Fuzzy Rule Based Color Space

Reshmalakshmi C, Sasikumar M

Abstract— ***Color prediction is still a critical issue in computer vision and image processing. It is necessary to ensure that the perceived color of object remains constant under varying illumination conditions. Novelty of this paper lies in introduction of new color space called linguistic color space designed using fuzzy system for better color constancy. In addition, mapping from RGB to linguistic space retains the precision and accuracy. While evaluating the algorithm, it is clear that the color components are preserved effectively and accurately with the help of combination of different types of membership functions. Inference rules with membership functions results intuitive and efficient color space.***

Index Terms— ***Color Space, Fuzzy inference, linguistic variable, membership functions.***

I. INTRODUCTION

Color is the perceptual ability of human beings to identify the aspects of things. In any image processing techniques, pre processing is usually done on intensity components rather color or tone. The color of an object changes with the illumination changes in its background and it is relatively tricky to predict it correctly. So it is necessary to maintain a constant color even if there is a variation in background or illumination. A color space helps to organize and describe the color components of an image effectively, so that the original color components are preserved. It is advisable to use HSV color model as it has the property to preserve original color component intact. But processing and converting from one color space to another usually causes gamut problem. To design gamut free image processing technique, it is advisable to preserve the actual color component of the image. HSI, HSV, YIQ, YUV, NTSC and LHS are some of such color preserving color spaces. Color is a combination of actual color component [1] (hue), depth of color (saturation/ brightness) and intensity (value). Other color representation schemes such as additive and subtractive model uses triplets RGB (red, green and blue) and CMY (cyan, magenta, and yellow) which performs on the gray value of the images and are usually affected by gamut. Therefore, a proper color decoupling method to maintain color is necessary and such a method is HSV color space. Modeling of such a color space in fuzzy domain has greater advantage in image processing and several authors have proposed to use fuzzy sets [2], [3]. Chamorro et. al. [4] proposed the concept of fuzzy color space based on histogram as a contrary to the well- known disadvantages of the ordinary sigma-count as an estimation of the probability. Fuzzy set [5] is an intelligent mathematical tool to model the uncertainties or lack of information about a problem to be solved. If the image is degraded, fragmented, incomplete, vague or unreliable, fuzzy technique easily cop up with these uncertainties by its well- known linguistic approach. While designing color spaces, imprecision in the color components are handled by fuzzy inference system [6]. Fuzzy inference system uses linguistic variables to mimic the human like reasoning while designing color components. As we know, RGB space requires three dimensions to represent color of an object. But it is possible to characterize the color components in one dimension if we go for HSV space. Since HSV is identical to human visual system, many authors suggest fuzzy logic as an effective modeling tool. However colors like 'pure red' is easier represent in any logic whereas 'pale red' or 'dark red' can mathematically be expressed using membership functions of fuzzy logic. Soto et al. [7] proposed Voronoi diagram for fuzzy membership function definition from crisp Euclidean. A histogram based fuzzy space [4] is designed for dominant color components in an image. An image retrieval method is also suggested [8] using fuzzy space. In this paper, a modified fuzzy color space is defined with better color constancy. In addition, this method can be effectively used to tackle gamut effect and shadow detection. Construction of fuzzy color space is purely based on how human understand each component to be designed. This paper is organized as follows. Section II describes the fuzzy colors and its membership function definition. Fuzzy color space is defined in Section III. Results and comparison of this method is mentioned in the Section IV.

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***** Correspondence Author (s)
Reshmalakshmi C, Department of Electronics and Communication, Marian engineering College, Kerala. India.
Sasikumar M. Department of Electronics and Communication, Marian Engineering College, Kerala. India.

II. COLOR REPRESENTATION AND MEMBERSHIP FUNCTIONS

Color is an evitable feature of image and it can be represented using color spaces. The color capability of particular device can be obtained with a help of color spaces. Although color is represented by RGB components it is not an appropriate method for all problems solving techniques. Different color spaces use different technique to represent color of an image. CMY, YCbCr or YUV represents color spaces as a linear combination of RGB space. And HSV, HSI, or HSL represent as a space to map human visual system. CIELab, CIELuv are represented as a perceptually uniform space. In order to reduce the ambiguity in color description, we introduce a linguistic color representation in terms of linguistic variable, which outperforms existing color spaces for some particular application.

A. Fuzzy color representation

In human perception system [9], color can be represented as a combination of hue, saturation and intensity (HSI). Since fuzzy sets are similar to human perception system, it is possible to mimic HSI or HSV as a linguistic space. We define fuzzy color space as a combination of three parameters namely actual color (hue), brightness and intensity. Hue of an image is defined as a combination of normalized fuzzy sets.

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A fuzzy set is said to be normalized if the maximum value of membership function is 1. Hue values of colors are shown in *figure 1.*

Here, we use set of 13 linguistic color names corresponding to 10 basic color set of C= {red, orange, yellow, lemon green, green, cyan, blue, violet, magenta, pink, red} and 3 achromatic colors of {gray, black, white} to represent the entire color combination or hue of an image.

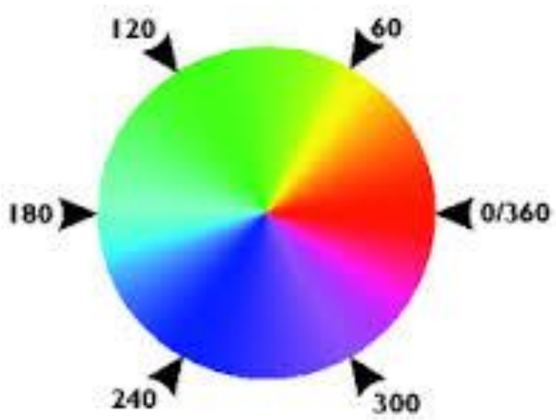

Figure 1. Hue Circle

Hue and brightness together represents color at a particular pixel of an image. Brightness /saturation of an image show the amount of dilution of each color from the white light. Here, saturation is calculated using Eq.1, in which = v_{max} and = v_{min} represents the maximum and minimum gray level value of each pixel.

Saturation= v_{max}-v_{min}/ v_{max} (1)

Intensity is considered as the maximum value at the particular point and is obtained by applying s-norm (max) or triangular conorm (t- conorm) to the RGB components.

Intensity = max (μ_{RED}, μ_{GREEN}, μ_{BLUE}) (2)

Where μ represents the degree of belongingness for review.

B. Specification of Membership functions

The degree of belongingness of each domain space component to the universal component is represented by a function called membership function. This mapping can be triangular, trapezoidal, Gaussian or sigmoid. When there is more number of membership functions to exist within a universe of discourse to describe an application, it should be noted that it may cause the response of the system to be too slow and fails to provide sufficient output. This may also cause oscillation in the system. At the same time more number of membership functions causes accurate firing of different rules for small changes in input and results output changes. Membership functions of fuzzy set in a universal set may get overlapped sometimes and the sum of grades at any point within the overlap should be less than or equal to 1. Also each color is characterized by different membership functions. The type and parameters of membership functions are determined by the property of color. Here primary colors are characterized by trapezoidal functions whereas secondary and tertiary by Gaussian functions. The membership functions are represented as follows. Where a, b, c and d are the limits to define a function over it.

$$f(x;a,b,c,d) = \begin{Bmatrix} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{d-x}{d-c}, & c \le x \le d \\ 0, & d \le x \end{Bmatrix}$$

(2)

Gaussian membership function is expressed with parameter center(c) and standard deviation (σ).

$$\text{Gaussian}(x;\, c,\, \sigma) = e^{-\frac{1}{2}(x-c/\sigma)2} \quad (3)$$

The hue values are mapped to linguistic variables of color ranges from 0-360 as shown in hue circle. Here primary colors are represented by wide trapezoid and secondary by Gaussian functions. The linguistic variables with different membership functions are shown in figure 2.

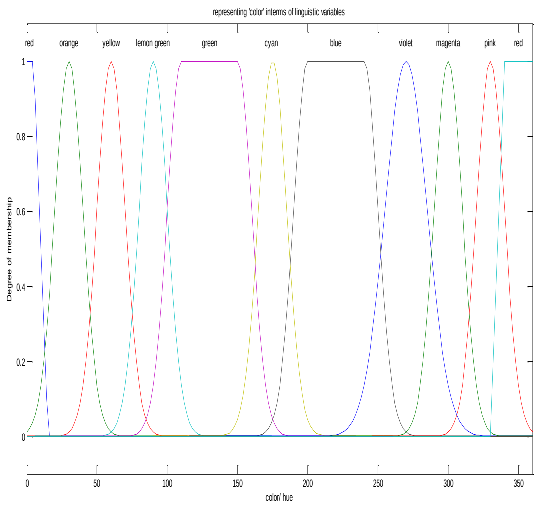

Figure 2. Membership functions representing hue.

Here, the type and shape of membership function depends on its parameters and are fixed based on their color property. The RGB values of 0-255 are mapped to values of 0-360 as it characterizes hue of an image.

III. Fuzzy Approach

The design steps of fuzzy color space comprises of three steps namely fuzzification, Inference with fuzzy rules, and defuzzification. It is possible to define fuzzy color space by means of fuzzy subset on each component of R, G and B of image plane. Similarly, each of these components (red, green and blue) are represented as a combination of other three fuzzy subsets namely 'low', 'medium' and 'bright'as defined and shown below. The use of specified membership functions makes the system more efficient and useful in the field of image processing applications like shadow detection, cloud detection.

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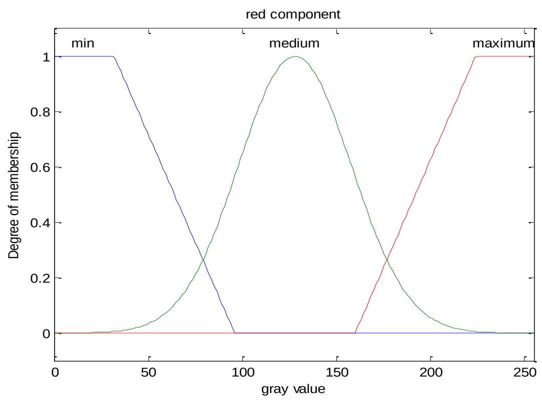

Figure 3.Membership functions of R component

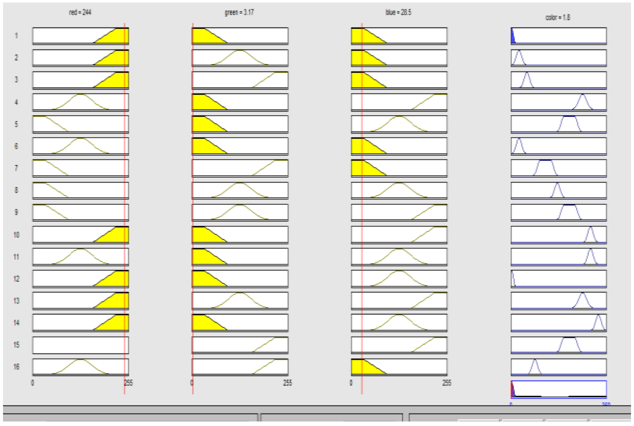

Figure 4. Fuzzy Rules to infer 'color'.

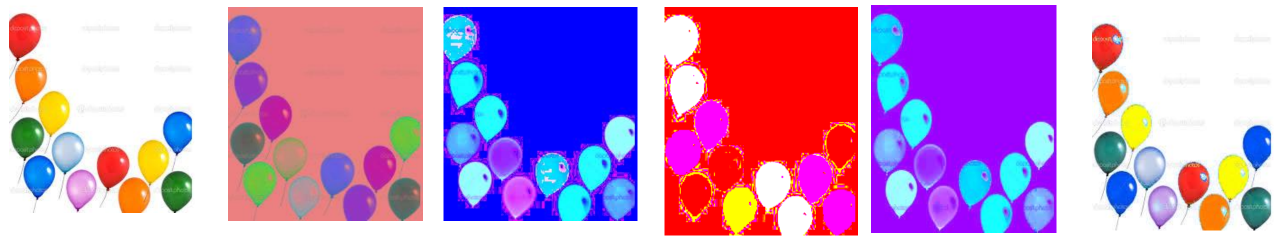

Fig.7. Comparison on Different Color Spaces. A) Input image. B) YC b Cr. C) HSV. D) CIELab Space E) Linguistic Space F) Output Image

A. Fuzzification

Fuzzification is the process of transforming real values of RGB in to fuzzy terms quantified by the fuzzy membership functions. These transforming curves define each point in the input space to the output space. Each component of RGB values are fuzzified and forms three fuzzy sets namely 'min', 'medium' and 'maximum' as shown in Fig.3.

B. Inference Rules

Rules of inference or transformation rules are the logic function which helps to infer or to deduce a conclusion from a set of premises. Commonly used inferring rules are modes ponens and modes tollens. Two types of fuzzy inference systems are Mamdani and Sugeno as described below. If *A*, *B*, *C* are fuzzy sets and *a*, *b*, *c* are constants to deduce a result;

Mamdani's model:

if x is A **and** y is B **then** z is C

Sugeno model:

if x is A **and** y is B **then** z =ax+by+c

The process of obtaining output from a set of rules and inference can be viewed as an implication. The simplest form of rule is *if...then*, statement. i.e.; *if x is A then y is B (if premises then consequence).* Mamdani's inference systems uses *maxmin()* composition as an implication approach. The set theoretical operation *if x is A then y is B else y is C* can be mathematically expressed as *max (min* $(\mu_A, \mu_B), \mu_C)$. Fig.4 shows how to infer 'red' color from a set of rules using linguistic space. If rule is expressed as follows and R, G, B values of the gray levels are 244, 3.17, 28.5 respectively, fuzzy sets x_{RED}, x_{GREEN} , x_{BLUE} are selected automatically and deduce a hue value 1.8 which shows that the color is *RED*.

Rule: if x_{RED} is 'maximum' and x_{GREEN} is 'min' and x_{BLUE} is 'min' then color is 'RED'.

As proposed, linguistic color space is a three dimensional space of hue, saturation and intensity. Comparison with additional color spaces like YCbCr, CIELab or HSV states that linguistic approach maps color and traces edge of an image effectively Fig. 7 shows such a comparative study on two different images. It is possible to evaluate the performance using subjective and objective evaluation [10] [11] methods.

From the above description it is clear that there is no artifacts present in the proposed method compared to the existing state of art methods. Additionally original is reconstructed from the fuzzy domain to the spatial domain.

IV. CONCLUSION

In this paper we introduced a definition for linguistic color space using fuzzy logic. Novelty of this paper lies in the use of different membership function and inference system. While comparing with HSV, YCbCr and CIELab color spaces, linguistic color spaces retains accuracy and precision of each gray level values of the pixels. In addition this method can be illustrated as a potential application of fuzzy logic.

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