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Fuzzy Logic Approach to Contrast Enhancement

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Abstract: Image enhancement is a process of improving the quality of the image by improving its features. Contrast enhancement is one of the challenging and interesting areas of image processing. In visual perception of the real world, contrast is determined by the difference in the colour and brightness of the object and other objects within the same field of view. The commonly used techniques for contrast enhancement fall into two categories:(1) indirect methods and (2) direct methods. Indirect approaches mainly modify histogram by assigning new values to the original intensity levels. Direct contrast enhancement method establishes a criterion of contrast measurement and enhancesthe image by improving the contrast measure. In this paper, we propose a fuzzy contrast enhancement method employing both direct and indirect methods.

Keywords: Fuzzy logic, Defuzzification, Histogram, Contrast improvement index.

I. INTRODUCTION

Contrast enhancement is one of the most important issues of image processing, pattern recognition and computer vision. Two techniques used here are both indirect and direct method. Indirect approaches mainly modify histogram by assigning new values to the original intensity levels. Histogram specification and histogram equalization are two popular indirect contrast enhancement methods. However, histogram modification technique only stretches the global distribution of the intensity. The basic idea of direct contrast enhancement methods is to establish a criterion of contrast measurement and to enhance the image by improving the contrast measure. Contrast improvement index(CII) is ratio of the measure of contrast of the enhanced image to the original image. CII is a parameter used to measure the enhancement of an image.

The indirect method used here is histogram equalisation and direct method used is Fuzzy logic. Fuzzy logic has found many applications in image processing, pattern recognition, etc. Fuzzy set theory is a useful tool for handling the uncertainty in the images associated with vagueness and/or imprecision rather than 0 or 1(true or false). The main purpose of this project is to enhance the contrast in fuzzy domain effectively. The image in RGB format is initially converted into gray scale using suitable MATLAB commands. Then the histogram equalized image is mapped into fuzzy domain using S membership function. The parameters of the membership function are selected based on the characteristics of the image and they are optimized. Defuzzification is done to obtain the enhanced image by using a suitable formula. Then CII parameter of several imagesare calculated and the it is compared with that obtained in other techniques. We have conducted experiments on many images and compared the results. The experimental results demonstrate that the proposed algorithm is very effective in contrast enhancement thus introducing a technique for contrast enhancement to overcome the defaults of the presently available methods with a latest technology using fuzzy logic and histogram equalization.

II. TECHNIQUES USED

A. Histogram Equalization

Histogram equalization is the first technique employed in this paper. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. Here, the overall shape of the histogram changes.The method is useful in images with backgrounds and foregrounds that are both bright or both dark.

B.Fuzzy Logic and membership function

The first step done here istherepresentation of the image having size m x n as an array from gray levels ranging from Lmin to Lmax. Membership function characterizes the fuzziness in a fuzzy set. The membership function of a fuzzy set maps all the elements of the set into real numbers in [0, 1]. The fuzzification of the image is performed using the most commonly used s membership function definedin H D Cheng,HuijanXu [1]as,

$$\mu_X x_{(mn)} = S(x_{mn}, a, b, c) = \begin{cases} 0 & 0 \le x_{mn} \le a, \\ \dfrac{(x_{mn} - a)^2}{(b-a)(c-a)} & a \le x_{mn} \le b, \\ 1 - \dfrac{(x_{mn} - c)^2}{(c-b)(c-a)} & b \le x_{mn} \le c, \\ 1 & x_{mn} \ge c \end{cases} \quad (1)$$

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wherea, b, and c are the parameters which determine the shape of the S-function.bis any point in between a and c.In our proposed method,bis taken as the midpoint of interval [a,c].

III.PROPOSED METHOD

The main purpose of this paper is to enhance the contrast using both direct and indirect techniques. The first step is the histogram equalization of the image .Then the histogram equalized image is mapped from s domain to fuzzy domain using the membership function as in [1].The parameters a,b,c is initially found out through the method in [1.]It is then defuzzified using the equations in [1] to obtain the enhanced image and CII is calculated using the formula in [3].Then the parameters for which higher value of CII is obtained is found out to obtain the enhanced image. The comparison of CII obtained through adaptive fuzzy contrast enhancement, histogram equalisation only and contrast stretching alone is found out.

A. Histogram equalisation of the image and parameters
Assume the maximum and minimum gray levels as Lmax andL_{min} respectively. The procedure is as follows:
1.Perform histogram equalisation of the image.
2.Obtain histogram of the image.
3.Find the local maxima of histogram $His(g_1)$, $His(g_2)$,…..$His(g_k)$ and then the average local maxima.
4.All the local maxima greater than the average height are considered and others are ignored.
5.Select the first peak and last peak and determine the gray levels B1 and B2 respectively.
6.Select$f_1$in the range ($0<f_1<1$) and let $f_2$be a constant in the range ($f_2<1$).
7. Determine the parameters a and c:
(a) $a = (1-f_2)(g_1-L_{min})+ L_{min}$
if (a<B1)
a=B1
(b) $c= f_2(L_{max} -g_k) + g_k$
if (c<B2)
c = B2
In our experiments, f1 and f2 are set to 0.01 and 0.5 respectively. The gray levels less than the first peak of the histogram may correspond to the background while the gray levels greater than the last peak may relate to noise. Take b as (a+c)/2 such that b϶[a+1, c-1].

B. Fuzzification and defuzzification
After a,b,c parameters are determined, the S function is decided and this is used to map the image from space domain to fuzzy domain.
1.Constructthe membership function μ_x which measures the the fuzziness of an image X.
$\mu_x(x_{mn}) = S(x_{mn}, a, b, c)$, m = 0,1,...,M-1,n=0,1,…N-1
2. Defuzzification: It transform the obtained membership value (μ_x) to the gray level using the formula in [1]

$$x_{mn} = \begin{cases} L_{min} & ,\mu_x(x_{mn})=0 \\ L_{min} + \frac{(L_{max} - L_{min})}{c-a} (\mu_x(x_{mn})(b-a)(c-a))^{1/2} & , 0<\mu_x(X_{MN}) \leq \frac{B - A}{c-a} \\ L_{min} + \frac{(L_{max} - L_{min})}{c-a} (c-a-(1-\mu_x(x_{mn})(c-b)(c-a))^{1/2}) & , \frac{b - a}{c-a}<\mu_x(x_{mn}) \\ L_{max} & , \mu_x(x_{mn})=1 \end{cases} \quad (2)$$

C. Calculation of CII
Contrast of the enhanced and original image is calculated using the eq (3) as in [3].
The gray level of background image and foreground image is found out by setting a threshold. In the proposed method,the threshold is set as 125 and then the CII is calculated using eq (4) as in [3].

ci=(ri-bi) / (ri+bi)(3)
bi=mean gray level of background image
ri=mean gray level of foreground image
Contrast Improvement Index (CII) is calculated using eq
CII =abs(cf)/abs(co) (4)
cf =Contrast of enhanced image
co=Contrast of original image

Image is said to be enhanced if the value of CII is greater than 1.The value of a,b,c for which higher value of CII is found out.

IV.RESULTS

We have applied the proposed algorithm to a variety of images. Fig 1- shows the input images and their enhanced images.As mentioned before, histogram equalization, contrast stretching are the methods commonly used for contrast enhancement.

Fig 1 Lena 512x512

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Fig 2 Enhanced image

Fig 3 Barbara 512x512

Fig 4 Enhanced image

Fig 5 Peppers 512x512

Fig 6 Enhanced Image

Fig 7 House 256x256

Fig 8 Enhanced image

Fig 9 Camera man 204x204

Fig 11 Enhanced image

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Inorder to demonstrate the performance of the proposed method,we compared the experimental results of our proposed approach with those of Histogram equalization ,contrast stretching and adaptive fuzzy contrast enhancement. The optimized parameters a ,c and the value of CII obtained through different methods is tabulated as shown in Table 1

Table 1 Performance comparison

IMAGE	a, c parameters	CII		
		PROPOSED METHOD	HISTOGRAM EQUALISATION	CONTRAST STRETCHING
BARBARA	a=30,c=181	6.695	5.0307	1.3361
LENA	a=26,c=191	3.1708	2.4203	1.3361
PEPPERS	a=38.5,c=232.5	2.0345	1.5224	1.6158
CAMERA MAN	a=20,c=242.5	1.08	0.8182	0.5683
HOUSE	a=97,c=240.5	2.007	1.5540	1.9742

The value of CII when adaptive fuzzy contrast enhancement was applied to the Lena image was found to be only 2.77 which is far less than our proposed method.. The histogram of the resultant images is found to be more expanded in the resultant image of the proposed method which is an indication of contrast enhancement.It is clearly understood from our experimental results that CII of our proposed method is greater than the other techniques.

V. CONCLUSION

Different contrast enhancement techniques possess different disadvantages while enhancing contrast .This project tries to overcome that and propose a technique suitable for any kind of images by the implementation of dfuzzification techniques. and optimisation of parameters
(1) The contrast enhancement is more effective with a better adaptability.
(2) The over enhancement is significantly decreased or eliminated. The superior performance of the proposed approach is due to the following reasons:
(a) The proposed approach takes care of the fuzziness in the images by using fuzzy set theory and fuzzy entropy principle.
(b) The necessary parameters are determined automatically based on the nature of the images.
(c) The proposed approach uses global and local information to decide enhancement/de enhancement, therefore, it can prevent over-enhancement effectively.

The proposed project of fuzzifying and defuzzifying a histogram equalized image improved its CII parameter, making this method much more better and efficient than existing methods like histogram equalization and contrast stretching. It is highly relevant in the areas of medical imaging, satellite images etc to extract vital information.

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