Design and Implementation of Color Detection Technique using Fuzzy Logic

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Abstract

In computers' user interface applications some complex artificial intelligence should be used as machine learning algorithm to implement the sense of detection in the software especially in digital image processing applications. In this paper its proposed that using of fuzzy logic approaches that adopts some datasets of colors information and with the image processing techniques, image application can be more intelligent and reliable for advanced usage and various applications. As such, a MATLAB-based software was that uses machine learning fuzzy logic was implemented to detect and predefine sense colors into an image. Furthermore, to extract the most dominant color in the image and implement some color model conversions for that image. The results demonstrated that fuzzy logic color detection mechanism is efficient and reliable. The contribution of this study can be of great value in improving computer vision and machine learning applications that based on color detection, also other basic practical image processing techniques are introduced which can be valued for interested researchers.

Keywords—Fuzzy Logic, Color Detection, 3D Histogram, HSV,HSI.

I. INTRODUCTION

In real world, human eye can detect and differentiate colors from predefined recognition or by experience from traditional learning, then the eyes can sense the color it sees and the mind interprets what that color is. In computer vision the color detection or color sensation mechanism is almost the same as in human eyes but it should be programmed using algorithms and some logic procedures that enables the CPU to take that piece of color and apply the proper mathematical and logical operations in order to take a decision of what color that piece includes according to its recognition about all color names[1].

Color refers to the human brain's subjective interpretation of combinations of a narrow band of wavelengths of light. For this reason, the definition of "color" is not based on a strict set of physical phenomena[2]. Therefore, even basic concepts like "primary colors" are not clearly defined. Light colors, more formally known as additive colors, are formed by combining red, green, and blue light. 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 image intensity components instead of 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[3].

Fuzzy logic is the most common way to implement machine learning algorithms. It is used in this research for color detection and comparison in an image file, using an acknowledged dataset to make the decision between colors of an image and the specified color by comparing the colors of the image with the colors in the Look-up Table (LUT) by the color name of the LUT. The implementation also includes a dominant color detection and RGB to HSV, HSI color spaces conversions, and also 3D histogram representation of an image. The whole project is implemented using MATLAB programming environment by creating a (GUI) based application to load the image selected. The user can perform and apply all the previously mentioned functions to get instant results. The project's results were successfully achieved as expected.

Generally, in this paper we managed to perform three different functions that deals with images and colors. The major one is using the fuzzy logic to implement a color detection application, then implementing a dominant color detection application, then implementing basic conversions between RGB, HSV, HIS color models. The whole idea of this study is implemented and performed using MATLAB programming environment. The fuzzy logic color detection algorithm's main function is implemented into two parts; firstly, implementing a fuzzy logic color learning and saving the colors' information into a predefined dataset. Secondly, examining all the information of the predefined colors into the acquired image, compare all the known colors with image color, and extract the required color that matches the user demand if found in the dataset by using leaner interpolation method. For the dominant color detection function, we managed to extract the RGB value of the dominant color by measuring the Euclidian distance of each color to all colors. And for conversation between RGB, HSV, and HSI image color models we used a built-in color space function added with the software.

Accordingly, this paper is organized into five sections. Section one provides the introduction and highlights the main problematic issues concerning image detection applications based on color detection mechanism; section two introduces a review of the related theoretical topics involved with proposed contribution study. Section three elaborates on the methodology used in this paper, while section four and five presents the conclusion and recommendations of this study, respectively.

II. Literature Review

In Computer Vision, images acquisition is an operation of reading the view from the real world into computer vision view which is performed with different types of sensors that commonly known as color models[4]:

1. RGB Color Model

The RGB color model works exactly like those color receptors of the human eye: the RGB color model describes a color by using 3 variables, Red, Green and Blue. These variables can be compared to the strength of the signals from the 3 types of color receptors in the nerves as shown in Fig.1.

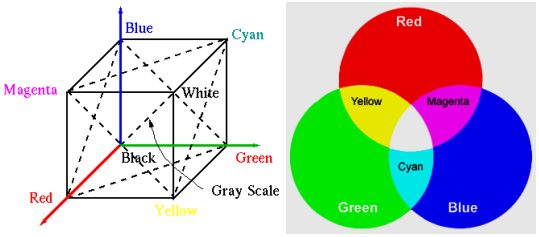

Fig. 1: RGB primary colors cube and primary colors representation.

2. HSL Color Model

HSL color obviously has the parameters H, S and L, or Hue, Saturation and Lightness. Hue indicates the color sensation of the light, Saturation indicates the degree to which the hue differs from a neutral gray, and Lightness indicates the illumination of the color. Fig.2 shows typical illustration of HSL color model.

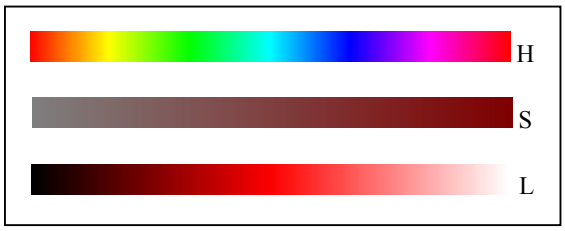

Fig. 2: HSL Color Model illustration.

3. HSV Color Model

The HSV color model, uses the parameter Value instead of Lightness. Value works different than Lightness, in that the color with maximum value (V=255) can be any color like red, green, yellow, white, etc..., at its maximum brightness. Value is defined as max-Color, where max-Color is the R, G or B component with the maximum value. So, the colors red (255,0,0) and white (255,255,255) both have a Value of 255 indeed. Fig.3 shows HSL versus HSV when S=255.

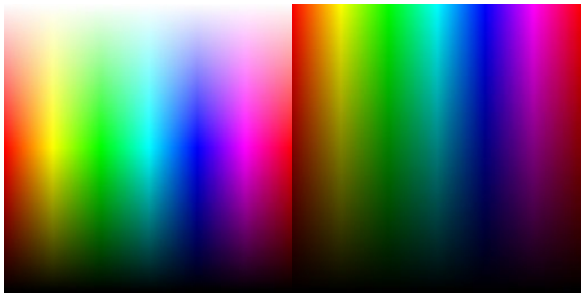

Fig. 3: HSL vs HSV when S=255

A. Fuzzy Logic

Fuzzy logic is a technique for representing and manipulating uncertain information. In probability theory, fuzzy logic attaches numeric values between 0 and 1 to each proposition in order to represent uncertainty. But whereas probability theory measures how likely the proposition is to be correct, fuzzy logic measures the degree to which the proposition is correct.

There are many benefits of using fuzzy logic, such as being conceptually easy to understand, having a natural approach[5]. Moreover, Fuzzy logic is flexible and can be easily added and adjusted. It is very tolerant of imprecise data and can model complex nonlinear functions with little complexity. It can also be mixed with conventional control techniques. There are three major components of a fuzzy system: fuzzy sets, fuzzy rules, and fuzzy numbers[6]. These are defined as follows:

- Fuzzy set: is the logic and thinking occur in sets.
- Fuzzy rules: are based on human knowledge.
- Fuzzy numbers: ways to associate a fuzzy number to a description in words. The association takes place in the form of a certain shape. This shape is called a membership function.

B. Fuzzy logic Applications

Fuzzy sets theory has been successfully applied to many image processing and pattern recognition problems[7]. Color detection in image sequence has been an active research area in the computer vision field in recent years' due to its potential applications, such as monitoring and surveillance, human computer interfaces, smart rooms, intelligent robots, and biomedical image analysis[8].

C. Histogram

In an image processing context, the histogram of an image normally refers to a histogram of the pixel intensity values. The histogram is a graph showing the number of pixels in an image at each different intensity value found in that image as shown in Fig.4. For an 8-bit grayscale image there are 256 different possible intensities, and so the histogram will graphically display 256 numbers showing the distribution of pixels amongst those grayscale values. Histograms can also be taken of color images, either individual histograms of red, green and blue channels, or a 3-D histogram, which can be produced with the three axes representing the red, blue and green channels, and brightness at each point representing the pixel count. The exact output from the operation depends upon the implementation. It may simply be a picture of the required histogram in a suitable image format, or it may be a data file of some sort representing the histogram statistics.

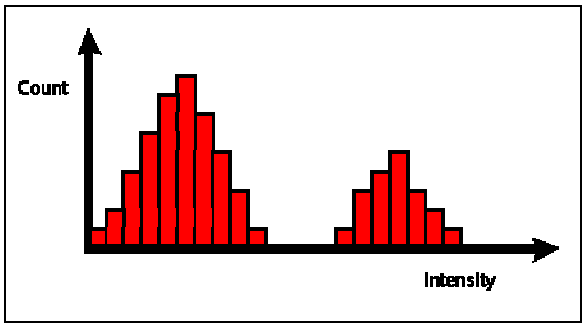

Fig. 4: Histogram values representation

D. Related Work

This section presents the topics that are related to this paper which are addressed by the previous studies, as such, have been considered to inspire this research criterion.

In [5] the authors provides a better understanding on applying Fuzzy Logic in solving real life application for engineering technology students by conducting experiments, that their results demonstrate the color classification using Fuzzy Logic successfully. Then, in 2011 a comprehensive laboratory of skin and frontal face detector by selecting optimized color spaces is presented in [9] using fuzzy logic for color sensing from applying the fuzzy inference system using MATLAB to implementation on a low-cost educational microcontroller-based system. Hardware details of the intelligent sensor and the software implementing the fuzzy logic algorithm are also given in this work. Meanwhile, a method based on the HSI model and anew inference process that resembles the human vision recognition process is introduced in [10]. The method allows the user to add, delete, or update inference rules. Additionally, its membership's intervals are designed with sine and cosine functions in the H channel and trigonometric style functions in the S and I channels. The membership degree is computed via an interval merging process. Next, the inference rules are applied to the result in order to infer the color information. Their results show that this method is more intuitive and efficient than that based on the RGB model. Accordingly, some of their implementation is used in this paper.

Later in [11] Fuzzy logic is used to cover the difference in the parameter of face. The method includes color segmentation, entropy, and Euclidian distance. The method provides a suitable information extracting mechanism that has been tested on various real images. While, its performance is found to be quite satisfactory with detection accuracy 94.74%. In 2016 the introduction of new color space called linguistic color space designed using fuzzy system for better color constancy was obtained in [3]. Similarly, mapping from RGB to linguistic space to retain the precision and accuracy. Thus, after evaluating the algorithm states, 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[3]. Finally, both studies in [12, 13] describe a human perception based approach to pixel color segmentation. Fuzzy sets are defined on the H, S and V components of the HSV color space and provide a fuzzy logic model that aims to follow the human intuition of color classification.

III. METHODOLOGY

A. Color Detection Algorithm Procedures

Describe the fuzzy logic algorithm of the color detection and the dataset used for fuzzy logic processing.

- Step1: Load the image as three-dimension array, each dimension represents the value of the color of Red, Green, and Blue.
- Step2: Convert the value of the colors are changes from 0-255 range to 0-1 range by dividing over 255 and take the double result.
- Step3: Reshape the converted 0-1 RGB image into one-dimension array for linear processing, and take the length of the serial array.
- Step4: Create an empty image with the same dimension and size for the results.
- Step5:take the index of the query color or the color to be compared with the data set, to loop over the index of the query color and make interpolation for 3-D gridded data in mesh grid format with linear method and make the decision of the color name and modify empty result image by the colors that found only.

In step 5, the interpolated values of a function of three variables at specific query points using linear interpolation. The results always pass through the original sampling of the function. R, G, and B nodes contain the coordinates of the sample points. Color Lookup table contains the corresponding function values at each sample point. R, G, and B contain the coordinates of the query image points. Table.1 describes the content of the dataset in MATLAB used in the fuzzy logic detection of color, used to get the color names by comparing colors with the look up table.

Table 1: Dataset Content description

Column	Description	Data type	Size
NCOLORS	Number of colors defined in the data set.	integer	1x1
COLORNAMES	The Names of the defined colors	Cell ”String”	1xNo. Of Colors
COLORLUT	Colors look up table to compare the difference between the source (defined) color and the color of image pixel. (polygons)	Cell “Doubles”	1xNo. Of Colors Of 52x52x52 double
RNODE	The red polygonsof the colors used in colors definition and interpolation.	double	1x52
GNODE	The green polygonsof the colors used in colors definition and interpolation.	double	1x52
BNODE	The blue polygonsof the colors used in colors definition and interpolation.	double	1x52

B. Dominant Color

- Step 1: Reduce the image dimensions (Resize to ¼) in order to reduce the time processing.
- Step 2: Reduce the image resolution (multiply by constant “0.25”) to reduce the time processing and better results.
- Step 3: Compute the image histogram to find the color pixel pins from the image and to retrieve the RGB values (cores) and the frequency of each color.
- Step 4: Compute Euclidian distance of each color to all colors.
- Step 5: identify the colors nearest to the most predominant color.
- Step 6: find the colors with distance less than or equal 3.
- Step 7: compute weighted mean of the colors.

C. Conversion from RGB to HSV

Input: RGB
Output: HSV
Method:
Step1: *[Find the max and min values]*
M = max (R, G, B), m = min(R, G, B)
Step2: *[normalized the RGB values to be in the range [0, 1]]*
r = (M-R)/(M-m) & g = (M-G)/(M-m) & b = (M-B)/(M-m)
Step3: *[Calculate V value]*V = max (R, G, B)
Step4: *[Calculate S value]*
if M = 0 then S = 0 and H = 180 degrees
if M <> 0 then S = (M - m) / M
Step5: *[Calculate H value]*
if R = M then H = 60(b-g)
if G = M then H = 60(2+r-b)
if B = M then H = 60(4+g-r)
if H >= 360 then H = H - 360
if H < 0 then H = H + 360
Where H in the range [0,360], S and H in the
Range [0,100]
Step6: *[output HSV]*
The calculated H, S, and V are the output of the algorithm.
END

D. Conversion from RGB to HSI

Input: RGB
Output: HSI
Method:
Step1: [Find the max and min values]
M = max (R, G, B), m = min(R, G, B)
Step2: [normalized the RGB values to be in the range [0, 1]]
r = (M-R)/(M-m)
g = (M-G)/(M-m)
b = (M-B)/(M-m)
Step3: [Calculate I value]
I = (R' + G' + B')/3
Step4: [Calculate S value]
if M = 0 then S = 0 and H = 180 degrees
if M <> 0 then S = (M - m) / M
Step5: [Calculate H value]
if R = M then H = 60(b-g)
if G = M then H = 60(2+r-b)
if B = M then H = 60(4+g-r)
if H >= 360 then H = H - 360
if H < 0 then H = H + 360
Where H in the range [0,360], S and H in the
Range [0,100]
Step6: [output HSI]
The calculated H, S, and I are the output of the algorithm.
End

IV. Results and Discussion

Following the implementation of the project in MATLAB, GUI based program demonstrated in order to easily manipulate different images with different program functions, Fig.5 shows the main interface of the application. After selecting an image and using the extraction of the dominant color procedure, as can be seen in the top left, the button to select the image need to be processed, in the top right side the color detection section, and below it the image conversions section, and at the bottom we have the dominant color and the 3D histogram buttons.

Fig. 5: Main application interface with dominant color result

Fig.6 below shows the using of the color detection algorithm for the same image in Fig.5, the figure shows the color detection of the green color.

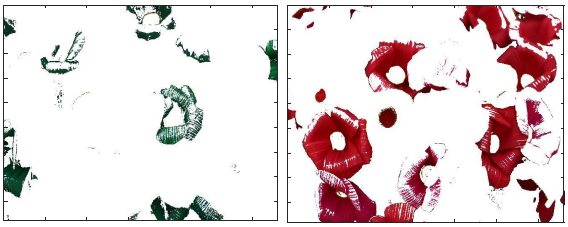

Fig. 6: Color detection (green and red)

The color conversions of the same image from RGB to HSV model and to HSI is shown below in Fig.7.

Fig. 7: Color Conversion (HSV and HSI)

Fig.8 shows the 3D histogram of the image above, it shows the mapping of the RGB colors value in each axes.

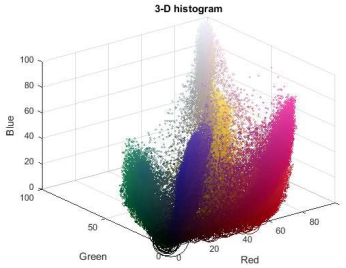

Fig. 8: 3D histogram of the image

Then by using the same application with different images to obtain different results, the images used for results are shown in Fig.9.

Fig. 9:images used in results

The color detection of the blue color in the above images is shown below in Fig.10 and Fig.11.

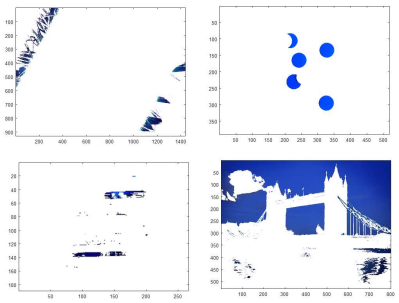

Fig. 10:color detected (blue)

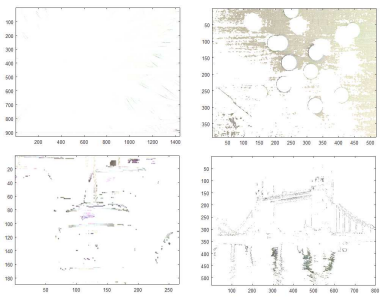

Fig. 11:color detected (pastel)

Below Fig.12 shows the most dominant colors calculated from the images.

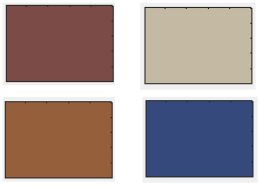

Fig. 12:Dominant colors

Below the Fig.13 and Fig.14 shows the conversion results of the images from RGB to HSV and HSI color model.

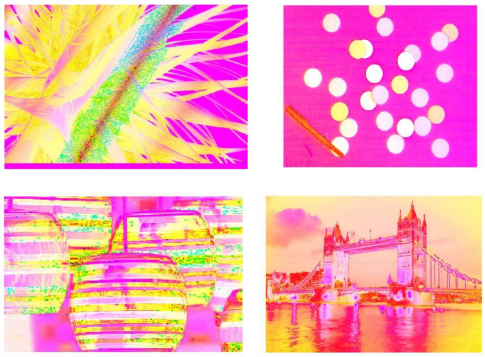

Fig. 13:Converted images (HSV)

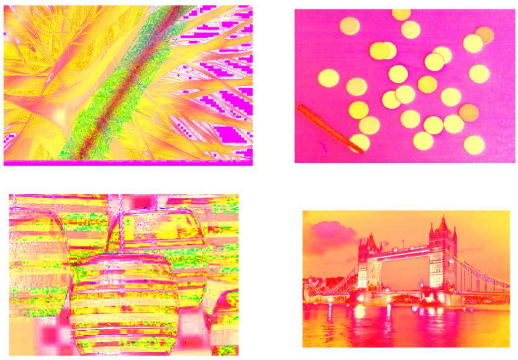

Fig. 14:Converted images (HSI)

And Finaly the 3D histogram of the selected previous image is shown in Fig.15.

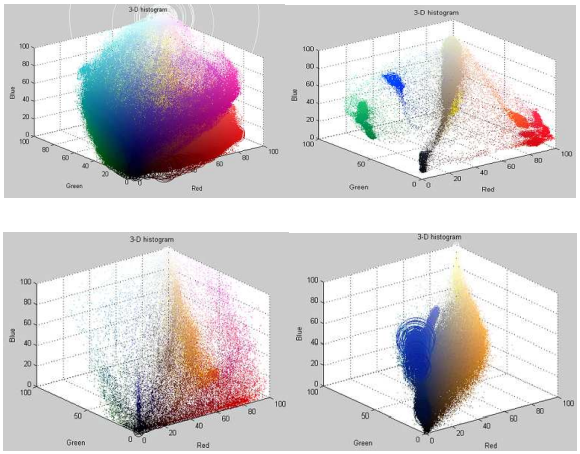

Figure 4- 1: 3D Histogram results

V. CONCLUSION

Fuzzy logic is one of the basic and common methods in artificial intelligence field and it has been implemented in too many applications. As such, in this project the fuzzy logic is used to implement a color detection algorithm using a predefined dataset that contain a lookup table with corresponding color names. The colors of the image are compared with the lookup table, and the result of the comparison is achieved if the values of the image colors are identified in the lookup table which matches the desired color to be detected by specifying the color name. In addition to three other function; most dominant color detection, HSV and HSI color models conversion, and 3D histogram illustration. The results show that the implementation was efficient and it satisfies the main objectives of the project.

VI. RECOMMENDATION

Machine learning algorithms represent the most concept that concerned by developers and programmers these days. While, the fuzzy logic has to be the basic of machine learning methods and it's recommended for those who wants to understand the basic idea of supervised machine learning. It's also recommended to be used with MATLAB environment which offers all the necessary tools and function for such proposes.

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