

ANALYZING COLOR FOR PERCEPTION BY FUZZY LOGIC

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ABSTRACT. This article presents a method to personalize user interface (UI) such as icon to suit each users' age by using fuzzy logic. First, the color of the icons are analyzed as RGB color values then converted to the HSV color model to make them more suitable to fuzzy membership functions. Then, the rules to define the color components to suite the perception of each user's group range were defined. These rules can then be used as a model to select appropriate icons suitable for the design of human-computer interfaces on smart mobile phones.

Keywords: color, icon, user interface, human interface, perception, fuzzy

INTRODUCTION

The current usage of mobile phones has increased steadily every year. From Figure 1 shows a forecast in the growth rate of each device type.

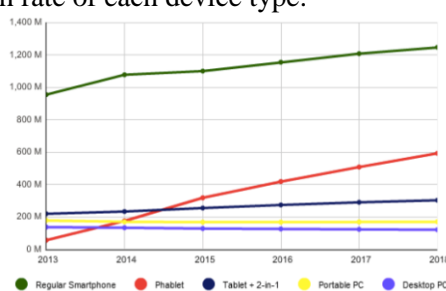


Figure 1. Worldwide Smart Connected Device Shipment Forecast, 2013-2018

(source : <http://www.technologytell.com/apple/files/2014/09/IDCPhabletgrowth.png>)

Although phablet type has high growth rate, but in terms of quantity, regular smartphone is still ranked first. From the rate of growth, smart phones have become a part of people's lives today. The educational software is another important factor for the development of smart phone usage and efficiency.

The United Nations Educational, Scientific and Cultural Organization (UNESCO), has held a meeting to promote learning with mobile phone (UNESCO Mobile Learning Week) in Paris before actually used in several countries in the Middle East, Africa, Asia, Europe, North America and Latin America. Learning Support Project of UNESCO emphasize on several activities. One of the major activities is the development of communication technology in mobile phones, which are beneficial to the students and teachers to develop educational content and searching (UNESCO, 2011) for effective realization of learning through digital media as much as possible.

To make use of the user interface efficiently and effectively, the sender (designer) and receivers (users) should understand the purpose of the communication clearly. But misunderstanding and discrepancy between the sender and receiver can be found in many different conditions, such as the format, content, uniqueness, aesthetic and Interpretation including a range of different age and health condition that would make the outcome different from the original and may give different results on the learning process (Sandhofer & Smith, 2001). Studies of Lynnay (Huchendorf, 2007) about color and memory while learning found that the tone of the color affects the recognition of students differently. Not only the children but also the elderly which should be paid attention as well.

The purpose of this research is to suit the colors for the user interface design and the conversion from RGB to HSV in order to use fuzzy logic to change the user interface particularly the color icons. It is the basis for the design of Human Interaction for mobile equipment to increase and improve efficiency. This could be the link between users from different ages. It helps reduce errors, including the loss in many aspects that may occur.

THEORIES

HSV (Hue Saturation Value)

Color System or Color Space is a mathematical model that has many models, such as RGB (R = Red, G = Green, B = Blue) and HSV (H = Hue, S = Saturation, V = Value). RGB, Additive Color Mode, display in the electronics, such as televisions and computers. Therefore, it is applied to Websites, or TV. HSV Color Mode that is widely used in computer graphics in general.

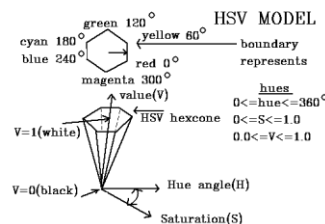


Figure 2. Munsell's HSV Model

(source: <http://www.siggraph.org/education/materials/HyperGraph/color/images/colorhs1.gif>)

This article has opted HSV color models (Georgieva, Dimitrova & Angelov, 2005) that are part of the Munsell theory used as a fuzzy set of colors. Because HSV color mode is the segmentation of color representation defined in polar coordinates expressed in degrees or radians. (Serway, Raymond, Jewett & John, 2005) For example, in Figure 2. HSV Color models is defined by three components: Hue (pure color) such as red, purple, green, yellow, by definition, is 0-360 degrees, Saturation (chroma) is defined as the percentage of 0-100 (0-255) and Value (light colors) is defined as the percentage of 0-100 (0-255).

Color Psychology

Color influence the human mind and each color has a different feel. The appropriate color for each time, place and culture is based on knowledge, experience, race, religion, gender, preferences, habits and tastes of each person. Goldstein said that the meaning of the color such as red and yellow are stimulating and generating conflicts (Goldstein, 1942). Green and blue means quiet and agreeable. Stone and English (1998) further studied wavelength of the color and found that the wide wavelength of the color red stimulates arousal. The short-wavelength like green induced relaxed feeling.

Research about color of font and memory found that blue and gray are suitable for men, while blue is suitable for women. The brighter color affects memory more than darker color (Le and Castillo, 2009). Among 3 background colors, white is the best for improving memory performance followed by yellow purple respectively (Thompson, 2011). Camps concluded that green and yellow-green raise awareness for the elderly more than young adult and children while pink and orange are likely to stimulate interest in children and adolescence better than the elderly (Camps & Pérez-Carpinell, 2013). Research has shown that while cool colors stimulate interest in the elderly well while warm colors stimulate interest in children and adolescence better.

Icon

From a survey of the United States' people activities on the mobile phone in the summer of 2012 (Duggan & Rainie, 2012). We learn about activities of the user's mobile phone to design icons such as Camera SMS Internet Email and Music icons. This research selected icons in iOS 6.2, Apple's operating system for mobile devices, for use in experiments.

Perception

Perception is the process of knowledge that has been linked to sensory perception and interpretation of it (Matlin, 2002). Recognition by the old knowledge, such as the memory of a face that had met or ever known, and the perception by associating stimuli in the environment, such as color, size, shape, surface, which can affect the recognition (Winawer & Witthoft, 2013). There are many differences value of color such as green, light green, dark green, so it's impossible to name all levels of color clearly.

Research on color perception from Jalil found that age and gender also influence the perception of color, with a survey among students (Jalil, Yunus & Said, 2013). Men will enjoy and have fun with red than females while the female is likely to use pink to convey the feeling of love than men. Some colors like blue, white and gray have the same preferences for both men and women.

Fuzzy Logic

Fuzzy Logic was invented by LA Zadeh in 1965. Fuzzy logic principles (Zadeh, 1965) rely on the idea of vagueness, that the truth can be both certainty and uncertainty. This uncertainty can be defined as a fuzzy set, uncertainty and ambiguity.

METHODOLOGY

Research Framework

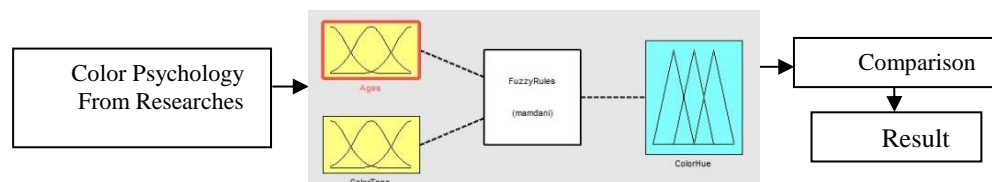


Figure 3. Research Framework

Input Data Variable

Input variables using fuzzy sets defined as two variables including Ages and Color Tones, the color temperature. Ages Fuzzy Set comprised of 3 members: Adolescent, Young Adult and Elderly. The age range was 0-80 years, so the membership functions are represented using Trapezoidal membership function. For example, in Figure 4. Color Tones Fuzzy Set has two members, hot colors and cool colors. The Color Tone range is defined as 0-360 degrees to match the color wheel, and the membership functions are defined as Trapezoidal membership function as well. For example, in Figure 5.

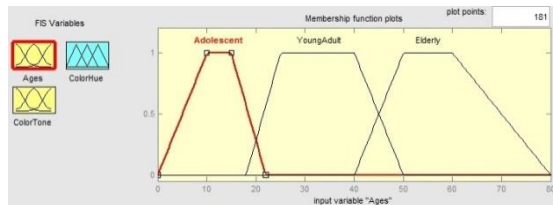


Figure 4. Ages Fuzzy Set

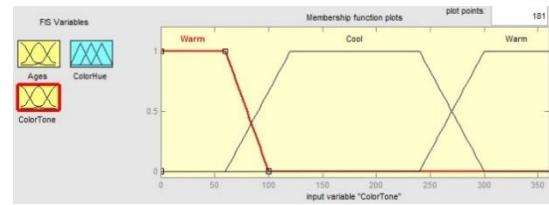


Figure 5. Color Tones Fuzzy Set

Results Data Variable

The result indicates that the colors are suitable for age groups by using fuzzy set of Hue. Fuzzy Set of Hue comprised of 6 members: Red, Yellow, Green, Blue, Violet and Magenta. The color range is 0-360 degrees to match the color wheel. For example, in Figure 6.

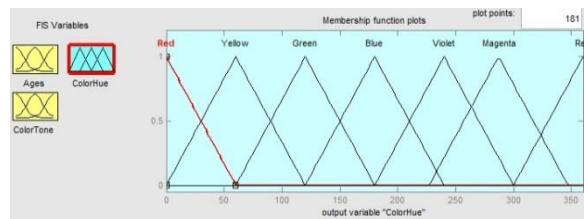


Figure 6. Hue Fuzzy Set

Fuzzy Rules

Fuzzy rules generated from colors research data and experiments. The research data are used as a model to create fuzzy rules for determining the appropriateness of age range, color tone and hue. For example, the possible fuzzy rules as shown in Table 1.

Table 1. Fuzzy rules

1. If (Ages is Adolescent) and (ColorTone is Warm) then (ColorHue is Red) (1)
2. If (Ages is Adolescent) and (ColorTone is Warm) then (ColorHue is Yellow) (1)
3. If (Ages is Adolescent) and (ColorTone is Warm) then (ColorHue is Red) (1)
4. If (Ages is Adolescent) and (ColorTone is Warm) then (ColorHue is Yellow) (1)
5. If (Ages is Elderly) and (ColorTone is Cool) then (ColorHue is Green) (1)
6. If (Ages is Elderly) and (ColorTone is Cool) then (ColorHue is Yellow) (1)
7. If (Ages is YoungAdult) and (ColorTone is Warm) then (ColorHue is Magenta) (1)
8. If (Ages is YoungAdult) and (ColorTone is Warm) then (ColorHue is Magenta) (1)
9. If (Ages is Adolescent) and (ColorTone is Warm) then (ColorHue is Magenta) (1)
10. If (Ages is Adolescent) and (ColorTone is Warm) then (ColorHue is Magenta) (1)

Determination of Hue for icon.

Adobe Photoshop CS5 and MATLAB R2012A applications are used to determine the pure color (Hue).

$$\begin{aligned}
 R' &= R/255 \\
 G' &= G/255 \\
 B' &= B/255 \\
 Cmax &= \max(R', G', B') \\
 Cmin &= \min(R', G', B') \\
 \Delta &= Cmax - Cmin
 \end{aligned}
 \tag{1}$$




RGB values are converted to HSV. This conversion is to bring out Hue value. Hue in HSV color mode is clearer than RGB because RGB has light and brightness values embedded in it.

Interpretations of Hue formula:

$$H = \begin{cases} 60^\circ \times \left(\frac{G'-B'}{\Delta} \bmod 6 \right), & Cmax = R' \\ 60^\circ \times \left(\frac{B'-R'}{\Delta} + 2 \right), & Cmax = G' \\ 60^\circ \times \left(\frac{R'-G'}{\Delta} + 4 \right), & Cmax = B' \end{cases}
 \tag{2}$$

Color Analysis of icons with Histogram can be explained clearly as shown in Table 2.

Table 2. Hue, RGB, and HSV of Icon Color

Name	Icon	Color Mode	Median	Min	Max
SMS		Hue (0-360)	80 (lime)	0	336
		RGB	165,218,148	17,52,0	255,255,255
Email		Hue (0-360)	265 (violet)	0	300
		RGB	187,213,239	27,54,53	255,255,255
Music		Hue (0-360)	23 (orange)	0	216
		RGB	209,147,81	0,0,0	255,255,255

THE EXPERIMENTAL RESULTS

The result from the analysis of icons using fuzzy rules to find the appropriate color for the perception of different age groups by bringing out true color in the icons are comparatively analyzed as followed.

As shown in figure 7, Elderly at the age value of 55.4 years and color tone at 185 degrees are in accordance with rule 5 and 6 of the fuzzy. From centroid defuzzification methods gives a result as the 90 degrees of Hue. When the results were compared with the colors wheel, it belongs in green color group. The results are compare to the hue of the icons, as shown in table 2 and were found to be similar to the SMS icon.

As shown in figure 8, Young-adult at the age of 36.3 years and color tone value of 76.9 degrees be in accordance with rule 7 of the fuzzy. From centroid defuzzification methods gives a result as the 278 degrees of Hue. When the results were compared with the colors wheel, it belongs to violet color group. The results are compare to the hue of the icons, as shown in table 2 and it was close to the email icon.

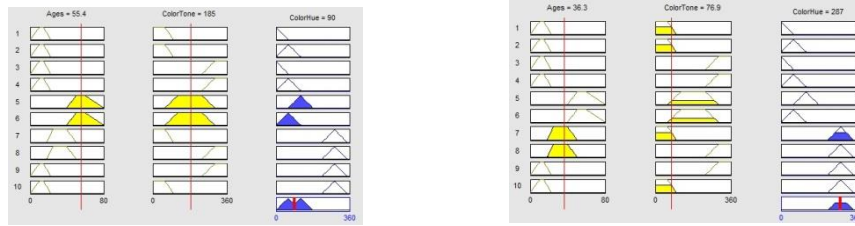


Figure 7. The result from fuzzy rule 5 and 6 **Figure 8. The result from fuzzy rule 7**

Icons are critical interfaces on mobile devices. By using fuzzy logic to analyze the appropriateness of the color of icons for each age group, it is possible to choose or create icons that can be used in mobile-learning course effectively.

CONCLUSIONS

The study of the icon color suitable for each age group found that color can affect the mind and the perception of the user. Each icon composes of many colors so it must analyzed to find the average value of the color to predict the suitability of the age-appropriate colors. The Research on color psychology (Camps & Pérez-Carpinell, 2013; Georgieva, Dimitrova & Angelov, 2005; Goldstein, 1942; Le & Castillo, 2009; Pérez-Carpinell, de Fez, Baldoví & Soriano, 2013; Thompson, 2011) presented the comparisons of colors with the matched age groups, so it can be used to prepare the fuzzy rules for the prediction.

To increase the value of this research, the experiment should be performed again with a new trial group. The reason for doing so is to confirm the suitability of the color that affects to user's perception. This will lead to the reasonable design of human-computer interfaces on smart phones.

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