Fuzzy Set Theoretical Approach to the Tone Triangle System

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ABSTRACT

The present study considers a fuzzy color system in which three fuzzy sets are constructed on the tone triangle. This system processes a fuzzy input and outputs a color on the color triangle system. Two fuzzy sets (not black and white) are applied to the tone triangle relationship. By evaluating the attributes of chromaticness, whiteness, and blackness on the tone triangle, a target color can be easily obtained as the center of gravity of the resulting fuzzy set. The output of the system is a tone triangle, which includes a compound vector with three weights (scalars) in color space. The differences between a fuzzy input and the resulting inference output is shown by the input-output characteristic (linear shape and right triangle shape) between the chromaticness, the whiteness, and the blackness of the input and the chromaticness of the output.

Keywords: Additive Color Mixture, Color Triangle, Conical Fuzzy Input, Fuzzy Rules, Fuzzy Set of Triangular Pyramid, Fuzzy Set Theoretical Approach, Tone-Tone Mapping, Tone Triangle, Vague Color

INTRODUCTION

Using the additive color mixing reported in recent studies (Sugano, 2006b; Sugano, 2007), the relationship between fuzzy sets on the color triangle and fuzzy inputs of conical membership functions was examined. A color triangle (planar region) represents the hue and saturation of various colors (Tilley, 1999). The six fundamental colors and white can be represented on a color triangle (see Figure 1b). With our method, vague colors on the color triangle and the chromaticity diagram are clarified.

A recent study (Sugano, 2011) reported a technique that used a fuzzy set theoretical method and an additive color mixing method to obtain expressions for the tone triangle in the red-green-blue (RGB) system. The relationship between two or three fuzzy sets on the tone triangle (antecedent) in Figure 1a and the conical fuzzy inputs was examined. The six fundamental colors and white can be represented on the color triangle (consequent) in Figure 1b.

In the present study, we reexamine a technique for obtaining expressions of the color triangle in the RGB system. This system clarifies colors that were vague so that the output can be represented on a tone triangle. In the proposed system, the average color value is determined as the center of gravity of the attribute information of vague colors.

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The motivation for this study is to better understand human-computer interactions with human subjectivity. The specific objective of this paper is to determine how fuzzy inputs are mapped from the tone triangle (antecedent) via the color triangle (consequent) to the tone triangle (Sugano, 2013). Fuzzy sets provide a mathematical way to represent vagueness and fuzziness in a humanistic system (Ross, 2004). The applications for which this fuzzy theoretical approach is useful include vague color information processing and color identification.

**METHODS**

**Color Triangle and Additive Color Mixture**

Additive color mixing occurs when two or three beams of differently colored light combine. It has been found that mixing just three additive primary colors (red, green, and blue) can produce the majority of colors. In general, a color vector can be described by a scalar and a direction. These quantities are referred to as the tristimulus values, $R$ for the red component, $G$ for the green component, and $B$ for the blue component, and are given as follows:

$$
\vec{C} = \vec{R} + \vec{G} + \vec{B}
$$  \hspace{1cm} (1)

This is referred to as the RGB color model (Figure 2) and allows colors to be represented by a planar diagram. The RGB color model can be used to identify colors as the red, green, and blue components ($R, G, B$) corresponding to the three axes of color space as shown in Figure 2. The coordinates ($r, g, b$) on the color triangle can specify one of a range of colors. These coordinates correspond to the relative amounts of $R, G,$ and $B$ that make up the color. For example, the coordinates specifying the center of the color triangle represent the case in which the three primary colors are mixed in equal proportion and thus indicate the color white. Such representations are referred to as chromaticity diagrams, which represent hue and saturation, but not lightness (Tilley, 1999).

On the color triangle (the dotted area in Figure 2) (Valberg, 2005), the percentages of redness, greenness, and blueness, where the total of the three attributes is equivalent to 100%, specify a
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