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FUZZY BASED CONTRAST STRETCHING FOR MEDICAL IMAGE ENHANCEMENT

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Abstract

Contrast Stretching is an important part in medical image processing applications. Contrast is the difference between two adjacent pixels. Fuzzy statistical values are analyzed and better results are produced in the spatial domain of the input image. The histogram mapping produces the resultant image with less impulsive noise and smooth nature. The probabilities of gray values are generated and the fuzzy set is determined from the position of the input image pixel. The result indicates the good performance of the proposed fuzzy based stretching. The inverse transform of the real values are mapped with the input image to generate the fuzzy statistics. This approach gives a flexible image enhancement for medical images in the presence of noises.

Keywords:

Contrast Stretching, Fuzzy Logic, Fuzzy statistics, Histogram Specification, Probability Density Function (PDF), Cumulative Density Function (CDF)

1. INTRODUCTION

The objective of image enhancement is to smooth an image with non impulsive noise. Linear filters are used for noise reduction, edge detection, segmentation, etc [12]. Contrast stretching can be viewed as replacing the grey-level intensity of every pixel in the image with a new value depending on the probability of the input image intensity values. Contrast enhancement is the process of linearly increasing or decreasing the intensity of the input image. Histogram processing is a non-linear contrast enhancement technique; the histogram of the original image is redistributed to produce a uniform population density of the image [2]. If different filters are used in the enhancement algorithm, the resultant image may not be smooth and the noises are also present. In an X-ray imaging system, photon noise occurs during the motion of electron. Impulsive noises in the X-ray and MRI (Magnetic Resonance Image) degenerate its performance and must be taken into account at the analysis stage. The stretching process reduces the salt and pepper noise and the object contour is extracted with smooth nature. The piece-wise approximation of contrast stretching is given below,

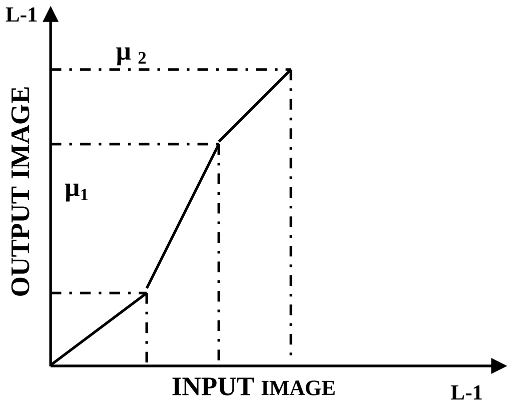

Fig.1. Piece-wise Contrast stretching

where μ_1 and μ_2 are the two control parameters of the fuzzy image transformation.

2. FUZZY STATISTICS ON DIGITAL IMAGES

Intensity variant and diffusion are the areas of the image enhancement and detection [12],[16]. This can be smooth and sharpen edges by applying multiple threshold value [8]. Median filtering has been used to remove impulsive noise and Gaussian noise with weighted value depend on the gray value difference from the central pixel [13],[14]. A gray scale transformation may be success for preserving edges in one image and fail in another one. Image enhancement is an important technique that can improve the quality of the input image by reducing noise and sharpening edges. There are many image enhancement methods, such as median filtering, image sharpening, inverse filtration and histogram equalization [9],[15]. Fuzzy sets are capable of representing for produce the statistical value based on the theory of Fuzzy sets [10],[17]. Fuzzy set A for digital images are defined in the ordered pairs

$$A \equiv \{(x, \mu A(x)) | x \in U\}, \tag{1}$$

where μA(x) is called the membership functions for the set of all values x in U [4],[6]. The membership values μ are permitted in the interval $0 \le \mu \le 1$, crisp set is consequently a special case of a Fuzzy set, with membership values restricted to $\mu \in \{0,1\}$. Fuzzy membership values are assigned from the following membership function [3],[4]

$$\mu A(x) = \frac{\max(0, 1 - |x - n|)}{\alpha}. \tag{2}$$

where, n and α are positive real numbers generated from the input image histogram.

3. PROPOSED METHOD FOR MEDICAL IMAGE ENHANCEMENT

In traditional rule based system, it may be described as below,

If (condition) then (Action)

The following steps are for the fuzzy enhancement system,

i. Fuzzification process
ii. Histogram computation
iii. Defuzzification

In fuzzy set, the image can be written in the following form [3],[6]

$$A = \frac{(\mu_{ij})}{f_{ij}} m * n \,, \tag{3}$$

where,

$$\frac{\mu_{ij}}{f_{ij}}, 0 \le \mu_{ij} \le 1 \,.$$

If $\mu_{ij} = 1$, then the pixel is bright and when $\mu_{ij} = 0$, it indicates black image. The reverse transform is given below,

$$F'_{ij} = I'(\mu_{ij}). \tag{4}$$

The output image has gray level value of the noise pixel and which require large number of if – then rules[11]. To overcome this problem, histogram specification process is applied in the fuzzy input image.

A fuzzy histogram is a sequence of positive real numbers $\{R_k\}$, $k \in \{0,1, \ldots L-1\}$ where R_k, is the frequency of occurrence of pixel values. The probability distribution $P_K = R_K \left| \sum_{i=0}^{L-1} R_k \right.$ is used for equalizing the gray values to attain a flat histogram. Let I(x,y) is the input gray image and the fuzzy histogram F(x,y) can be computed as

$$R_k = R_k + \sum_x \sum_y \mu_{I(x,y)k} \qquad k\varepsilon |a,b| \,, \tag{5}$$

where, $a = \min(k | \mu_{I(x,y)k} > 0)$ and

$b = \max(k | \mu_{I(x,y)k} > 0)$

Fuzzy histogram is a real number and is computed from the fuzzy membership of gray levels. The proposed fuzzy gray values are better compared to classical histogram.

4. FUZZY BASED HISTOGRAM SPECIFICATION

The histogram of a digital image with gray levels in the range [0,L-1] is a discrete function with $h[r_k] = n_k$, where r_k is the gray level value and n_k is the number of pixel with gray level k in the input image I(x,y)[5],[10]. Histogram h[k] is occurrence probability (frequency) of gray level k in an image

$$h(k) = \frac{n(k)}{n} \,. \tag{6}$$

where, n is the total number of pixels. Transform intensities so as to obtain a desired (specified) shape of histogram of output image is called histogram specification [2],[7]. $P_x(U)$ is the continuous Probability Density Function(PDF) function for the given image and $P_z(U)$ is the specified(derived) PDF for output image. The equalization of the given image I(x,y) is

$$Y = f(x) = \int_0^x px(u)du \,. \tag{7}$$

The histogram transformation of the specified image is given below,

$$Y' = g(x) = \int_0^z pz(u)du \tag{8}$$

The fuzzy specification of the input image and the derived value is given below,

$$Z = \max(\mu_{xi}, \mu_{yk}) \tag{9}$$

where, μ_{xi} is the input image and μ_{yk} is the output image. The Fuzzy values of μ_{xi} and μ_{yk} are compared and the maximum value is assigned for constructing the resultant image. The following Fig.2 shows the histogram specification process for the input image and the derived image.

The fuzzy statistics of digital images are represented in a matrix form $[h_{ij}]$ where h_{ij} is the probabilities of occurrence of gray level values. The fuzzy histogram mapping process is given below,

$$f_{i,j} = f_{i,j} + \max(\mu_{xi}, \mu_{yk}) \tag{10}$$
$$i\,\varepsilon |a1, b1|,\; k\,\varepsilon |a2, b2|$$

where, a1 and a2 are the minimum values of the fuzzy histogram. Similarly, b1 and b2 are the maximum values of the histogram value.

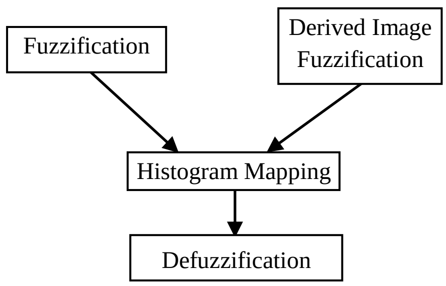

Fig.2. Block Diagram for Fuzzy Histogram Specification process

The Fuzzy statistical values are determined on the basis of the pixel intensities of the spatial domain. The image intensity is transformed with the specified Probability Density Function (PDF). The Cumulative Density Function (CDF) is used to accumulating pixel values in an ordered manner. The smooth image is produced in the output domain.

The Fuzzy statistical value (μ_{xi}) of the input image and the inverse transform (μ_{yk}) are given in the below hypothetical

Fuzzy histogram specification diagram. The specification values [max(μ_{xi}, μ_{yk})] are specified in the dark region, which is also shown in the Fig.3. The Fuzzy statistics values ($0 \leq \mu_{xi} \leq 1$) and ($0 \leq \mu_{yk} \leq 1$) are used for constructing the smooth output image. Defuzzification is the process of converting fuzzy statistical values into precise quantity. The decrypt process (Defuzzification) which produces the enhanced image in the output domain. Fuzzy Defuzzification process performed on the inverse transformation function for achieving the enhanced image.

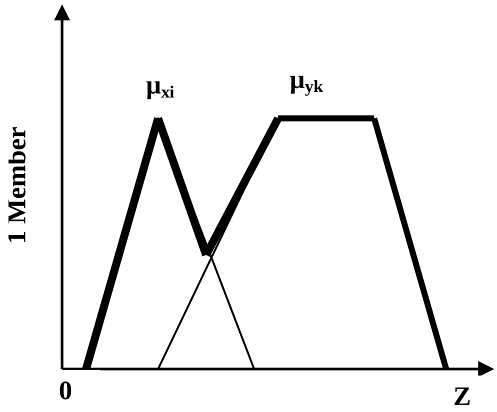

Fig.3. A Hypothetical Image Fuzzy Histogram Specification

In the above Fuzzy maximization process, the discrete fuzzy gray levels are cumulated and the result is better than the classical Histogram Equalization (HE) method.

5. EXPERIMENTAL RESULTS

In this section, we demonstrate the results of the proposed fuzzy based method through different brain MRI images (brain and brain abnormal meninges). The original image of brain is in Fig.4(a) and the Histogram Equalized method image is in Fig.4(b). Fig.4(c) gives the proposed Fuzzy stretching method. Here the noises are reduced and the edges are clearly identified. The histogram of the brain image is given in Fig.4(d). Similarly in Fig.5(a) the original brain image with abnormal meninges is given. The equalized method is given in Fig.5(b). Fig.5(c) the fuzzy based image with smooth boundary is given. Fig.5(d) shows the histogram of the brain image.

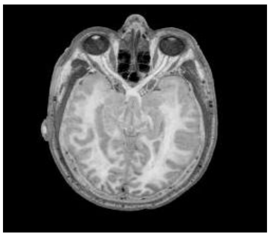

Fig.4(a) Brain Image

Fig.5(a) Abnormal meninges

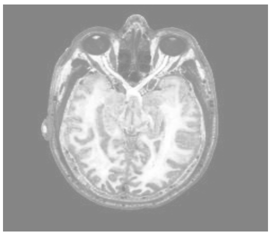

Fig.4(b) Equalized image

Fig.5(b) Equalized image

Fig.4(c) Proposed Fuzzy image

Fig.5(c) Proposed Fuzzy Image

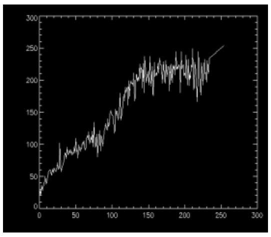

Fig.4(d) Histogram of the Proposed Image

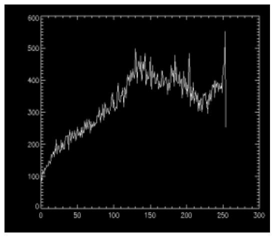

Fig.5(d) Histogram of the Proposed Image

6. EVALUATION CRITERIA

There are three evaluation measures used for comparing the fuzzy based filtering method with the other methods. The PSNR value [5][6] is evaluated from Eq. (11) and Eq. (12). The image metric is expressed in terms of visual decibels (dB)

$$MSE = \sum_{i=1}^{N}\sum_{j=1}^{M} I(i,j) - S(i,j), \tag{11}$$

$$PSNR = 10\log_{10}(255)^2/(MSE)^2(dB). \tag{12}$$

The second evaluation metrics is SSIM (Structural Similarity Metric)[1]. It consists of three different metrics. Let $x = \sum_{i=x}^{n} x_i$ and $y = \sum_{i=x}^{n} y_i$ be the original and the resultant image respectively. The SSIM is defined as,

$$Q = l(x,y)^{\alpha}.c(x,y)^{\beta}.s(x,y)^{\delta} \tag{13}$$

where, α, β and δ are the positive constants used to weight each function. The parameters l(x,y), c(x,y) and s(x,y) are used for finding the luminance, contrast and structural comparison respectively. The specific SSIM quality metric function is given below,

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c1)(2\sigma_{xy} + c2)}{\mu^2{}_x + \mu^2{}_y + c1)(\sigma^2{}_x + \sigma^2{}_y + c2)} \tag{14}$$

where, μ_x and μ_y are the mean values of the input and output images. σ_x and σ_y are the standard deviations. c1 and c2 are constants.

The third evaluation measure is Complex Wavelet Structural Similarity (CWSSIM) [1] and is evaluated from the following equation.

$$CWSSIM(c_x, c_y) = \frac{2\left|\sum_{i=1}^{N} c_{x,i} * c_{y,i}\right| + k}{\sum_{i=1}^{N} \left|c_{x,i}\right|^2 + \sum_{i=0}^{N} \left|c_{y,i}\right|^2 + k} \quad (15)$$

where, k is a small positive constant and c_x, c_y are complex wavelet co-efficients that correspond to image patches x and y. μ_x and μ_y are the mean values of the image. The value σ_x and σ_y are the standard deviations of the resultant image. The results of PSNR, SSIM and CWSSIM are tabulated in Table.1.

Table.1. Performance Comparison with PSNR, SSIM and CWSSIM

Image	Method	PSNR	SSIM	CWSSIM
Brain	Histogram Equalized	30.32260	0.457156	0.759017
	Proposed Fuzzy Logic	30.36840	0.937308	0.946463
Abnormal meninges	Histogram Equalized	28.5280	0.717215	0.911637
	Proposed Fuzzy Logic	28.3078	0.949613	0.952008

7. CONCLUSION

Our paper describes the concept of Fuzzy statistic for contrast stretching study of Magnetic Resonance Image (MRI) of brain images. Fuzzy logic provides a different approach on histogram specification for contrast enhancement and it gives effectiveness. The Fuzzy histogram generates gray values, which may be used for improve the quality of the input image. In the traditional enhancement methods which cannot deal with the narrow intensity values. This method solves the problem of narrow gray range images. The proposed algorithm is tested with several types of medical images and the result shows that the generated images are smooth and have less noise in the object boundary.

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