Gall Bladder Ultrasonic Image Analysis by Using Discrete Wavelet Transform

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Abstract

The edge detection algorithms are important in biomedical image analysis. In this work, the histogram equalization and the discrete wavelet transform techniques were used to improve the quality of the gall bladder ultrasonic images for edge detection. Also the median filtering algorithm was used after applying the both techniques. Then the performances of the two algorithms were compared by several performance measures such as image entropy, paired t-test, and CPU time.

1. Introduction

The extraction of the relevant features in medical images play an important role for medical diagnosis. However, such task is prevented by the presence of artifacts and distortions in the images introduced by the acquisition process. Additionally, the presence of multiplicative noise (such as speckle and poisson) and the low SNR are typical in several medical image modalities and make this task even more difficult. This is typical in the ultrasound imagery, which is one of the most used for diagnosis purposes. Generally, ultrasound imagery is used for differentiation of solid from cystic, or waterfilled, structures. Diagnostic ultrasound is employed to detect low contrast lesions in soft tissue such as the liver, the gall bladder, the spleen, and the kidney. Also, ultrasound imaging is used to scan breast tissue and the abdomen for the presence of cysts or tumors. The images produced by the ultrasound scanning are usually read by a radiologist or a physician, who characterizes the tissue as normal or abnormal [1] [2] [3].

There are several image enhancement methods used to improve the quality of the image for further processing. The gall-bladder ultrasonic images contain information at low frequencies; the shape of the gall-bladder is extracted from the low frequency components. Therefore before applying the edge detection algorithms to the gall-bladder ultrasonic images, eliminating the high frequency components improves the quality of the edge detection and removes the noise.

Adaptive histogram equalization is an extraordinary contrast enhancement method for natural images, medical images and other nonvisual images [4] [5].The contrast of an image specifies the range of the gray scale values in the image. Adaptive histogram equalization can be used to improve the local contrast of an image for further processing. The high contrast image results in better performance for edge detection.

Wavelet theory provides a combined structure for a number of techniques which have been developed independently. It is very general techniques that can be applied to various tasks in signal processing such as medical signals and images, etc. The wavelet transform generally is applied to nonstationary signals, because it provides an alternative solution to the classical Fourier transform and short time Fourier transform.

The discrete wavelet transform gives the resolution of the signal for different scales. The approximate coefficients and detail coefficients of the signal are calculated at every decomposition level. The approximate coefficients can be used to extract the low frequency information from the signal [6] [7].

The above mentioned two methods are important in gall bladder ultrasonic image analysis. Therefore, these two methods are applied to gall-bladder ultrasonic images before median filtering. The median filtering can be used to remove the noise contained in an image by preserving the edge sharpness which is important for edge detection performance. The resulted images from these two methods are compared by using image entropy, paired t-test and CPU time.

The paper is organized as follows. After introducing the adaptive histogram equalization method in Subsection 2.1, we focus in Subsection 2.2 on very useful method that are based on dydic transformation called the discrete wavelet transform. In Subsection 2.3 and Subsection 2.4 it is given the briefly informations about median filtering and edge detection algorithms. Results applied on gall bladder ultrasonic images is presented in Section 3.

2. Theoretical Review

In this section the theoretical foundations of adaptive histogram equalization, discrete wavelet transform, median filtering and edge detection are presented.

2.1. Adaptive Histogram Equalization

Histogram of an image gives an estimate of the probability of occurrence of gray level. The histogram equalization performs transformation function on an image to spread the gray scale values. This increases the global contrast of an image, and performs only one transformation function on image. The adaptive histogram equalization uses different transformation functions each corresponding to a distinct section of an image and improves the local contrast of an image [8].

2.2. 2D Discrete Wavelet Transform

Mallat proposed a fast algorithm to implement the wavelet series which based on an iterative filter structure [9]. The transform coefficients are calculated form fine to coarse scales. Fig. 1 shows this structure which is called as the discrete wavelet transform. Because of an iterative structure, it is initialized with coefficients at some fine scale.

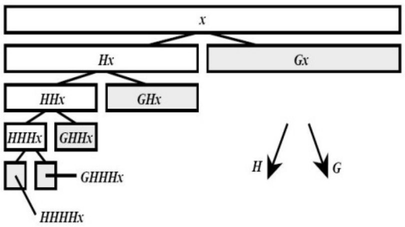


Fig.1. Discrete wavelet transform algorithm

Eq. 1 and Eq. 2 represent recursive scaling and wavelet functions, respectively. By observing that wavelet function must be expressible as a linear combination of scaling functions at the next finer scale.

$$\phi(t) = \sqrt{2}\sum_n h(n)\phi(2t-n). \quad (1)$$

$$\psi(t) = \sqrt{2}\sum_n h(n)\phi(2t-n). \quad (2)$$

Discrete wavelet transform can be considered as digital filtering of an image at different cut-off frequencies. Digital filtering is performed by using the low frequency and high frequency coefficients of the mother wavelet function. This gives the decomposition of a signal by calculating the approximate and detail coefficients vector. The approximate coefficients give low frequency information and detail coefficients give high frequency information contained in a signal. In one level decomposition the signal is filtered and down sampled by 2, giving approximate and detail coefficients which sum up to the original signal samples. Second level decomposition filters approximate coefficients obtained in first decomposition and down samples by 2 giving second level approximate and detail coefficients vector. This process continues until the desired level of decomposition.

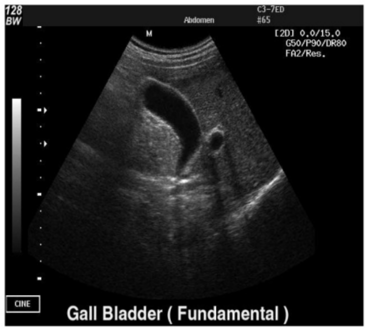
The 2D discrete wavelet transform performs digital filtering of an image and results in approximate coefficients, horizontal detail coefficients, vertical detail coefficients and diagonal detail coefficients vector.

2.3. Median Filtering

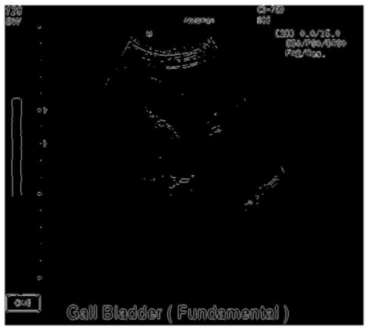
Smoothing filters takes the average of the pixel values of an image in a specified neighborhood and blurs edges and sharp details. However, median filtering replaces center pixel value of an image by the median of the pixel values in a specified neighborhood. First the pixel values in a given neighborhood are sorted in an ascending order and the median pixel value is replaced with the center pixel value. This eliminates the noise in an image and preserves the edge sharpness [8].

2.4. Edge Detection

Edge is the boundary between two regions in an image with distinct gray level properties [10]. The edge detection algorithms try to extract the edge boundaries contained in an image. The idea under the most edge detection algorithms is the computation of local derivatives. When the change in the pixel values is high corresponding to the edge, the result of a local gradient operator is high which can be used to specify the edge. In order to perform the edge detection the image masks can be used. There are several operators such as ‘sobel’, ‘prewitt’ etc. which can be used as image mask for edge detection [8]. The Fig. 2 shows the original gall bladder ultrasonic image and image after edge detection with ‘prewitt’ operator.



a)



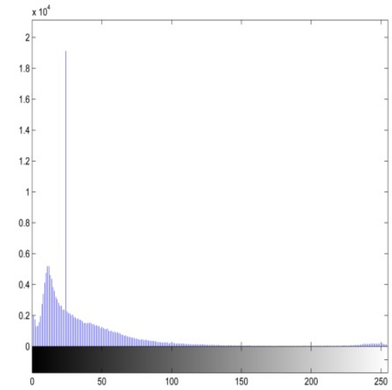
b)

Fig. 2. a) Original gall-bladder ultrasonic image, b) Image after edge detection applied to original image

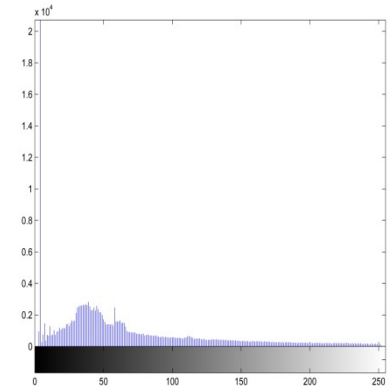
3. Results

The all experimental results are obtained using Matlab. First, the adaptive histogram equalization algorithm is applied to the gall bladder image. Then median filtering with 20-20 neighborhood mask is applied to the resulted image. Fig. 3 shows the histogram values of original image and after histogram equalization. As can be seen from Fig. 2 the adaptive histogram equalization increases the local contrast of an image rather than increasing global contrast. When the edge detection with ‘prewitt’ operator is applied to the image obtained after adaptive histogram equalization and median filtering, the increase in edge detection performance can be seen from Fig. 5a when compared to Fig. 2b.

After adaptive histogram equalization, the same procedure is repeated by using the discrete wavelet transform instead of adaptive histogram equalization. The two level wavelet decompositions are used with ‘sym5’ mother wavelet function. As described in section 1, the information in gall-bladder ultrasonic image is contained in low frequency components.



a)



b)

Fig. 3. a) Histogram values of original image, b) Histogram values after adaptive histogram equalization

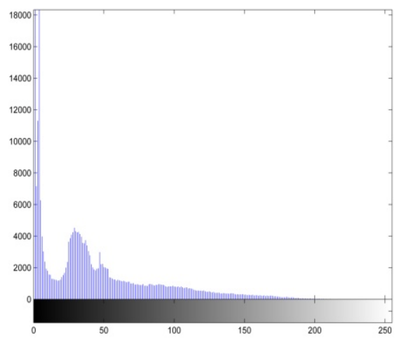
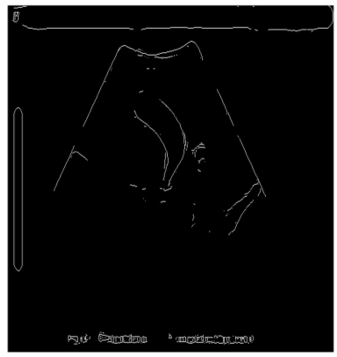
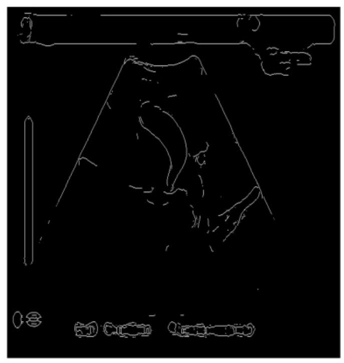


Fig. 4. Histogram values of an image after two level wavelet decompositions



a)



b)

Fig. 5. a) Edge detection applied to the image after adaptive histogram equalization and median filtering, b) edge detection applied to the image after two level wavelet decomposition and median filtering

Therefore, the upsampled approximate coefficients of two level wavelet decompositions are used for further processing. The information in detail coefficients are neglected because they correspond to high frequency components.

The Fig. 4 shows the histogram values of two level wavelet decompositions. In Fig. 5b, the edge detection result after the discrete wavelet transform and median filtering is shown. As can be seen from Fig. 5 the both two methods increase the performance of edge detection algorithm. The discrete wavelet transform shows better performance when compared to adaptive histogram equalization.

In order to compare the performances of adaptive histogram equalization and the discrete wavelet transform methods, the change in the entropy values and the time elapsed in CPU for these two methods are calculated. Two more gall bladder ultrasonic test images are chosen in order to compare the performances of both methods for different image inputs. The Table 1 and Table 2 show the change in entropy values and the time elapsed in CPU for both two methods, respectively. The used entropy for the images is defined as

$$E = -\sum p.log_2(p). \quad (3)$$

Table 1. The change in image entropy values

	Org. Image	Test Im. 1	Test Im. 2
Org. Image	4.6429	4.8528	4.5980
Ad. Hist. Eq.	5.2434	5.4637	5.2081
DWT	5.6686	5.5744	5.4743

Table 2. The elapsed CPU time for both two methods

	Org. Image	Test Im. 1	Test Im. 2
Ad. Hist. Eq.	0.2344s	0.1719s	0.2031s
DWT	0.2813s	0.2969s	0.3125s

In paired t-test the rejection of the null hypothesis is tested between two different inputs. This test is applied in order to understand whether the differences between the means of two input variables are meaningful or not. The null hypothesis is tried to be rejected. The paired t-test is applied to the original image/test image 1, original image/test image 2 and test image 1/test image 2, and because the image is two dimensional, the rejection of the null hypothesis is tested between each columns of two images. The Table 3 shows the number of columns at which the null hypothesis is rejected.

Table 3. The number of columns at which the null hypothesis is rejected

	Org.Im./Test Im.1	Org.Im./Test Im.1	Test Im.1/Test Im.2
Org. Image	371	469	460
Ad. Hist. Eq.	466	423	511
DWT	559	535	571

4. Conclusion

The both adaptive histogram equalization and the discrete wavelet transform methods increase the edge detection performance for the gall bladder ultrasonic images. The entropy value of the original image and the number of columns at which the null hypothesis is rejected, are increased in both two methods. However, the discrete wavelet transform shows better performance. The entropy values are greater, and the differences between the means at each column of two test images become more meaningful when compared to adaptive histogram equalization. The adaptive histogram equalization shows better performance in CPU time, but this is negligible because there is no significant difference in the CPU time for both two methods.

5. References

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