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FUZZY ENHANCEMENT TECHNIQUE USING S-MEMBERSHIP FUNCTION IN MEDICAL APPLICATIONS

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ABSTRACT

This paper presents a new image enhancement method through fuzzy logic based S-shaped membership function for contrast enhancement of X-ray images in medical diagnosis. The main idea is to enhance the tissues and also smooth the distorted regions adaptively from a proposed Fuzzification technique using S-shaped Membership function. Firstly, we apply the median filtering operation for reducing unwanted noise contents and sequentially the transformation operation. Experimental results show that the proposed method can enhance tissues brightness level for better image quality.

KEYWORDS: Image Enhancement, Fuzzy Logic, Membership function, X-Ray Images

INTRODUCTION

It is a well-known fact that an image gets degraded adversely either during its capturing by a camera or its transmission for further processing by means of a digital computer. For instance, the quality of an image captured by means of a digital camera may sometimes become low due to imperfections in the camera’s lens system, the relative motion between the target and the camera and other factors such as environmental changes. Therefore, it becomes inevitable that the quality of the image should be improved in order to select some interested image features. To accomplish this we need image enhancement technique that not only removes the unknown degradation in the image but also makes the image visually good. There are many image enhancement methods such as histogram equalization (or linearization), histogram matching, image smoothening and image sharpening.

The main aim to enhance X-ray image is that it is a major medical diagnostics due to its non-invasive and non radiation properties. The problem with this technology is low resolution and high noise, making the pictures difficult to read and diagnose. Acoustic View has a goal to make X-ray image as a leading diagnostic by enhancing its resolution and reducing the noise associated with the images. Clinicians are becoming increasingly reliant on X-ray techniques due to some advantages, such as convenient, non-invasive and real-time scanning. Recently, technical advances in diagnostic ultrasound can help clinicians diagnose unknown disease with the visualized information in patients' anatomy. Specifically, the technique has been valuable potential for the examinations in maternal fatal bonding or gynaecology problems.

However, the aforementioned traditional image enhancement methods yield undesired results especially when the images to be processed are rich in uncertainties and inaccuracies. Since, Fuzzy Logic representations based on fuzzy set theory try to capture the way humans represent and reason with real-world knowledge in the face of uncertainty they have attracted the attention of many researchers. A fuzzy set can be defined mathematically by assigning to each possible individual in the universe of discourse, a value representing its grade of membership in the fuzzy set. Though fuzzy enhancement technique yields good results in terms of enhancement, the dynamic range of the gray levels in the output image remains unaltered. Hence, this method is unfit for those images characterized by narrow gray levels and low contrast. Besides, the membership function of the gray scale in the fuzzy enhancement method is not in normalized form, i.e. [0 1].

When both domain and range filtering is combined then it is known as bilateral filtering. Since bilateral filters assume that an explicit notion of distance in the domain and in the range of the image function that can be applied to any function for which there two distances can be defined. The different results of the bilateral filters are compared with the Gaussian filter and the variations are compared in terms of mean square error (MSE), peak signal to noise ratio (PSNR) and contrast to noise ratio (CNR).

To compare the simulation results of various methods with those of traditional image enhancement methods like histogram equalization different fidelity criteria have been suggested. Basically there are two classes of fidelity criteria. The first is the mathematically defined objective fidelity criteria such as mean squared error (MSE), peak signal to noise ratio (PSNR), and signal to noise ratio (SNR) and so on. The subjective fidelity criterion falls into second category and includes human visual system (HVS) to incorporate image quality measures. However, because of their easiness and less computational efforts the mathematically defined metrics are still attractive and are independent of viewing conditions and individual observers. Hence, a great deal of effort has been made in recent years to develop various objective quality metrics like structural similarity method (SSIM).

The rest of this paper is organized as follows. The basic needs for Medical Image enhancement represented firstly. The fuzzy enhancement proposed by S. K. Pal et al is reviewed secondly. To overcome the disadvantage of the traditional enhancement, the proposed fuzzy enhancement method is proposed in this thirdly. Fourth that combines the merits of the fuzzy enhancement using the experimental results.

BRIEF TREATMENT OF CLASSICAL FUZZY ENHANCEMENT TECHNIQUE

The fuzzy enhancement is done in three main steps, namely:

- Fuzzification
- Iterative computations
- Defuzzification

Given an image f (i, j) with m×n pixels and let $f_{ij,}$ with i=1, 2...m, j=1, 2...n be the gray level of the pixel at $(i, j)^{th}$ location. In view of fuzzy theory this image can be thought of as an array of fuzzy singletons, each with a membership function that denotes the degree of having some appointed brightness. The fuzzy set F corresponding to this image can be represented in the following form**.**

$$F = (\mu_{ij} / f_{ij})_{m\times n} \tag{1}$$

where $0\leq \mu_{ij} \leq 1$, means the degree of having some appointed brightness by the $(i,j)^{th}$ pixel with the gray level f_{ij} .More specifically, $\mu_{ij} = 0$ indicates darkness and $\mu_{ij} =1$ points out brightness and all intermediate values refer to the grade of maximum gray level of the pixel. The set of all μ_{ij} is known as *fuzzy property plane* of the given image.

S-Shaped Membership Function (Smf)

The syntax of the S-shaped built-in membership function that operates on a vector ‘x’ is,

y = smf(x, [a b]); (2)

This s-shaped curve depends on two parameters ‘a’ and ‘b’ which locate the extremes of the sloped portion of the curve, as given by the expression (3). The graphical representation of the membership function is as shown in the Figure 1.

$$f(x;a,b) = \begin{cases} 0, & x \le a \\ 2(x-a / b-a)^2, & a \le x \le a+b / 2 \\ 1-2(x-b/ b-a)^2, & a+b / 2 \le x \le b \\ 1, & b \le x \end{cases} \quad (3)$$

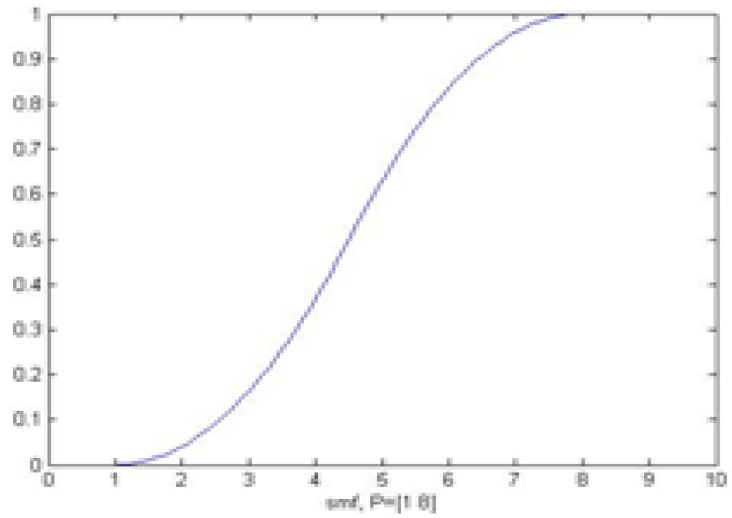

Figure 1: Graphical Representation of S-Membership Function

Once the membership function is chosen the fuzzy property plane of the given image can be obtained from the expression,

$$\mu_{ij} = G (f_{ij}) \quad (4)$$

Where ‘G’ is the transformation function, f_{ij} indicates the pixel at (i, j) th location in the given image and μ_{ij} gives the membership value of that pixel.

The key to the fuzzy enhancement is the availability of the contrast intensification operator (INT) that aids in eliminating the fuzziness of F. This INT operator operating on the fuzzy set F results in another fuzzy set that is characterized by the following membership function:

$$\mu^1_{ij}=T (\mu_{ij}) =\text{imadjust} (\mu_{ij}, \text{stretchlim} (\mu_{ij}), [\ ]); \quad (5)$$

Where “imadjust” is a built-in function that adjusts the contrast of the image. To do so, it makes use of the “stretchlim ( )” function that calculates the histogram of the image and assigns the adjustment limits automatically. ‘T’ denotes the transformation operation. Finally, the enhanced image can be obtained using the following inverse transformation

$$f^1_{ij}=G^{-1}(\mu^1_{ij}), \quad (6)$$

Where f^1_{ij} represents the gray level of the $(i,j)^{th}$ pixel in the enhanced image, and G^{-1} represents the inverse transformation of ‘G’. It can be observed that the gray-level maximum of f^1 (i, j) is same as that of the original image f (i, j).

PROPOSED FUZZY ENHANCEMENT ALGORITHM

In section 2 we pointed out that the gray level maximum of the fuzzy enhanced image and the original image are similar. Only the local gray levels are either increased or decreased in the final image. Hence, to expand the range of gray levels for those images characterized by low contrast and narrow range of gray levels, the generalized fuzzy enhancement technique, that employs the gray transformations on the fuzzy enhanced result, is proposed. Diagrammatically, it is as shown in the Figure1 below.

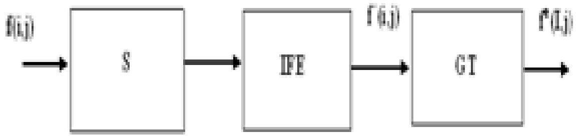

Figure 2: Block Diagram of the Generalized Image Enhancement System

Referring to the figure, 'S' denotes the smoothening operation that suppresses noise or any other fluctuations in the input image f (i, j). However smoothening of the image results in slight blurring of the edges. Median filtering is a nonlinear smoothing method that reduces the blurring of the image edges. After iterating fuzzy image enhancement (IFE) with equations (4), (5) and (6), the improved image can be obtained from the equation (7). Note that for a particular membership function the inverse transformation of equation (4) can be obtained by finding out the value of the vector 'x' from f(x) for a set of specified parameters.

The final processed result f^{e}_{ij} can be obtained using the equation (7).

$$f^{e}_{ij} = \{(f_{max} - f_{min}) / (f'_{max} - f'_{min})\}(f'_{ij} - f'_{min}) + f_{min} \quad (7)$$

Where f^{e}_{ij} represents gray level of the (i, j) th pixel in the final image, f_{max} and f_{min} are the maximum and minimum gray levels in the input image f (i, j) respectively and f'_{max}, f'_{min} are the maximum and minimum gray levels in the fuzzy enhanced image respectively.

Based on the above analysis the proposed fuzzy enhancement algorithm is outlined as follows.

Algorithm Proposed for Fuzzy Enhancement

- Input the original image f(i,j) and define the maximum (f_{max}) and minimum (f_{min}) gray levels of the original image.
- For each pixel at (i, j) th location replace its gray level by the median of the gray levels in its 3x3 neighbourhood.
- For the membership selected from the above mentioned, calculate the fuzzy property plane μ_{ij} using the respective definitions and equation (4).
- Using equation (5) transform the fuzzy property plane using the INT operator and let the result be represented by μ^{1}_{ij}.
- Solve the inverse transformation of G from equation (6). Let the output be f^{1} (i, j).
- Calculate the fuzzy enhanced image f^{e} (i, j) using the gray transformation in equation (7).

COMPUTER SIMULATION RESULTS

To illuminate the validity of the proposed fuzzy image enhancement algorithm, an application to the low-contrast and narrow gray levels image is presented in this section (refer Figure 3, Figure 4 and Figure 5). The original degraded images that have been shown in figure (a) represent the images of a chest, an X-ray and a mammogram. The enhanced images obtained by means of s-shaped membership function and histogram equalization are shown in the figures (b) and (c) respectively.

From the figures, it can be noticed that the image that has been enhanced using s-shaped membership function is rich in content when compared to that has been obtained using histogram equalization. And also the histogram equalization yields an image that has been over-enhanced and is not good for either visual perception or for further interpretation by means of a digital computer.

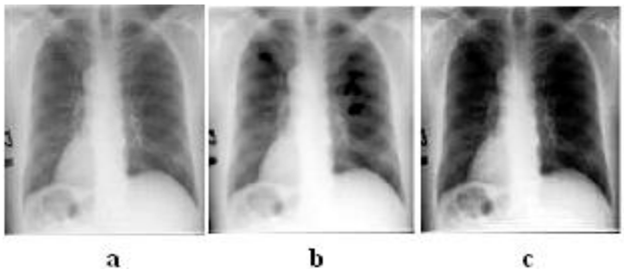

Figure 3: Enhancement Results of a Chest Image
(a) Original Image (b) Fuzzy Enhanced Image and (c) Histogram Equalized Image

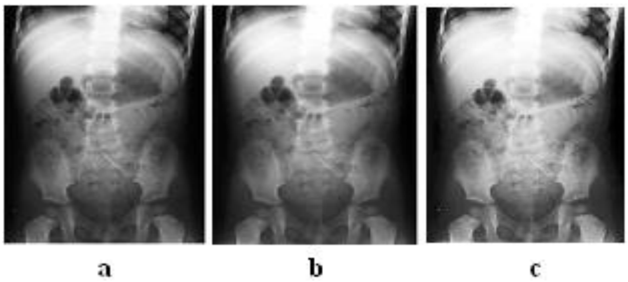

Figure 4: Enhancement Results of an X-Ray
(a) Original Image (b) Fuzzy Enhanced Image and (c) Histogram Equalized Image

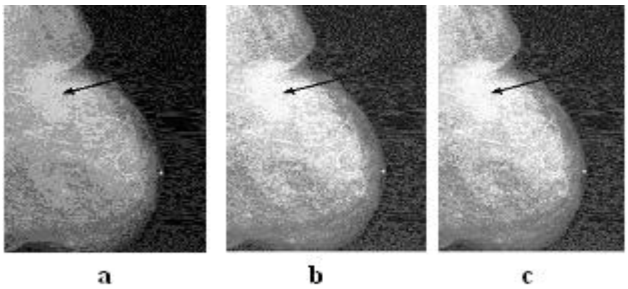

Figure 5: Enhancement Results of a Mammogram
(a) Original Image (b) Fuzzy Enhanced Image and (c) Histogram Equalized Image

Table 1: Performance Evaluation of Fuzzy and Histogram Equalized Enhanced Images Using Energy and Entropy

S.N0	Image	Characteristics	Original Image	Fuzzy Image	Histogram Image
1	Synus.bmp	Energy	8.9E+3	2.4E+4	0
		Entropy	7.183	0.0673	5.9638
2	Lung1.jpg	Energy	2.9E+4	2.8E+4	0
		Entropy	7.4386	0	5.9824
3	Scard.jpg	Energy	1.5E+4	1.6E+4	0
		Entropy	7.7646	0.1157	5.9815
4	Breast.jpg	Energy	2.0E+4	2.0E+4	0
		Entropy	6.8440	0.1165	5.4486

Table 2a, Table 2b: Comparison of Fuzzy Image and Histogram Equalized Image Using MSSIM, Correlation, PSNR

Table 2a

S.No	Fuzzy Image		
	MSSIM	CORR	PSNR
1	.8368	.9757	36.17
2	.9348	.9913	23.56
3	.9664	.9983	33.08
4	.8815	.9944	33.33

Table 2b

S.No	Histogram Image		
	MSSIM	CORR	PSNR
1	.85	.95	13.2
2	.79	.99	15.15
3	.89	.97	15.04
4	.5	.98	23.64

CONCLUSIONS

The classical fuzzy enhancement technique is more suitable for enhancing those images, in which there are many uncertain and inaccurate factors, than the traditional image enhancement methods such as histogram equalization, histogram matching, local enhancement and image sharpening. However, the resulting image has same range of gray levels as that of the original image. In addition, the membership function is also not in normalized form i.e. [0 1]. To deal with these types of problems the fuzzy enhancement algorithm using different membership functions has been proposed in this paper. From the computer simulation results, it is evident that the proposed algorithm shows better results in terms of image enhancement, especially for those images characterized by low contrast and narrow dynamic range of gray levels.

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