Color Preference and Personality Modeling using Fuzzy Logic

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Abstract—Human ability to perceive colors is a very subjective matter. The task of measuring and analyzing appropriate colors from colored images, which matches human sensitivity for perceiving colors, has been a challenge to the research community. In this paper we propose a novel approach, which involves the use of fuzzy logic and reasoning to analyze the RGB color intensities extracted from sensory inputs to understand human sensitivity for various colors. Based on this approach, an intelligent system has been built to predict the subject's personality. The results of experiments conducted with this system are discussed in the paper.

Index Terms—Fuzzy Logic, Intelligent System, Color Perception, Human Psychology

I. INTRODUCTION

Color perception by an individual involves attaching a label denoting the color in order to categorize the perceived color. Human beings rely on color for a variety of reasons including recognizing color of the traffic signal while driving. However, human beings also regard it as an aesthetic issue when it comes to color perception for choosing the colors for their clothing, furniture and objects that surround them. The choice often reflects their personality. It is often difficult to label these colors exactly by using a finite number of categories like, red, blue green etc.

Human eye contains rods, which identify black & white, and three types of color cones, which are sensitive to blue, green and red. By combining the cone type's relative light intensities, color is perceived by the human brain. Combined response of cones is called the Eye Luminous Efficiency. Differences in individual's visual sensitivity results in different color perception by each human being. Psychologists have linked people's preference for colors with their personalities [1,2].

Computer monitors display a wide range of colors by assigning real values to the intensity of red, green and blue (RGB) colors and then fusing them. Number of bits is used to represent intensity of each color, hence if 2 bits are used only two values (black and white) can be represented. As the number of bits is increased more gray levels can be represented, which can result in providing excellent color saturation.

However, the task of perception involves categorizing into color classes. If a single label is attached to the given pixel intensity value there is a high likelihood of making an error. This paper uses fuzzy logic and reasoning to determine the most appropriate linguistic label to the color selected from the given color palate in order to minimize the error.

The entire process of applying fuzzy logic in this paper contains the following steps:

Step 1 : Define fuzzy sets
Step 2 : Relate observations to fuzzy sets
Step 3 : Define fuzzy rules
Step 4 : Evaluate each case for all fuzzy rules
Step 5 : Combine information from rules
Step 6 : Defuzzify results

II. HUMAN EYE COLOR SENSITIVITY & PERCEPTION

Many researchers [3,4,5] have studied the color sensitivity of the human eye. Bjorstadt has used a variety of survey methods to study color sensitivity and human ability to perceive color. The study investigates [6] the relationship between color preference and the personality of the perceiver. According to the study, people who perceive yellow and red color and prefer warmer colors demonstrate a tendency to be "stimulus-receptive". People who prefer warm colors are usually very active, straightforward and tend to be reasonable rather than confrontational by nature. They can be easily distracted, tend to give up easily and not struggle, and display strong emotions. On the other hand, people who prefer cold colors, i.e. green and blue, tend to be "stimulus-selective". Table 1 shows the relationship between color preference and personality.

Table 1 Relationship between color preference and personality

Color Preference	Personality
White	These people tend to be very self-conscience and behave based on how other people will perceive their actions. They tend to lack self-confidence and are often reluctant to express their own preferences.

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Black	They tend to be unhappy, lack self-confidence and self-esteem, and are prone to dwell.
Gray	These people are not happy unless they are with other people and assisting them with their problems. They have great loyalty to country and home. They are independent, cautious, and prefer comfort to glamour. They are neat and fashionable.
Yellow	They tend to be intellectuals. They are definitely extrovert and likely, if crossed, to "roar like a lion." They are very generous, forthright, and open with people. People preferring yellow have a strong spiritual or metaphysical interest.
Orange	They are full of enthusiasm and look for adventure. Their ideas are unique. Their strong determination helps them carry through any plan of responsibility.
Brown	They see the good in all people. They have a very logical mind. They are understanding as well as firm. Their quick adaptability is a great asset.
Pink	They seem to be always dissatisfied. They usually do not express their own opinion.
Red	They tend to be extrovert, full of vigor and vitality. They are of youthful mind, which aspires to freedom of movement.
Green	They are usually kind, generous, and loyal. They are inclined to be methodical and you have great determination.
Sky blue	They are stubborn. They are sensitive and conscientious.
Blue	They are very sensitive and have a tendency to be moody. Introvert by nature.

III. DEALING WITH SENSITIVITY USING FUZZY LOGIC

A. Membership functions for colors

The first task is to define fuzzy sets corresponding to high, low and intermediate values. An advantage of the fuzzy approach is that we don't have to define each possible level [7,8]. Intermediate levels are accounted for as they can have membership on both the high and low fuzzy sets. For these the fuzzy sets we assume the membership function shown in Fig 1.

$$\textit{if } C \le 45 \textit{ then } \mu_{Low}(C) = 1$$
$$\textit{else if } C > 45 \textit{ and } C \le 81 \textit{ then}$$
$$total = \left(\frac{95-C}{50} + \frac{C-31}{50}\right)$$
$$\mu_{Low}(C) = \frac{C-31}{50} \times \frac{1}{total}$$
$$\mu_{LM}(C) = \frac{95-C}{50} \times \frac{1}{total}$$
$$\textit{else if } C > 81 \textit{ and } C \le 109 \textit{ then}$$
$$\mu_{LM}(C) = 1$$
$$\textit{else if } C > 109 \textit{ and } C \le 145 \textit{ then}$$
$$total = \left(\frac{159-C}{50} \times \frac{1-95}{50}\right)$$
$$\mu_{LM}(C) = \frac{C-95}{50} \times \frac{1}{total}$$
$$\mu_{HM}(C) = \frac{159-C}{50} \times \frac{1}{total}$$
$$\textit{else if } C > 145 \textit{ and } C \le 173 \textit{ then}$$
$$\mu_{HM}(C) = 1$$
$$\textit{else if } C > 173 \textit{ and } C \le 209 \textit{ then}$$
$$total = \left(\frac{223-C}{50} + \frac{C-159}{50}\right)$$
$$\mu_{HM}(C) = \frac{C-159}{50} \times \frac{1}{total}$$
$$\mu_{High}(C) = \frac{223-C}{50} \times \frac{1}{total}$$
$$\textit{else if } R > 209 \textit{ then } \mu_{High}(R) = 1$$

For each R, G, and B color values set memberships (Low, Low Medium, High Medium and High) are selected using a triangle type membership function and calculated using the intensity range. Based on the intensity value, membership value for each of the four fuzzy sets is calculated. Fig. 1 shows the fuzzy membership functions for each color based on the color intensity using 8-bit representation, i.e. range of 0-255. Table 2 shows the interval for each fuzzy set membership function. H represents high function range, HM represents medium high function range, LM represents the next lower function range, and L represents the lowest function range.

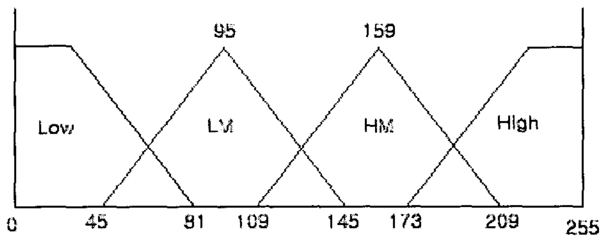

Fig. 1 Membership functions for each color based on the color intensity.

Table 2 Intervals for the fuzzy membership function

Fuzzy membership class	Intensity interval
Color frequency low.(L)	[0,81]
Color frequency little low.(LM)	[45,145]
Color frequency little high.(HM)	[109,209]
Color frequency high.(H)	[173,255]

B. Define decision rules for color information

First the intensity values for each color (red, blue and green) are obtained and the membership value for H, HM, LM, and L fuzzy sets is calculated using the function shown in Fig. 1.

Table 3 Rule of color reasoning

Color Preference	R	G	B	Membership Degree
White	H	H	H	H
	HM	HM	HM	HM
Black	L	L	L	H
	LM	LM	LM	HM
Gray	LM	LM	LM	H
	HM	HM	HM	H
Yellow	H	H	L	H
	HM	HM	L	HM
Orange	H	HM	L	H
	H	LM	L	HM
Brown	LM	LM	L	H
	HM	LM	L	HM
Pink	H	HM	HM	H
	H	LM	HM	H
Red	H	L	L	H
	H	LM	LM	HM
Green	L	H	L	H
	LM	H	LM	HM
Sky blue	LM	HM	H	H
	HM	HM	H	HM
Blue	L	L	H	H
	LM	LM	H	HM
Purple	HM	L	H	H
	HM	LM	H	HM

Now we must define the decision rules. These rules are defined in simple language terms. There are no decisions to be made about breakpoints. There are no decisions to be made about the functional form of the relationships. The rules can be understood at a common sense level. At the same time these rules result in specific and repeatable (same inputs gives same output) results. Table 3 shows the decision rules that relate the color to the fuzzy set membership value for the RGB color. It is possible to assign numerous different color categories. However, only 12 color categories are chosen for the fuzzy reasoning rules.

C. *Defuzzification to obtain precise color*

Next step is to draw inference using the rules shown in Table 3. In this case, we want to relate the observations to the rules. We are interested in what degree an observation has membership in the fuzzy set associated with each rule. The following memberships need to be evaluated as follows:

$$\mu_{Ri}(R_m G_m B_m, Y_m) = \min(\mu_R(R_i), \mu_G(G_i), \mu_B(B_i), \mu_Y(Y_i))$$
$$\mu_T(m_i) = \max(\min(\mu_R(R_i), \mu_G(G_i), \mu_B(B_i)), \mu_Y(Y_i))$$

For logical "and" operations using fuzzy sets the resulting membership functions are defined as the minimum of the values of the memberships on the component sets. If the rule has "or" operations the maximum of the memberships would be used. Further these memberships can be used to define a fuzzy set for the outcomes of the rules. Specifically, the membership of an observation on the rules fuzzy set becomes the maximum membership of the outcomes fuzzy set.

In this paper we use the Max-Min method to determine the membership of an observation. In step 5 combinations are performed. The task is to define one fuzzy set for the outcome considering all the rules and the values for a specific observation. One way to do this is take the maximum of the score for the membership function defined for each rule. In this paper, the composite score is determined using center of gravity method. The composite score X is calculated using equation below.

$$X = \frac{\sum (x_i \times \mu_i)}{\sum x_i}$$

In this phase, linguistic meaning is assigned to each pixel in the set using a fuzzy inference operation. To do this we first combine the results from all rules into the outcome fuzzy set and then transform this composite fuzzy set to a crisp number. Table 4 shows the final result of color evaluation using defuzzification.

A certain color is not chosen when the function range is less than 0.4 in spite of the maximum value. However, certain color is selected when function range is more than 0.4.

Table 4 The final color evaluation

Final color	Evaluation range
As membership value is low crisp value is 0	$0 \le X \pi 0.4$
To result of inference for membership value is highest color intensity	$0.4 \le X \le 1.0$

IV. EXPERIMENTAL ANALYSIS & RESULTS

In order to embody color sensitivity using fuzzy theory, experiments were carried out using Visual C++ 6.0 on an IBM PC with a Pentium TV CPU. Fig. 2 shows the screen capture of a window designed using an image editing program for providing a range of color options to the user. The user chooses the color by clicking on the color palate provided in that window. Note that a large variety of colors are available to the user to choose from. After the user selects the color from the variety of options, fuzzy logic and reasoning approach discussed in this paper is applied and the nearest matching color is determined. Fig. 3 shows the screen capture where a user has chosen a color from the palate (on the left). On the right the nearest match chosen by our approach is shown in Fig. 3.

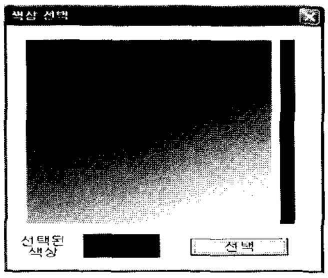

Fig. 2 Screen capture of the computer application showing the color palate.

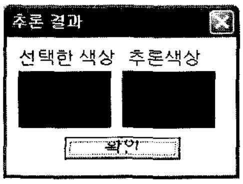

Fig. 3 Screen captures showing the color chosen by the user and the color match obtained by the fuzzy intelligent system.

Fig. 3 here shows selection of optional black level color, RGB(41,11,1) by the user on the left. On the right the fuzzy logic and reasoning analysis result shows the value RGB (0,0,0). Based on the color value obtained by fuzzy logic and reasoning analysis Fig. 4 shows the result based on the research of Bjurstadt.

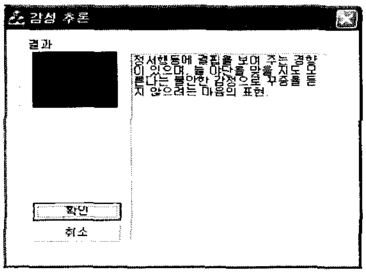

Fig. 4 Screen captures displaying the color preference and the personality of user.

V. CONCLUSIONS

We have discussed a fuzzy logic based approach for assigning linguistic labels to a variety of color combinations. An intelligent system has been designed which displays a color palate to the subject. The subject chooses the color of his preference and based on the fuzzy reasoning algorithm system performs computations. Finally, the color preference is linked by the system to subject's personality based on existing psychological studies. Results of experiments with this system demonstrate its success.

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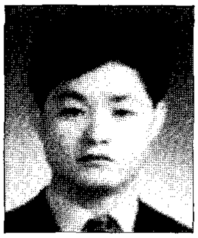

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