A New Image Contrast Enhancement in Fuzzy Property Domain Plane for a True Color Images

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***Abstract*—The present work demonstrate an application of the theory of fuzzy sets in the field of colored image enhancement. The aim of this work is to introduce a new fuzzy image enhancement technique in fuzzy property domain based on logarithmic functions. Fuzzy set theory is a useful tool for handling the ambiguity in the images associated with vagueness and/or imprecision. A standard Gaussian membership function is used to fuzzify the image information in spatial domain. We introduce a new contrast intensification operator (INT), which contains some parameters to generalized and control the enhancement of the colored image. By using the proposed technique, the experimental results demonstrate that the proposed algorithm is very effective in contrast enhancement and there is a visible improvement in the image quality.**

***Index Terms*—image enhancement, fuzzy contrast, image quality, fuzzy property domain, intensification operator**

I. Introduction

Image enhancement is the modification of an image to alter its impact on the viewer. In an image enhancement system there is no conscious effort to improve the fidelity of a reproduced image with regard to the same ideal form of the image. There are several methods of image enhancement like histogram modification and evaluation and stretch or scaling and so on.

Contrast enhancement methods of an image are of particular interest in photography, satellite imagery, medical applications and display devices [1]. A spatial domain and frequency domain methods are the two major methods which used in domain of image enhancement. In the spatial method, image pixels are directly modified to enhance the image. In the latter method, the enhancement is conducted by modifying the frequency transform of the image. However, computing the enhancement in frequency domain is time consuming process even with fast transformation technique thus made it unsuitable for real time application [2]. There are several techniques which are used in enhancement of pixel contrast, normalized the image intensities and often fail to produce satisfactory results for a broad range of non-uniform illumination image [3]. Low contrast image is the image whose intensity levels of the pixels resides densely in a narrow range in the histogram of the image. The objects in this type of image are not clear or distinct. To improve the quality of the image and visual perception of human beings, different enhancement methods can be applied. Some methods work in frequency domain, some works in spatial domain and some works in fuzzy domain.

A fuzzy set is a superset of classical set theory that has been extended to handle the concept of partial truth–false values. So, fuzzy set theory accepts partial memberships, and, therefore, in a sense generalizes the classical set theory to some extent. It was introduced by Dr. Lotfi Zadeh of UC/Berkeley in the 1960s as a means to model the uncertainty of natural language. The truth of a logical expression in fuzzy logic is a number in the interval [0, 1].

Using fuzzy set theory in image processing is a form of signal processing for which input and output both are images. Fuzzy image processing is divided into three main stages: image fuzzification, modification of membership values, and image defuzzification. Power of fuzzy image processing lies in the intermediate step (modification of membership values) after first phase (image fuzzification), appropriate fuzzy techniques (such as fuzzy clustering, fuzzy rule-based approach, fuzzy integration approach and so on) modify the membership values.

The organization of the paper is as follows. In Section II, we introduce definitions of fuzzy sets, image definitions in fuzzy property domain, definitions of some membership functions and definitions, relationships of fuzzy Gaussian membership function. In Section III, we give an introduction to image enhancement in fuzzy property domain. In Section IV, proposed relationships for enhancement fuzzy domain for an image have been introduced. In Section V, we introduce the method to back from fuzzy domain to spatial domain. The experimental results and conclusion are discussed in Sections VI and VII, respectively.

II. Fuzzy Set and Membership Functions

A fuzzy set (A) with its finite number of supports x_1, $x_2, \ldots x_n$ in the universe of discourse U is defined, as in (1):

$$A=\{(\mu_A(x_i), x_i)\} \tag{1}$$

where $\mu_A(x_i)$ is the membership of element x_i in A.

The membership function $\mu_A(x_i)$ having positive value in the interval (0, 1) denotes the degree to which an event x_i may be a member of A. This characteristics function can be viewed as a weighting coefficient which reflects the ambiguity (fuzzification) in A. A fuzzy singleton is a

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fuzzy set which has only on supporting point. If $\mu_A(x_i)$ =0.5 is said to be crossover point in A. The α level set of A is defined as A_α, whose supporting points have membership value between α and 1.

Similarly, the property p defined on an event x_i as a function $p(x_i)$ which can have values only in the interval (1, 0). A set of these functions which assigns the degree of possessing some property p by the event x_i constitutes what is called a property set [4].

A. Image Definition [5]

With the concept of fuzzy set, an image X of M x N dimension and L levels can be considered as array of fuzzy singletons, each with a value of membership function denoting the degree of having brightness relative. In the notation of fuzzy, we may therefore write, as in (2):

$$X = \cup_m \cup_n p_{mn}/x_{mn} \tag{2}$$

m=1, 2, 3, …, M; n=1, 2, 3, …, N.

where p_{mn}/x_{mn} ($0 \le p_{mn} \le 1$) represents the grade of possessing some property P_{mn} by the (m, n) pixel intensity x_{mn}. This fuzzy property P_{mn} may be defined in a number of ways with respect to any brightness level depending on the problems at hand. In the following section we will define the standard S, π and Gaussian fuzzy membership functions and their approximations.

A. Gaussian, S and π Functions and Property Plane

Gaussian, S, and π are standard functions which are found in many cases to be convenient to represent the membership function of a fuzzy set in the real problems. These are defining, as in (3), (4) and (5):

$$\left.\begin{aligned} S(x;a,b,c) &= 0, && x \le a \\ &= 2\left(\frac{x-a}{c-a}\right)^2, && a < x \le b \\ &= 1-2\left(\frac{x-c}{c-a}\right)^2, && b < x \le c \\ &= 1 && x > c \end{aligned}\right\} \tag{3}$$

With,

$b = \frac{a+c}{2}$;

And,

$$\left.\begin{aligned} \pi(x;b,c) &= S\left(x, c-b, c-\frac{b}{2}, c\right),\ x \le c \\ &= 1 - S\left(x; c, c+\frac{b}{2}, c+b\right),\ x > c \end{aligned}\right\} \tag{4}$$

Another fuzzy membership function that is often used to represent vague, linguistic terms is the Gaussian membership function. The symmetric Gaussian function depends on two parameters σ and c, as in (5):

$$f(x;\sigma,c) = e^{\frac{-(x-c)^2}{2\sigma^2}} \tag{5}$$

where c is the center of the fuzzy set, and σ parameterizes the width of the fuzzy set.

In S(x; a, b, c), the parameter b is the crossover point, i.e., $S(b; a, b, c)$=0.5. In π(x; b, c), b is the bandwidth, i.e., the separation between the crossover points of π function, and c is the central point at which π=1.

B. Background of Gaussian Fuzzy Sets, Fuzzy Inference Systems [6]

A Gaussian MF (see Fig. 1) can be represented as in (5). Where c is the center of the fuzzy set, and σ parameterizes the width of the fuzzy set. The α-cut of a fuzzy set is a crisp set that contains all the elements of the universe set X that have a membership grade equals to or greater than α, where 1≥α>0 (Note that a Gaussian MF is a non-zero MF). Based on the -cut of a fuzzy set, the width of the fuzzy set, W_α, is determined, as in (6).

$$W_\alpha = ac = cb = \sqrt[2]{(-ln\alpha)(2\sigma^2)} \tag{6}$$

III. Fuzzy Image Enhancement [7]

Fuzzy image enhancement is done by mapping image gray or color level intensities into a fuzzy plane using membership function, and then modifies those member functions for contrast enhancement and maps the fuzzy plane back to image gray or color level intensities.

The heart of fuzzy image enhancement is the middle step where we modify the membership values. Expert knowledge is considered to decide the best suitable membership function and the membership function modification operator. Fig. 2 shows a block diagram of image enhancement using fuzzy logic [7].

IV. Proposed Relationships for Enhancement of Contrast in Property Domain Plane

The standard INT operator operating on a fuzzy set A and generates another fuzzy set A'=INT (A), the membership function of which is defined, as in (7) [7]:

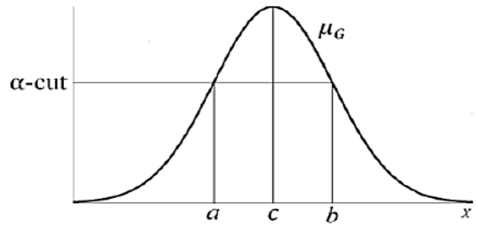


Figure 1. A Gaussian membership function [6]

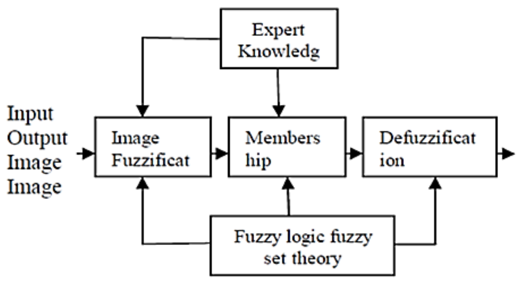


Figure 2. Block diagram of image enhancement using fuzzy logic [7]

$$\mu_{A'}(x) = \mu_{INT(A)}(x)$$

$$\left.\begin{aligned} \mu_{A'}(x) &= 2\left(\mu_A(x)\right)^2, && 0 \le \mu_A(x) \le 0.5 \\ &= 1-2\left(1-\mu_A(x)\right)^2, && 0.5 < \mu_A(x) \le 1 \end{aligned}\right\} \tag{7}$$

This operation reduces the fuzziness of a set A by increasing the value of $\mu_A(x)$ which are above 0.5 and decreasing those which are below it.

If we use a Gaussian membership function for fuzzification process, we can define and introduce a new enhancement of contrast method that deals with logarithms functions for smoother enhancement of fuzzy single tones which is defined, as in (8):

$$\begin{aligned} \mu_{A'}(x) &= \ln\big(k_1 + \mu_A(x)\big), \quad 0 \le \mu_A(x) \le 0.5 \\ &= \ln(e^{k_2} - \big(k_3 - \mu_A(x)\big), \quad 0.5 < \mu_A(x) \le 1 \end{aligned} \quad (8)$$

This operation can enhance the fuzziness of a set A by smoothing and increasing the value of $\mu_A(x)$ which are below 0.5 (close to darkness) with a small change to those which are above it. Best enhancement results can be obtained by proper selection of the parameters k_1, k_2 and k_3.

V. Inverse Membership Function

After enhancement of the property domain we can retrieve the enhanced spatial pixels by produce $\mu_{A'}(x) \rightarrow x'_{mn}$ transformation, as in (9):

$$x'_{mn} = k * \left| \mu_{A'} * \left[1 - \sqrt[2]{\big(\log\big(2 - \mu_{A'}(x)\big)} \right] \right| \quad (9)$$

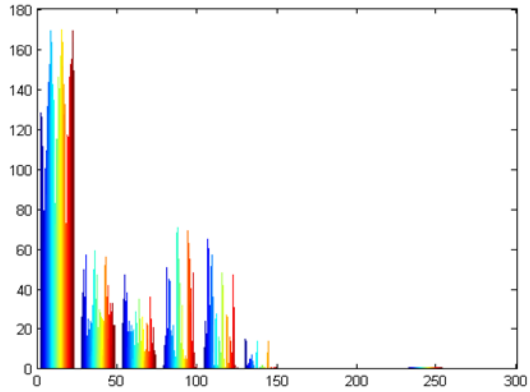
k is constant its value is optional to control the value of contrast.

The resulting image X' would have value either $x_{mn} \geq x_{max}/2$ or $x_{mn} \leq x_{max}/2$ corresponding to $\mu_A(x) \geq 0.5$ and $\mu_A(x) \leq 0.5$ in the alternate regions. The contrast (difference in gray level) between any two consecutive regions of X would therefore approach x_{max}.

VI. Experimental Results

We have considered many colored images girl, port and meeting [5]. The original images have poor brightness, i.e., under exposed and the details are not discernable. Also colors are not perceivable to the eye. The original images, enhanced images and the histogram of each image are shown in Fig. 3-Fig. 11; the parameters of Gaussian membership function are σ=60 and c=100. For proposed relationships, in (8) the parameters are k_1=1.7, k_2=1 and k_3=0.5. To show the effect of the proposed relationships on the enhancement of property domain we keep value of k, in (9) constant at 1.

(a)

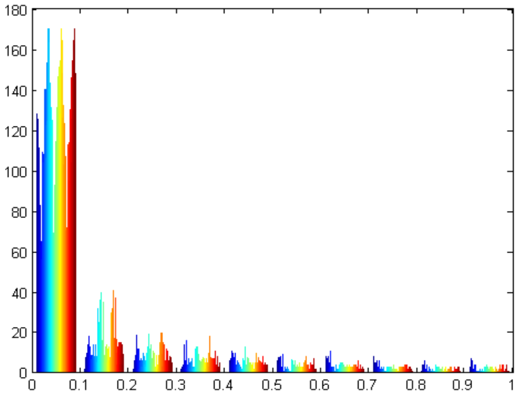


(b)

Figure 3. Meeting Image. (a) Original Image before enhancement (b) Histogram of the image.

A clear improvement is seen as far as the details are concerned after the application of the proposed enhancement method. Referring to Fig. 3a (Meeting Image) and its histogram shown in Fig. 3b the first enhancement step is accomplished by using (7) and the resulting enhanced image is shown in Fig. 4a with its histogram that is shown in Fig. 4b.

(a)



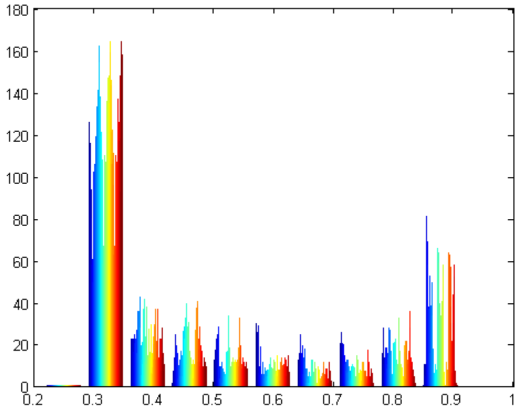
(b)

Figure 4. Meeting image. (a) Enhanced image using equations (5), (7) and (9). (b) Histogram of the enhanced image.

The second enhancement step is accomplished by using (8) and the resulting enhanced image shown in Fig. 5a with its histogram that is shown in Fig. 5b. In Fig. 3b, we can note the histogram of the RGB image concentrated to pixel values near to zero (more darkness), so to enhance image visualization, all pixel values must spread in all of contrast values (0-255). This can be accomplished by enhance the property domain of the image using (7) or the proposed relationship shown in (8). Equation (7) use a square function for enhancement so we can considered the membership enhancement is rough enhancement, so we produced a relationships shown in (8) which increasing the value of membership of pixel value which are below 0.5 (close to darkness) with a small change to those which are above it. Good enhancement results can be produced with proper selection of the parameters k_1, k_2 and k_3.

Referring to Fig. 6, Fig. 7 and Fig. 8, we can note same enhancement results which we obtained for image shown in Fig. 3a. In Fig. 6a, we can note the histogram of the RGB image concentrated to pixel values near to zero (more darkness). Enhancement steps are accomplished using (7) and the proposed relationship in (8). The same steps are accomplished to image shown in Fig. 9a; the results are shown in Fig. 10 and Fig. 11.

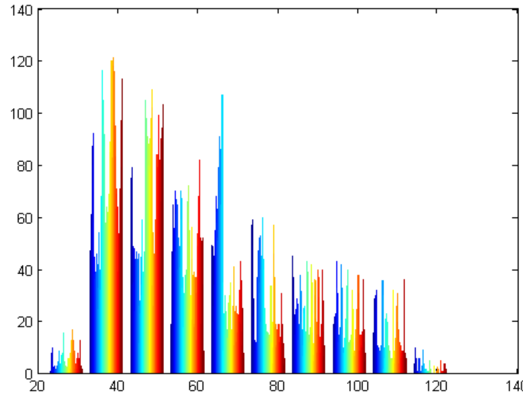
(a)



(b)

Figure 5. Meeting image. (a) Enhanced image using equations (5), (8) and (9) (b) Histogram of the enhanced image.

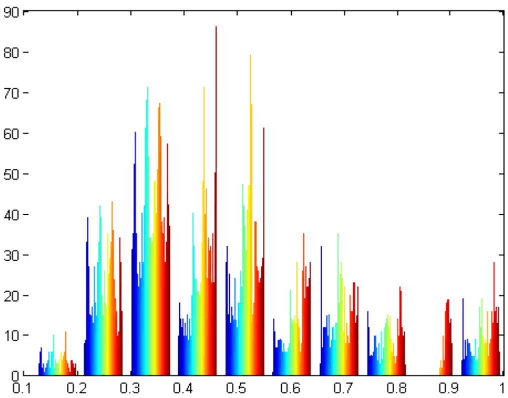
(a)



(b)

Figure 6. Girl image. (a) Original image original image before enhancement. (b) Histogram of the image.

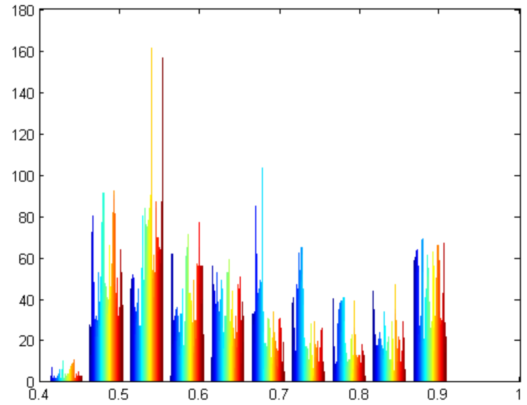
(a)



(b)

Figure 7. Girl image. (a) Enhanced image using equations (5), (7) and (9) (b) Histogram of the enhanced image.

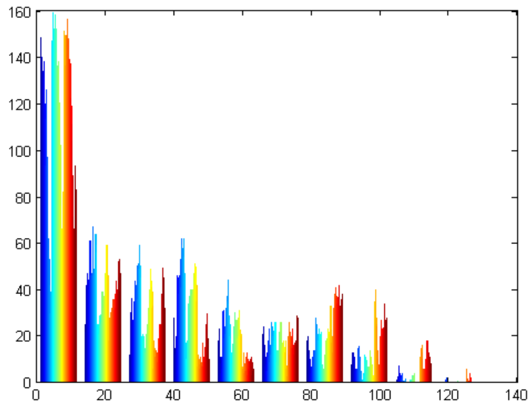
(a)



(b)

Figure 8. Girl image. (a) Enhanced image using equations (5), (8) and (9) (b) Histogram of the enhanced image.

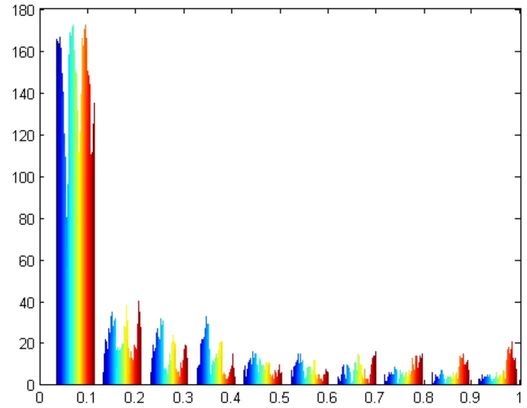
(a)



(b)

Figure 9. Port image. (a) Original image before enhancement. (b) Histogram of the image.

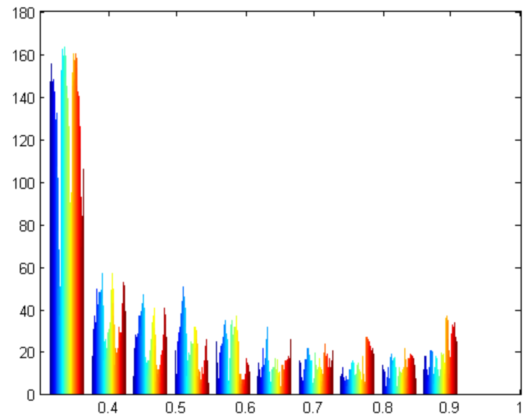
(a)



(b)

Figure 10. Port image. (a) Enhanced image using equations (5), (7) and (9) (b) Histogram of the enhanced image.

(a)



(b)

Figure 11. Port Image. (a) Enhanced Image Using equations (5), (8) and (9) (b) Histogram of the enhanced image.

VII. Conclusions

The concept of the fuzzy set and its associated operations are found to be applied successfully to the problems of color image processing. The use of fuzzy Gaussian function along with the successive use of contest intensifier is found to be suitable in enhancement of color images. The center point and bandwidth of the Gaussian function in enhancement operation are controlled by the fuzzifier which plays the role of creating different amounts of fuzziness in property domain. The new enhancement of contrast in property domain by using the new relationships that depend on logarithmic distribution of fuzzy single tone gives good results. This function gives good results in enhancement of color images as compared with the standard methods.

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