the process of combination the information from set of images to form one image that is more informative than of the original images. The main objective of fusion process is enhancement images and giving output image that more clarify than original images.

The fusion method should attain the following situations:
- It retains all information in the fused images.
- It prevents dissimilar parts of the image as noise.
- It decreases any ambiguity in the fused image [3].

![Figure 2. original image and noisy images (a) Original image without noise (b) Image with salt & pepper noise (c) Image with Gaussian noise (d) Image with Poisson noise (e) Image with speckle noise [7].](image)

5. Related Work
This section introduces some of previous works that their closeness to the paper as table 1.

Ram Nivas and Himanshu Agarwa [8] presented fusion of medical image using wavelet. They used the wavelet transform, PCA for fusing and bicubic interpolation while in this paper is used discrete wavelet transform to remove the noise and improved the edge between sub bands by using fusion method depends on higher PSNR value for each sub band.

Arin H. Hamad et.al. [9] presented noise removal from medical images in spatial domain. They used various kinds of filters are Average filter, Log filter, Gaussian filter, Wiener filter and Median filter. In this paper is used wavelet denoising using threshold to remove the noise from the medical images in the frequency domain in addition to fusion process for producing the optimal image.

Prerana and Deepali [10] presented efficiency MRI and CT images fusion methods. They extended this method by using curvelet transform with wavelet transform methods to achieve
the objective of improving the performance while in this work is used wavelet transform with fusion method based on higher PSNR value of each sub band. Hari and Smriti [11] discussed MRI and CT image fusion by using wavelet transform. They implemented the wavelet transform by using fusion rules like maximum, minimum and average methods on the images. They decided that maximum method provides result better higher PSNR values. In this paper is computed wavelet coefficient for each sub band based on higher PSNR value. PSNR value of sub band is compared with value of other sub band and is selected higher value to form the fused image.

Nayera Nahvi and Deep Mittal [12] proposed medical image fusion using DWT. They used different fusion methods of dwt including pixel average, max min and min max for medical image fusion while in this paper is used wavelet coefficient with fusion based on the higher PSNR measure of each sub band and comparing with other sub band to select the optimal sub band to produce the fused image and not based on maximum or minimum or average of wavelet coefficient.

Table 1. Comparative study of related work with this work.

| No. of Reference | The algorithm | Denoising Domain | Types of The used Thresholds | Fusion method |
|------------------|---------------|------------------|------------------------------|--------------|
| 8                | Discrete wavelet transform | —— | —— | PCA |
| 9                | Filters       | Spatial domain   | Average filter , Gaussian filter, Wiener filter and Median filter. | —— |
| 10               | curvelet transform with wavelet transform | —— | —— | curvelet transform with wavelet transform |
| 11               | Discrete wavelet transform | —— | —— | maximum, minimum and average |
| 12               | Discrete wavelet transform | —— | —— | pixel average, max min and min max |
| This work        | Discrete wavelet transform | Frequency | Wavelet denoising (Universal and soft threshold) | Different sub band of wavelet based on PSNR value |

6. Materials and Methods

The proposed work is illustrated in Figure 3 that includes many of steps:

Figure 3. Block diagram of the proposed work.
The block diagram in above contains of many stages are:

6.1. Input set of images
the images used in this paper are noise medical images. These images will be converted to
two dimensions array with size M*N. These images were of same size and same scene but
capturing under different conditions.

6.2. Apply wavelet transform for each image
perform wavelet transform on each image with two level will consists seven sub bands as
clarified in Fig. 3 are the vertical, horizontal, diagonal and detail coefficients for each level.
DWT coefficient are calculated by using low pass filter and high pass filters on the images
and then down sampling process on both rows and columns of images according to
equations (1) and (2).

6.3. Apply wavelet denoising for each image
in this step is applied hard and soft thresholding to calculate threshold value for detail sub
band and compared with wavelet coefficient according to the equation (3) . The soft and
hard thresholding computed according to the equations (4) and (5) respectively.

\[ X[n] = \begin{cases} 
Y[n] - T & Y[n] \geq T \\
Y[n] + T & Y[n] \leq -T \\
0 & |Y[n]| < T 
\end{cases} \]  
(4)

\[ \hat{X}[n] = \begin{cases} 
Y[n] & |Y[n]| \geq T \\
0 & \text{otherwise} 
\end{cases} \]  
(5)

6.4. Calculate PSNR for each sub band
in this step is computed PSNR value for each sub band of images and for each level of
discrete wavelet transform. The optimal sub band is the better for selecting it to form
fused image that has the highest PSNR value.

For example they have three images and they compute PSNR for sub band LH1:

Now calculate sum PSNR for three image for LH1 sub band as follow:

Image 1 = 10+20 = 30
Image 2 = 10+40 = 50
Image 3 = 20+40 = 60

PSNR_{LH1} between (image 1 and image 2) = 10
PSNR_{LH1} between (image 1 and image 3) = 20
PSNR_{LH1} between (image 2 and image 3) = 40
The higher PSNR is 60. The image 3 is better for selecting sub band LH1 to form fused image. The same method is repeated on the rest of other sub bands to select the optimal sub band. The fused image is the combining optimal sub bands that has higher PSNR for each image (in frequency domain).

6.5. Apply inverse discrete wavelet transform (IDWT)
This step implements on the resulted image (fused image) to transform the image from frequency domain to the spatial domain. IDWT is computed by finding low and high pass filter in reverse manner compared with DWT process to get on the output image (optimal image) that it resulted from merging optimal sub bands form each image.

7. Results and Discussion

The results are implemented on 3 original medical noisy images (see Figure 4).

![Figure 4. The noisy medical images.](image)

(a) Gaussian noise  (b) poisson noise  (c) salt&pepper noise

Figure 5 clarified applying fusion process on medical noisy image to produce the optimal image (fused image). Fusion process is used based on PSNR metric to determine the optimal sub bands that has less noise of image. Inverse discrete wavelet transform is applied on the fused image to convert from the frequency domain to the spatial domain.

![Figure 5. The fused medical images.](image)

(a) fused by Soft thresholding  (b) fused by hard thresholding
Table 2. Results PSNR of sub band for universal thresholding of noisy images (200*200).

| Sub bands of images | Peak Signal to Noise Ratio | Soft Universal thresholding | Hard Universal thresholding |
|---------------------|----------------------------|-----------------------------|----------------------------|
| LH2 of image 1 and 2| 50.994                     | 25.791                      |
| LH2 of image 1 and 3| 33.546                     | 22.278                      |
| LH2 of image 2 and 3| 51.736                     | 26.173                      |
| HL2 of image 1 and 2| 28.803                     | 24.659                      |
| HL2 of image 1 and 3| 31.312                     | 25.625                      |
| HL2 of image 2 and 3| 27.298                     | 22.695                      |
| HH2 of image 1 and 2| 48.130                     | 40.440                      |
| HH2 of image 1 and 3| 53.884                     | 38.210                      |
| HH2 of image 2 and 3| 53.884                     | 37.959                      |
| LH1 of image 1 and 2| 48.130                     | 48.130                      |
| LH1 of image 1 and 3| 47.132                     | 43.063                      |
| LH1 of image 2 and 3| 47.132                     | 43.063                      |
| HL1 of image 1 and 2| 37.632                     | 26.973                      |
| HL1 of image 1 and 3| 30.674                     | 25.557                      |
| HL1 of image 2 and 3| 34.887                     | 37.856                      |
| HH1 of image 1 and 2| 79.831                     | 37.339                      |
| HH1 of image 1 and 3| 55.367                     | 36.766                      |
| HH1 of image 2 and 3| 55.383                     | 45.848                      |

Table 2 shows PSNR values for universal threshold with soft and hard thresholding of between sub bands while Table 3 shows the sum of PSNR values of each sub band. The image that has value higher of PSNR is the better for selecting it.

Table 3. Sum PSNR of sub band for universal thresholding of noisy images (200*200).

| No. of Levels | No. of Images. | Sub band | Soft Universal thresholding | Hard Universal thresholding |
|---------------|----------------|----------|----------------------------|----------------------------|
| 1             | Image 1        | LH       | 143.394                    | 139.324                    |
|               |                | HL       | 103.821                    | 74.864                     |
|               |                | HH       | 214.589                    | 110.579                    |
|               |                | LH       | 143.394                    | 139.324                    |
|               |                | HL       | 109.367                    | 89.659                     |
|               |                | HH       | 224.765                    | 127.087                    |
|               |                | LH       | 141.398                    | 129.189                    |
|               |                | HL       | 97.504                     | 88.201                     |
|               |                | HH       | 166.132                    | 124.370                    |
|               |                | LH       | 136.276                    | 74.243                     |
|               |                | HL       | 87.414                     | 72.980                     |
|               |                | HH       | 150.146                    | 118.735                    |
|               |                | LH       | 139.713                    | 79.585                     |
|               |                | HL       | 101.997                    | 84.619                     |
|               |                | HH       | 150.146                    | 117.366                    |
|               |                | LH       | 100.725                    | 69.785                     |
|               |                | HL       | 93.107                     | 85.685                     |
|               |                | HH       | 161.653                    | 113.440                    |
| 2             | Image 1        | LH       | 143.394                    | 139.324                    |
|               |                | HL       | 103.821                    | 74.864                     |
|               |                | HH       | 214.589                    | 110.579                    |
|               |                | LH       | 143.394                    | 139.324                    |
|               |                | HL       | 109.367                    | 89.659                     |
|               |                | HH       | 224.765                    | 127.087                    |
|               |                | LH       | 141.398                    | 129.189                    |
|               |                | HL       | 97.504                     | 88.201                     |
|               |                | HH       | 166.132                    | 124.370                    |
|               |                | LH       | 136.276                    | 74.243                     |
|               |                | HL       | 87.414                     | 72.980                     |
|               |                | HH       | 150.146                    | 118.735                    |
|               |                | LH       | 139.713                    | 79.585                     |
|               |                | HL       | 101.997                    | 84.619                     |
|               |                | HH       | 150.146                    | 117.366                    |
|               |                | LH       | 100.725                    | 69.785                     |
|               |                | HL       | 93.107                     | 85.685                     |
|               |                | HH       | 161.653                    | 113.440                    |
8. Conclusions

This paper presents removing noise from medical images using wavelet fusion method. The outcomes of this work is signed that PSNR value soft thresholding is given higher than PSNR value of hard thresholding that means soft thresholding makes the image more clarifier than hard thresholding. Also, PSNR value for level 1 is higher than level 2 that means the image in level 1 is clearer than level 2. This paper is not work for merging two images because PSNR value for one image is equal to value of other image.

9. References

[1] Tawfiq A Abbas and Firas Sabar Miften 2012 Fractal recognition by using wavelet transform Journal of Babylon University vol 20.
[2] Israa hadi ali and Russell H. Al_taie 2016 Image Deblurring Using Fusion Technique Based on Inverse Filtering Research Journal of Applied Sciences vol 11 pp:1206-1210.
[3] Israa hadi ali and Russell H. Al_taie 2016 Wavelet coefficient fusion method based image denoising Research Journal of Applied Sciences vol 11 pp:1045-1049.
[4] Vinay Sahu and Dinesh Sahu 2014 Image Fusion using Wavelet Transform: A Review Global Journal of Computer Science and Technology: FGraphics & Vision vol 14 pp:21-28.
[5] João M. Sanches Jacinto C. Nascimento, and Jorge S. Marques 2008 Medical Image Noise Reduction Using the Sylvester–Lyapunov Equation IEEE transactions on image processing vol 17 pp:1522-1539.
[6] Mr. Rohit Verma and Dr. Jahid Ali 2013 A Comparative Study of Various Types of Image Noise and Efficient Noise Removal Techniques International Journal of Advanced Research in Computer Science and Software Engineering vol 3 pp:617-622.
[7] Sarbjit Kaur and Er. Ram Singh 2015 Image de-noising techniques: a review paper International Journal for Technological Research in Engineering vol 2 pp:2347-4718.
[8] Ram Nivas Singh Yadav and Himanshu Agarwa 2015 Fusion for Medical Image Using Wavelet Transform International Journal of Scientific Engineering and Applied Science (IJSEAS) vol 1 pp:119-121.
[9] Arin H. Hamad Hozheen O. Muhamad and Sardar P. Yaba 2016 De-noising of medical images by using some filters International Journal of Biotechnology Research vol 2.
[10] Prerana G Agarkar and Prof. Deepali R Sale 2015 Efficient MRI and CT Images Fusion Technique: Analysis International Journal of Advanced Research in Computer Science and Software Engineering vol 5 pp:594-599.
[11] Hari Om Shanker Mishra and Smriti Bhatnagar 2014 MRI and CT Image Fusion Based on Wavelet Transform International Journal of Information and Computation Technology vol 4 pp:47-52.
[12] Nayera Nahvi and Deep Mittal 2014 Medical Image Fusion Using Discrete Wavelet Transform Int. Journal of Engineering Research and Applications vol 4 pp:165-170.