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A proposed method for contrast enhancement of breast ultrasound images using FDHE

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***Abstract*— Speckle noise generally affects the quality of ultrasound images and reduces the resolution and contrast of the images, Consequently, the accuracy of detection reduces. Image enhancement is one of the most important issues in low-level image processing. Its purpose is to improve the quality of low contrast images and to correct deficiencies of the contrast.**

In this paper, fuzzy dynamic histogram equalization (FDHE) method is proposed for image contrast enhancement. The method works based on fuzzy logic to enhance the fine details of ultrasound image features, while avoiding noise amplification and over-enhancement. The FDHE consists of four steps. First, gray-level normalization is, because the distribution of gray levels of breast ultrasound images may vary greatly. In the second step, fuzzy histogram is computed based on fuzzy set theory to handle the inexactness of gray level values in a better way compared to classical crisp histograms. In the third step, the fuzzy histogram is divided into multiple sub-histograms based on local maximum and then equalizes based on Dynamic Histogram Equalization (DHE) method to preserve image brightness. Finally, the defuzzification operation transforms the enhanced ultrasound images to the spatial domain. Experimental result on breast ultrasound images show that the proposed method can effectively and significantly to keep fine details of lesions, without over- or under-enhancement.

Keywords-ultrasoud image; fuzzy set; image enhancement; FDHE; DHE

I. INTRODUCTION *(HEADING 1)*

Breast cancer is a serious disease that can prove fatal if not caught early. Thus, early detection is essential. Breast ultrasound imaging is an important alternative to mammography. Due to their fuzzy and noisy nature and the low contrast of ultrasound images, however, it is difficult to provide accurate and effective diagnose using ultrasound images. Image enhancement uses to improve the quality of the image and to correct deficiencies of the contrast.

Image enhancement is another important step in image preprocessing. Image enhancement improves the quality of images for human viewing. Increasing contrast and revealing details are important tasks of enhancement operations. The aim of image enhancement is to improve the perception of information in images for viewers, or to provide better input for other automated image processing techniques[1].

Image enhancement techniques can be categorized by two approaches, global and local histogram equalization [2-4]. Generally, global methods are implemented by using histogram of the whole image modification. One of the most useful global methods is histogram equalization (HE). This technique is commonly employed for image enhancement because of its simple and effective in enhancing an entire low contrast image containing only single object or no apparent contrast change between the object and the background, but it can neither increase nor decrease the local contrast at some local positions in the image. It is also not effective in texture enhancement. Global histogram equalization (GHE) [2] is another of global method that it uses the histogram information of the entire input image for its transformation function. Though this global approach is suitable for overall enhancement, it fails to preserve the local brightness features of the input image. When there exists some gray levels in the image with very high frequencies, they are usually dominating the other gray levels with lower frequencies.

The authors of [5] proposed a variation of histogram equalization known as adaptive histogram equalization (AHE), or local area histogram equalization (LHE) uses uses a small window that slides through every pixel of the image sequentially and only the block of pixels that fall in this window are taken into account for HE and then the gray level mapping for enhancement is done only for the center pixel of that window. Dale-Jones [6] modified LHE by varying the window size over different regions of the image in order to enhance each region equally. Although LHE makes more detail in the image visible, it is still unsuitable for medical ultrasound image processing due to the computational complexity and background distortion.

Several brightness preserving histogram modification approaches, such as bi-histogram equalization (BBHE [7], MMBEBHE [8]), multi-histogram equalization (DHE [9], BPDHE [10]) and histogram specification (BPHEME [11]) have been proposed in literature.

Dynamic Histogram Equalization (DHE) [9] partitions the image histogram based on local minima and assigns specific gray level ranges for each partition before equalizing them separately. However, this method does not consider the preserving of brightness. For this goal, Brightness Preserving

Dynamic Histogram Equalization (BPDHE) [10] technique, use the concept of smoothing a global image histogram using Gaussian kernel followed by its segmentation of valley regions for their dynamic equalization. Finally the output intensity is normalized to make the mean intensity of the resulting image equal to the input one. BPDHE shows the best result compared with all the above mentioned algorithms. However, it produces false contouring in the connected regions and ignores details. The main reason for this problem is the use of crisp histograms of images to enhance contrast.

The crisp statistics of digital images suffers from the inherent limitation that it does not take into account the inexactness of gray values. Additionally, crisp histograms need smoothing to achieve useful partitioning for equalization. Sheet et al. proposed a modification to BPDHE [10] technique with the use of fuzzy statistics of digital images (fuzzy histogram) [12] which is an enhanced version of BPDHE. The BPDFHE technique manipulates the image histogram in such a way that no remapping of the histogram peaks takes place, while only redistribution of the gray-level values in the valley portions between two consecutive peaks takes place. The results using BPDFHE method show well-enhanced contrast and little artifacts.

In this paper a Fuzzy Dynamic Histogram Equalization (FDHE) method for breast ultrasound images are presented to overcome the unwanted over enhancement, noise amplifying, low contrast and some degree of fuzziness, such as indistinct cyst borders, ill-defined mass shapes, and different tumor densities, which make it hard to read masses in an image. The proposed method not only preserves the image brightness but also improves the local contrast of the original image.

The rest of this paper is organized as follows. The proposed algorithm for fuzzification and contrast enhancement are presented in Sections 2 and 3. Simulation of the test images and the qualitative and quantitative comparison of the results are discussed in Sections 4 and the final section concludes this paper.

II. PROPOSED ALGORITHM

The proposed method consists of four steps:

1) Gray-level Normalization.
2) Image Fuzzification and Fuzzy Histogram Computation.
3) Histogram Partitioning and equalization.
4) Image Defuzzification.

The following subsections include the details of the parts involved.

A. Gray-level Normalization

The distribution of gray levels of breast ultrasound images may vary greatly; however, the ranges of the intensities are thin. Normalization is a necessary part that in this section normalize the ultrasound image by mapping the intensity levels into the range [g_{min},g_{max}]:

$$g(i,j) = g_{min} + \frac{(g_{max}-g_{min})\times(g_o(i,j)-g_{omin})}{(g_{omax}-g_{omin})} \quad (1)$$

Where g_{omin} and g_{omax} are the minimum and maximum intensity levels of the original image, g_{min} and g_{max} are the minimum and maximum intensity levels of the normalized image(speckle reduction), and g_o(i,j) and g(i,j) are the gray levels at the coordinates (i,j) before and after normalization, respectively.

B. Image Fuzzification and Fuzzy Histogram Computation

Image Fuzzification: In order to apply fuzzy logic to deal with the fuzziness of a breast ultrasound image, we use a suitable membership function. It maps the gray level intensities to fuzzy set whose value ranges between 0 and 1. A fuzzy set G for breast ultrasound image is defined as follows:

$$G = \{(x, \mu G(x))|x\epsilon U\} \quad (2)$$

Where μG(x) is the membership function of element x in set deterministic A. The fuzzy membership values μ are permitted in the interval 0≤μ≤ 1. Fuzzy membership values are assigned from the following fuzzy function [13,14].

$$\mu G(x) = max(0,1 - \frac{|x-n|}{\alpha}) \quad (3)$$

Where n and α are the positive real values generated from the input histogram image. In fuzzy set, the fuzzy matrix G corresponding to g image can be written as follows:

$$G = \begin{bmatrix} \frac{\mu_{11}}{g_{11}} & \frac{\mu_{12}}{g_{12}} & ,\dots, & \frac{\mu_{1N}}{g_{1N}} \\ \frac{\mu_{21}}{g_{21}} & \frac{\mu_{22}}{g_{22}} & ,\dots, & \frac{\mu_{2N}}{g_{2N}} \\ \dots & \dots & & \dots \\ \frac{\mu_{M1}}{g_{M1}} & \frac{\mu_{M2}}{g_{M2}} & ,\dots, & \frac{\mu_{MN}}{g_{MN}} \end{bmatrix}_{M\times N} \quad (4)$$

$$and \quad 0 \le \mu_{ij} \le 1 \;\; that \; i = 1,\dots,M \; and \; j = 1,\dots,N$$

Where g is an image of size M × N pixels that indicate intensity of gray levels in the range [0, L-1] and here μ_{ij}= 1 indicates that the pixel is bright and μ_{ij} = 0 indicates that the pixel is dark. Each average value refers to the grade of maximum gray level of the pixel. A set consisting of all μ_{ij} is called the fuzzy property of the image.

Fuzzy Histogram Computation: Here the fuzzy histogram are used to make dark pixels darker and bright pixels brighter[4]. A fuzzy histogram is a sequence of real numbers $h(i)$, $i\epsilon\{0,1,\dots,L-1\}$ where $h(i)$ is the frequency of occurrence of gray levels that are around i. By considering the gray value g(x,y) as a fuzzy number $\mu_{G(x,y)}$, the fuzzy histogram is computed as:

$$G \leftarrow h(i) + \sum_x \sum_y \mu_{G(x,y)} \quad (5)$$

Where $\mu_{G(x,y)}$ is the fuzzy membership function. Fuzzy statistics is able to handle the inexactness of gray values in a much better way compared to classical crisp histograms thus producing a smooth histogram. Thus the use of fuzzy histogram is suitable for contrast enhancement of breast ultrasound images.

C. Histogram Partitioning and equalization

In this step is divided the fuzzy histogram of image into number of sub-histograms based on local maximums. Thus, each valley placed between two consecutive local maximum of a partition. The local maximum in the Fuzzy Histogram are calculated using the first and second derivative of the Fuzzy histogram. Since the histogram is a discrete data sequence, we used the proposed method [15].

First, the signs of the first derivative of the fuzzy histogram are calculated. Since there are still fluctuations in the calculated signs, a process of removing stray signs is applied. In this process, by using inspecting three consecutive signs, we change +-+ to +++ and -+- to ---. Then, the local maximums are detected as the points where four successive negative signs are followed by eight successive positive sign [15].

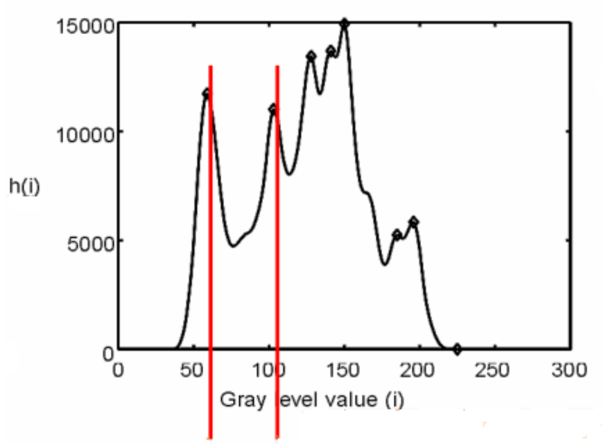

FIG1. FUZZY HISTOGRAM DIAGRAM WITH DETECT LOCAL MAXIMUM POINTS.

The local maximum points in the fuzzy histogram can now be used to combination of partitions. Let m_0, m_1,…,m_n are (n+1) intensity gray levels correspond to the local maximums detected in determination of local maximum step. If the original fuzzy histogram to have a spread in the range of [I_{min}, I_{max}], then, the first sub-histogram is in the range of [I_{min}, m_0], the second sub-histogram in the range of [m_0+1, m_1], the third one[m_1+1, m2], and the last sub-histogram [m_n+1, I_{max}]. Then the (n+1) sub-histograms obtained after partitioning are {[I_{min}, m_0], [m_0+1, m_1],..., [m_n+1, I_{max}]}.

The sub-histograms obtained are separately equalized by using DHE [16] technique. The equalization method uses a spanning function based on the total number of pixels contained in the sub-histogram. This function is described using the following:

$$span_i = high_i - low_i \qquad (6)$$

$$factor_i = span_i \times log_{10}\mathrm{M} \qquad (7)$$

$$range_i = (L-1) \times factor_i / \sum_{k=1}^{n+1} factor_k \qquad (8)$$

Where $high_i$ is highest intensity gray values contained in the ith input sub-histogram, and low_i is lowest intensity gray values contained in the sub-histogram i and M is the total pixels available in this section. The dynamic range of the input image sub-histogram is specified by $span_i$, while the dynamic range used in the output image sub-histogram is $range_i$ [16].

The dynamic range for the ith output sub-histograms can be obtained from $range_i$ as:

$$start_i = \sum_{k=1}^{i-1} range_k + 1 \qquad (9)$$

$$stop_i = \sum_{k=1}^{i} range_k \qquad (10)$$

Where set the first sub-histogram of the output image is in the range of [0, $range_i$] (for i>1).

For each sub-histogram i in range of [$start_i$,end_i] equalization calculates from the following equation:

$$y(j) = start_i + range_i \sum_{k=start_i}^{j} \frac{h(k)}{M_i} \qquad (11)$$

Where h(k) is the histogram value with intensity gray level k on the fuzzy histogram, and M_i is the total pixels contained in the ith partition of the fuzzy histogram.The output image b={b(i,j)} is expressed as:

$$b(i,j) = y_{min} \cup y_0 \cup \dots \cup y_{max} \qquad (12)$$

D. Image Defuzzification

Image defuzzification is the inverse of fuzzification. Defuzzification process is performed with the fuzzy statistical value for achieving the enhanced specification image that the algorithm converts the fuzzy set to gray level intensities. In this section, the enhanced image B(i,j) obtain by the following inverse equation:

$$B(i,j) = T^{-1}(b(i,j)) = \cup_{i=1}^{M} \cup_{j=1}^{N} b(i,j) * (max-1) \quad (13)$$

Where B(i,j) is the gray level of the (i,j)th pixel in the enhanced image and T^{-1} is the inverse transformation of T. This brightness preserving procedure ensures that the mean intensity of the image obtained after process is the same as that of the input.

III. CONTRAST ENHANCEMENT OF BREAST ULTRASOUND IMAGES

After the defuzzification operations, the entire image becomes smoother and clearer, and the Image granular appearance reduced greatly. However, most of the pixels are in the intensity gray level range of [0, 0.5], thus the whole image looks dark and dim. To adjust the intensity gray level range to [0, 1] use the following brightness equation:

$$E(i,j) = \begin{cases} 1 - 4(B(i,j) - 0.5)^2 & 0 \le B(i,j) \le 0.5 \\ 1 & 0.5 < B(i,j) \le 1 \end{cases} \quad (14)$$

To further increase the contrast between lesion and background, the following intensification function employ to make the bright pixels brighter and dark pixels darker. Thus, the contrast between lesion and background is greatly enhanced.

$$E(i,j) = \begin{cases} 2(E(i,j))^2 & 0 \le E(i,j) \le 0.5 \\ 1 - 2(1 - E(i,j))^2 & 0.5 < E(i,j) \le 1 \end{cases} \quad (15)$$

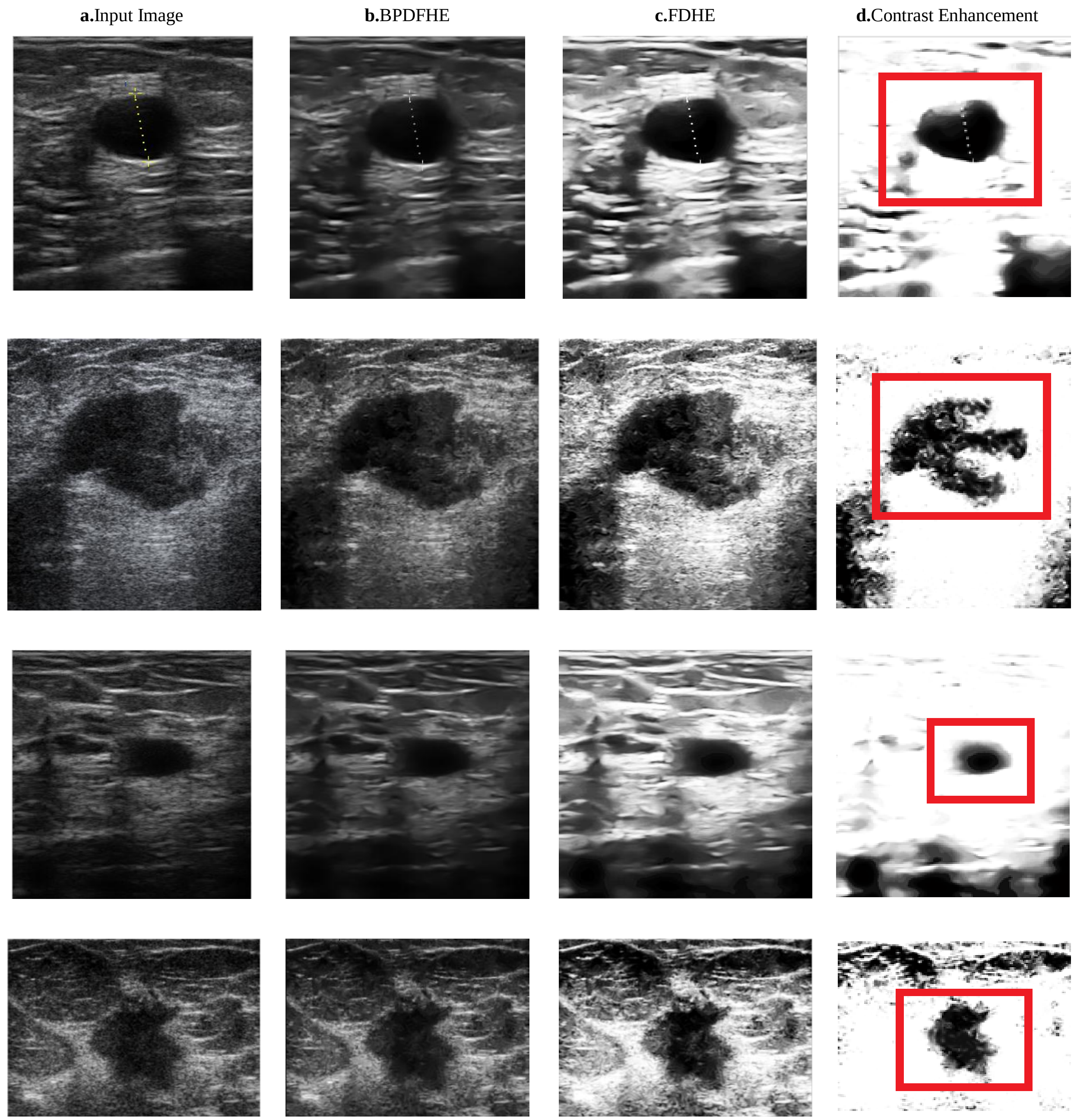

FIG 2. RESULT OF PROPOSED ALGORITHM. (**a**) INPUT IMAGE; (**b**) RESULT OF BPDFHE ALGORITHM; (**c**) RESULT OF FDHE ALGORITHM; (D) RESULT OF CONTRAST ENHANCEMENT TO DETECT THE LOCATION OF THE LESION.

IV. EXPERIMENTAL RESULTS

In this section, performance of the proposed method is evaluated by using clinical breast ultrasound images. To evaluate the performance of the proposed method, the results obtained by the proposed method compare with brightness preserving dynamic histogram equalization (BPDHE) [10] and Brightness preserving dynamic fuzzy histogram equalization (BPDFHE) [12] methods.

The major advantage of a proposed algorithm after contrast enhancement (Figure 2(d)) is that without much change to the original intensity distribution range, the local contrast between foreground and background is increased and the texture of the image becomes smoother and clearer. Comparing Figures 2(a) and 2(c), the proposed algorithm granular appearance inherent in ultrasound imaging is significantly reduced and the lesion boundary becomes clearer.

We use Luminance Distortion measure to compare the quality of the proposed method, BPDHE and BPDFHE. Luminance Distortion (Q), a measure of how close the mean luminances of two images are [17], is used here to evaluate the brightness preserving capability of a contrast enhancement the proposed method. It measures the change in the mean brightness of an image introduced by a contrast enhancement the proposed method.

Let G=$\{g_i | \ i = 1,2, \dots , N\}$ and E==$\{e_i | \ i = 1,2, \dots , N\}$ be the original and test image with the proposed method, then the luminance distortion is defined as:

$$Q = \frac{2\mu_g\mu_e}{\mu_g^2+\mu_e^2} \qquad (16)$$

Where μ_g and μ_e are the mean luminance of G and E respectively. Q takes value in the range [0,1] and Q=1when the mean luminance of the two images being compared is exactly the same.

Let $Q_{i,j}$ be the luminance distortion at location (i,j) in the image of size M×N, then the luminance distortion value for the entire image is given by

$$Q_{image} = \frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} Q_{i,j} \qquad (17)$$

Comparing the results of the luminance distortion values, by using the BPDHE, BPDFHE and the proposed method (FDHE) are given in Table 1. The performance of the proposed method has been compared with BPDHE, BPDFHE and the proposed method, both quantitatively and visually. Experimental result shows that the proposed method not only outperforms in contrast enhancement but also provides good visual representation in visual comparison. Hence, the proposed method (FDHE) gives better visual quality images.

TABLE 1. LUMINANCE DISTORTION

Image no	BPDHE	BPDFHE	FDHE
1	0.92	0.95	0.97
2	0.85	0.88	0.93
3	0.92	0.94	0.96
4	0.89	0.92	0.95

V. CONCLUSION

In this paper, Fuzzy dynamic histogram equalization (FDHE) is proposed for image contrast enhancement. FDHE uses fuzzy statistics of digital images to handle the inexactness of gray level values in a better way compared to classical crisp histograms, resulting in improved performance. The defuzzification process is finally applied to obtain the enhanced image.

The proposed method is very efficient and effective in contrast enhancement.The lesions' features in breast ultrasound images has been further enhanced, and all details are well preserved. Over-enhancement is avoided. Further contrast enhancement provides a better distinction between lesion and background for final segmentation.he results show that the proposed method can very efficiently preserve the mean image brightness and its performance is at least as good as BPDHE and BPDFHE methods. Therefore, the proposed method is useful for breast ultrasound image analysis and CAD systems.

The proposed method can deal with normal shadowing effect but sometimes fails the images having strong posterior shadows. Strong posterior shadows include the cases that the intensity values of lesion and shadow are quite close and they are tightly connected. Future research will focus on improving and extending existing methods that the proposed method could overcome on strong posterior shadows.

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