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A Highly Efficient Color Image Contrast Enhancement using Fuzzy Based Contrast Intensification Operator

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Abstract: **In this recent period, the image processing plays a key function in different fields of engineering and Research. Perhaps to increase the effectiveness of this field, quality of an image should be enhanced to support the human sensitivity or machine visualization. The contrast of an image is a subjective assess of difference of gray levels presented in the image. There are a number of straight forward methods available for image contrast enhancement, like Gamma Correction, Power law transformation, histogram equalization etc. they all are based on the crisp logic. In this paper a novel approach for color image contrast enhancement is proposed using the fuzzy logic based contrast intensification operator. The proposed method deals with the fuzzy logic based method because, fuzzy logic is a strong tool to handle vagueness, and since images are vague in terms of pixel values fuzzy logic is most appropriate logic for its analysis. The proposed method is implemented for color images using RGB color model. The input color image will be first divided into red, green and blue single channels then by applying the fuzzy logic based contrast intensification operator which is single channel technique on each channels of color image will lead to contrast enhancement of all the three components simultaneously. After enhancement of red, green and blue channels simultaneously combining all the three components leads to the contrast enhancement of color images using fuzzy logic based contrast intensification operator.**

After implementation of the proposed algorithm in MATLAB a comparative analysis has been also performed on the basis contrast per pixel parameter. The results obtained clearly indicate that the proposed technique for color image contrast enhancement is efficient as compare to straight techniques such as histogram equalization and adaptive histogram equalization.

Keywords: **Image contrast enhancement, soft computing, fuzzy logic, image contrast uncertainty, histogram equalization.**

1. INTRODUCTION

Image enhancement processes consists of a collection of techniques that seeks to improve the visual appearance of an image, or to convert the image into a form better suited for analysis for a human or a machine perception. Most of the time it is observed that images acquired suffers from the poor contrast problem; in that case it is not possible to extract required information from the images. Therefore image contrast enhancement is the crucial field in the image processing. In the past mostly histogram equalization (HE) and adaptive histogram equalization (AHE) has been used to stretch the contrast level of the poor contrast image. After a large experimental work done in this paper it is observe that HE and AHE techniques sometimes provide poor contrast enhancement or over contrast enhancement. In addition to this it is also observed that both the techniques generate rectangular artefacts in the output.

The proposed research work trying to address this problem by employing the advantage of fuzzy logic, so that an efficient contrast enhancement can be achieved. The basic idea is to utilize vague and imperfection condition handling capability of fuzzy logic based soft computing.

Because Fuzzy logic has a good capability of interpretability and can also integrate expert's knowledge. In proposed research work, the objective is to develop single channel image enhancement technique using fuzzy logic based soft computing.

2. IMAGE ENHANCEMENT

Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or a machine. The principle objective of image enhancement techniques is to process an image so that the result is more suitable than the original image for a specific application. It is often used to increase the contrast in images that are substantially dark or light as well as noise removal. Hence image enhancement entails operations that improve the appearance to a human viewer, or operations to convert an image to a format better suited to machine processing.

Image enhancement refers to those image processing operations that improve the quality of input image in order to overcome the weakness of the human visual system [6], [7].

There is no general theory of image enhancement. When an image is processed for visual interpretation, the viewer is the ultimate judge of how well a particular method works.

Figure (1) Block diagram of Image Enhancement

3. IMAGE ENHANCEMENT TECHNIQUES

Image enhancement techniques can be divided into three broad categories:

i) Spatial domain methods, which operate directly on pixels.

ii) Frequency domain methods, which operate on the Fourier transform of an image.

iii) Fuzzy domain methods, which involves the use of knowledge-base systems that are capable of mimicking the behavior of a human expert.

Unfortunately, there is no general theory for determining what good 'image enhancement is when it comes to human perception. If it looks good, it is good! However, when image enhancement techniques are used as pre-processing tools for other image processing techniques, then quantitative measures can determine which techniques is most appropriate [1], [8].

4. FUZZY IMAGE PROCESSING

Fuzzy image processing is not a unique theory. It is a collection of different fuzzy approaches to image processing. It is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved [3], [4].

The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use [12], [13].

The last statement is perhaps the most important one and deserves more discussion. Natural language, which is used by ordinary people on a daily basis, has been shaped by thousands of years of human history to be convenient and efficient. Sentences written in ordinary language represent a triumph of efficient communication [15].

Fuzzy image processing has three main stages: image Fuzzification, modification of membership values, and, if necessary, image Defuzzification. Figure (2) shows the block diagram representation of Fuzzy Image processing.

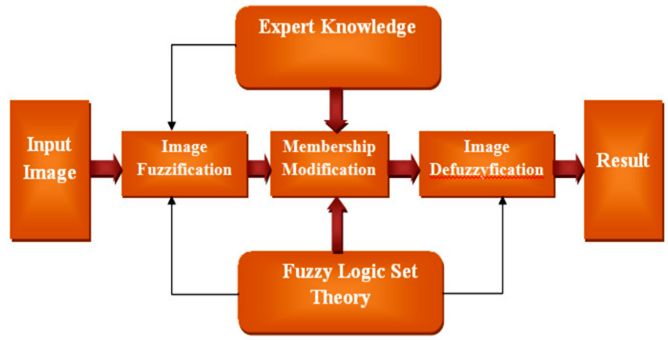

Figure (2) Fuzzy Image processing.

The Fuzzification and Defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (Fuzzification) and decoding of the results (Defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values). After the image data are transformed from gray-level plane to the membership plane (Fuzzification), appropriate fuzzy techniques modify the membership values [16], [17]. This can be a fuzzy clustering, a fuzzy rule based approach, and a fuzzy integration approach and so on.

5. FUZZY LOGIC BASED CONTRAST INTENSIFICATION OPERATOR

A large part of mathematical models are based on a recent extension of the ordinary set theory, namely, the so-called Fuzzy Sets (FSs). FSs were introduced by Lotfi A Zadeh in 1965. Later on, fuzzy linguistic variables find very important place in the area of real life applications. The advantage is crisp variables can be made into fuzzy variables, meaning that problems that are dominated by uncertainty and impreciseness could also be completed using this FSs. Starting from 1985, this theory was further generalized into many-valued logic with the efforts of Lukaiwicz, Gottwald, Post, Godel and so on [8].

The operator contrast intensification, as its name implies, reduces the fuzziness of a fuzzy set A by increasing those of $\mu_A(x)$ which are above 0.5, and deceasing those which are below it. Its definitions on FSs, first and second type fuzzy sets are given in this section.

Definition 5.1 [6]

Let X be a non empty set. A fuzzy set A in X is characterized by its membership function $\mu_A : X \to [0, 1]$ and $\mu_A(x)$ is interpreted as the degree of membership of element x in fuzzy set A for each x ϵ X. That is, A = {(x, μ_A(x))|xϵX}.

Definition 5.2 [4]

Let X be a nonempty set. An fuzzy set (FS) in X is defined as an object of the form A = {⟨x, μ_A(x), Υ_A(x)⟩ : xϵX}, where the fuzzy sets $\mu_A : X \rightarrow [0, 1]$ and $\Upsilon_A : X \rightarrow [0, 1]$ denote the membership and non-membership functions of A respectively, and $0 \leq \mu_A(x) + \Upsilon_A(x) \leq 1$ for each $x \in X$.

Definition 5.3[8]

Let X be a nonempty set. A second type IFS A in X is defined as an object of the form A = {⟨x, μ_A(x), Υ_A(x)⟩ : xϵX}, Where the fuzzy sets $\mu_A : X \rightarrow [0, 1]$ and $\Upsilon_A : X \rightarrow [0, 1]$ denote the membership and non-membership functions of A respectively, and $0 \leq \mu_A(x)^2 + \Upsilon_A(x)^2 \leq 1$ for each $x \in X$.

Definition 5.4 [8]

The contrast intensification operator on a first type FS A of the Universe X, denoted by INTEN(A), is defined as $INTEN(A) = \{\langle x, \mu_{INTEN1}(x), \Upsilon_{INTEN1}(x)\rangle : x \epsilon X\}$, where $\mu_{INTEN1}(x) = 1 - (1 - \mu_A(x)^2)^2$

and $\gamma_{INTEN}(x) = [1 - (1 - \mu_A(x))^2]^2$.

6. PROPOSED METHODOLOGY

The proposed method uses the fuzzy contrast intensification operator to reduce the fuzziness of the image that results in an increase of image contrast. The algorithm is formulated as follows:

Step1. Read the Color Image to be enhanced and divide it into red, green and blue components.

Step2. Set the parameters F_e, F_d and calculate X_{max}.

$$F_e = 2, \quad F_d = \frac{X_{max} - X_{mid}}{0.5^{\frac{-1}{F_e}} - 1}$$

Where F_e, F_d are constants for image Fuzzification, and
X_{max} = Maximum gray value of input image.
X_{mid} = Mid gray value of input image.

Step3. Define the membership function for image Fuzzification.

$$\mu_{mn} = G(X_{mn}) = \left[1 + \frac{X_{max} - X_{mn}}{F_d}\right]^{-F_e}$$

Where μ_{mn} is membership function.
Step4. Modify the membership values of all the three red, green and blue components using contrast intensification operator on fuzzy sets [9].

$$\mu'_{mn} = \begin{cases} 2[\mu_{mn}]^2, & 0 \leq \mu_{mn} \leq 0.5 \\ 1 - 2[1 - \mu_{mn}]^2, & 0.5 \leq \mu_{mn} \leq 1 \end{cases}$$

Step5. Generate new gray levels by Defuzzification for all the three components for generation of Contrast intensified output red, green and blue component images.

$$g'_{mn} = G^{-1}(\mu'_{mn}) = X_{max} - F_d\left(\left(\mu'_{mn}\right)^{\frac{-1}{F_e}}\right) + F_d$$

Step6. Combine all three red, green and blue component enhanced images to generate output color image.

7. RESULT AND DISCUSSION

Fuzzy logic based Contrast intensification for color images has been successfully implemented in MATLAB. In this paper, for the proportional comparative analysis of the developed technique and available histogram equalization (HE) and adaptive histogram equalization (AHE) techniques contrast per pixel (CPP) is used.

Higher value of CPP corresponds to good contrast enhancement. A comparison for image contrast enhancement between Conventional HE, AHE and the proposed technique three standard images have been used. For the proper evaluation of the techniques the input image contrast has been reduced to 60 percent using MATLAB. The input image sand corresponding resultant images are shown from Figure (3) to Figure (5). For example, the first input image shown in Figure (3) is suffering from low light problem (ie. sixty percent contrast is reduced). The resultant images are shown from figure (3.a) to figure (3.c), in which Figure (3.a) shows fuzzy contrast intensified image. Figure (3.b) shows contrast intensified image using histogram equalization technique and Figure (3.c) shows contrast intensified image using adaptive histogram equalization technique respectively.

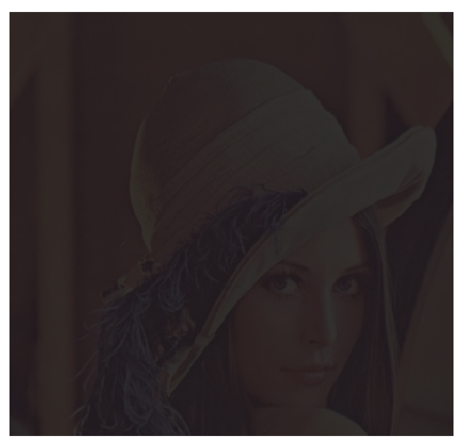

Figure 3.

Figure 3.a

Figure 4.a

Figure 3.b

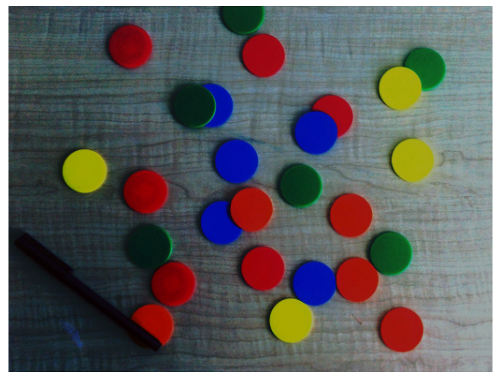

Figure 4.b

Figure 3.c

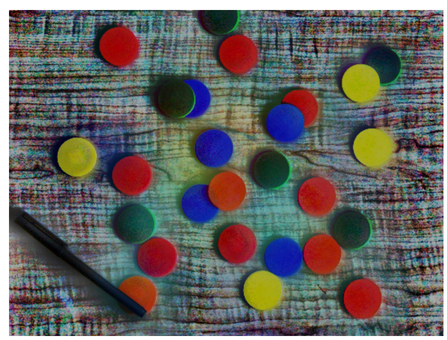

Figure 4.c

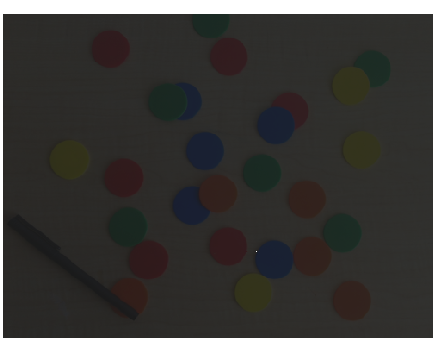

Figure 4.

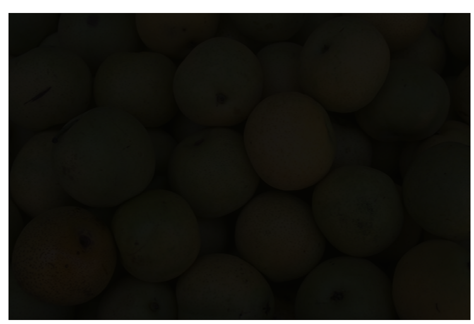

Figure 5.

Figure 5.a

Figure 5.b

Figure 5.c

Now table 1. shows the comparison between developed technique, histogram equalization and adaptive histogram equalization techniques based on CPP values obtained after contrast enhancement.

Table 1.

S. No.	Image	Fuzzy Based Proposed Method	Histogram Equalization	Adaptive Histogram Equalization
1	Lena	18.6526	10.956	11.2511
2	chips	25.0272	10.9664	11.5477
3	pears	19.3318	10.8142	10.9971

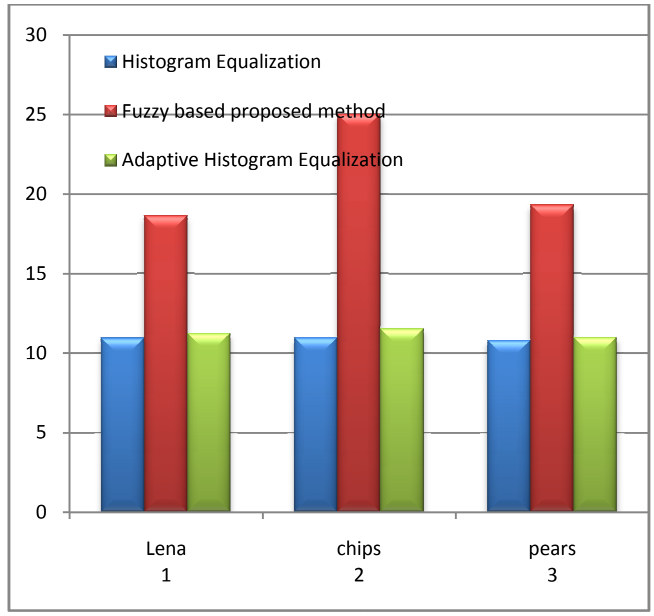

Figure 6 .CPP values plot for all three images for HE, Proposed and AHE methods.

8. CONCLUSION

The main focus of this paper was the development of fuzzy soft computing based image contrast enhancement technique for efficient color image enhancement. Although the conventional image enhancement techniques can able to provide image enhancement up to some extent, but they are not able to provide a good quality enhancement due to the ambiguity and vagueness present in images. This problem can be efficiently handled by fuzzy logic because, fuzzy techniques can manage the vagueness and ambiguity efficiently, and it has been found that fuzzy techniques are powerful tools for knowledge representation and processing.

In this paper, it is proved that the fuzzy logic based contrast intensification operator plays an important role in improving the contrast of an image. It has been found during the analysis of results that the contrast enhancement obtained from the fuzzy logic based contrast intensification operator is more proficient as well as suitable compare to the conventional technique histogram equalization and adaptive histogram equalization. In addition to this it is also apparent from the resultant images and table (1) that developed fuzzy based technique provides higher CPP for all the three images as compare to HE and AHE, hence able to produce efficient contrast enhancement.

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