Soft Computing as a Methodology for Color Processing

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Summary

High successful applications of soft computing and fuzzy logic can be found in engineering disciplines. Current research is done for computational subject, e. g. computing with words, or computing with colors, which is one of the new ideas for the processing of color information. The main fact of this approach is the adequate representation of color and its linguistic description. This approach can be applied to different engineering fields. This work continues the idea of linguistic color processing, that we presented in [8] for the first time.

Keywords: Color, Color Models, Fuzzy Logic

1 INTRODUCTION

Color is a human perception, created by light of specific wavelengths that falls on different cones in the eye's retina. There are three types of cones that approximately correspond to red, green and blue lights and one additional type that corresponds to the brightness. As a result, color is created in our brain, when we see a distribution of light of different wavelengths. This individual perception and also the individual naming of colors makes it difficult to use knowledge that is based on colors in technical applications.

A adequate representation of colors and the use of fuzzy logical for a linguistic and vague description is described here to overcome the stated problems.

2 COLOR MODELS

Many color representations are based on technical demands. Examples are the red, green, blue division of colors for televisions or the cyan, magenta, yellow division for the printing media. These two representations reflect the additive and subtractive mixing of few base colors to obtain a large set of displayable or printable colors. Technical representations are suitable for displaying colors, but fail if a deeper understanding of color is needed [10].

One field of applications is the knowledge based reasoning, where knowledge of human experts is acquired to set up systems for decision support. Human description of colors is not based on the additive or subtractive mixing of base colors [5, 7]. It is more oriented by characteristics like hue, brightness or lightness. Apart from technical color models another class of color models exist, that fulfills these human demands.

Modeling colors in this way is more like an artist view of mixing colors: Starting from a pure color (hue), white pigments are used to lighten the color (decrease of saturation), and black pigments are used to darken the color (decrease of lightness). One of the earliest of these color models was the one originated by A. H. Munsell in 1915 [4, 6].

The interesting fact in this color model is that Munsell arranged the hues in a 360° polar coordinate system. The same arrangement of colors is used in the HSI-color model, which is similar to Munsell's color model.

The HSI-model is well suited for the linguistic processing of color, because colors that are similar for humans are grouped together and there is a clear distinction of colors and grays. The 3-dimensional model can be easily reduced to a 2-dimensional one, by simply dropping the intensity coordinate when the pure and light colors are important, or by dropping the saturation coordinate when pure and dark colors are important. These operation result in the HS- and HI-sub models, that are used throughout approach [8].

2.1 COLOR MODEL CONVERSION

A conversion from the RGB-color model to the HSI-color model can be easily done by using the following algorithm [3, 11]. At first some constant values have to be defined: The unit vector $\vec{I}_u$, the red vector $\vec{R}$, and the green unit vector $\vec{G}_u$ are defined:

$$\vec{I}_u = \left\| \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \right\|, \; \vec{R} = \begin{pmatrix} 2 \\ -1 \\ -1 \end{pmatrix} \tag{1}$$

$$\vec{G}_u = \left\| \vec{I}_u \times \vec{R} \right\| = \begin{pmatrix} 0 \\ \frac{1}{\sqrt{2}} \\ -\frac{1}{\sqrt{2}} \end{pmatrix} \tag{2}$$

$$\vec{R}_u = \left\| \vec{R} \right\| = \begin{pmatrix} \frac{\sqrt{6}}{3} \\ -\frac{\sqrt{6}}{6} \\ -\frac{\sqrt{6}}{6} \end{pmatrix} \tag{3}$$

A color $\vec{c}$ that is given as

$$\vec{c} = \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

where R, G, B denote the red, green, and blue part of the color can then be converted into hue, saturation and intensity using

$$I(\vec{c}) = \frac{1}{\sqrt{3}} \vec{c} \cdot \vec{I}_u \tag{4}$$

$$S(\vec{c}) = 1 - \frac{\min(\vec{c})}{I(\vec{c})} \tag{5}$$

$$H(\vec{c}) = \operatorname{atant}\left(\vec{c} \cdot \vec{G}_u, \vec{c} \cdot \vec{R}_u\right) \tag{6}$$

The operations $\|\vec{v}\|$, $\vec{v}_1 \cdot \vec{v}_2$, and $\vec{v}_1 \times \vec{v}_2$ stand for normalization, vector dot, and vector cross product.

3 SOFT COMPUTING APPROACH

The main idea of fuzzy logic and fuzzy logic based based color processing can be found in [1, 8]. Like other fuzzy systems, the automated generation of the necessary fuzzy sets is not simple. An automated generation, based on the combination of evolution strategies and fuzzy logic [2] can be used, if a sufficient number of supporting points can be found.

To calculate these supporting points a statistical analysis of the image colors and a representation of the color distribution as a histogram is needed. Examples are shown in figure 1 and 2.

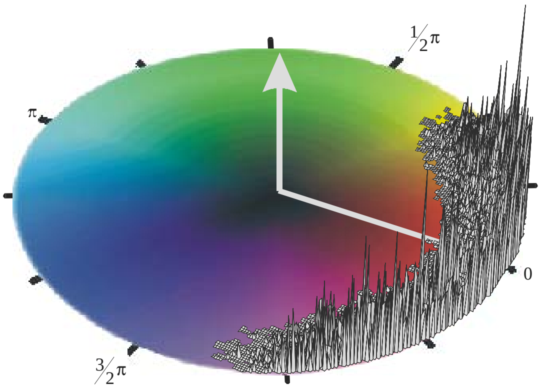

Figure 1: Color histogram 1

The shown histograms are results of the processing of some samples. These histograms are frequency distributions of the used colors in those images. The histograms can directly be used to calculate the membership of a given color. The only calculation needed is the normalization of the frequencies to the interval [0, 1].

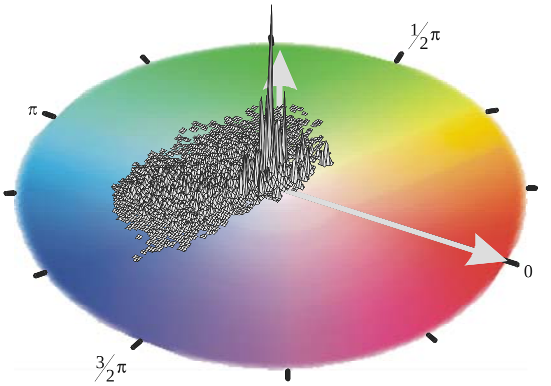

Figure 2: Color histogram 2

Another approach is the automated generation of fuzzy sets, that corresponds to the given frequency distribution. These fuzzy sets should be of the shape described in [8]. An example for the base color red, green and blue, defined this way shows figure 3.

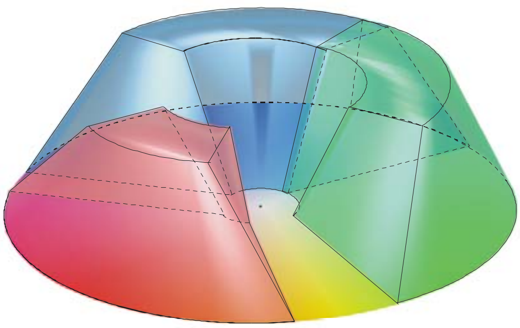

Figure 3: Definition of red, green, and blue

One way to generate them is the extension of our algorithm described in [2] from 1-dimensional fuzzy sets to 2-dimensional ones. This generation of 2-dimensional fuzzy sets may not be confused with the generation of 2-dimensional fuzzy rulebases. The first method, that is needed here, is the generation of fuzzy sets defined over a 2-dimensional universe. The latter one is the generation of a fuzzy rulebase system with 2 input variables.

4 APPLICATION EXAMPLE

Resistance spot welding is a welding process that uses the inherent resistant of metal workpieces to join two sheets of metal by the flow of electrical current. This current is passed trough the metal sheets and generates the welding heat. The same electrodes that supply the current, apply simultaneously a force and the two metal parts are joined.

Most of the quality testing systems have to destroy the welding joint in order to obtain quality measures like longitudinal and transverse tensile strength, bend strength, or hardness. The quality criteria of a single welding spot can be divided into two major ranges: physical and optical criteria. Physical criteria, like tensile or bend strength describe the physical properties of a welding joint. Most important quality criteria can be determined using color information of the welding spot. Some preprocessing using standard methods from the field of image processing may be necessary [9].

Using the idea of fuzzy color description only few colors (blue, red, and gray) have to defined. The use of modifiers allows to automatically generate corresponding color definitions like light red, dark red, light blue, and dark blue. Transforming the experts knowledge about the colors into a fuzzy rulebase leads to the following set of rules:

IF COLOR_OF_INNER_SPOT IS BLUE
THEN QUALITY IS GOOD

IF COLOR_OF_OUTER_SPOT IS LIGHT_BLUE
THEN QUALITY IS GOOD

IF COLOR_OF_IMPACT_ZONE IS DARK_RED
THEN QUALITY IS GOOD

IF COLOR_OF_INNER_SPOT IS LIGHT_RED
THEN QUALITY IS POOR

IF COLOR_OF_OUTER_SPOT IS BLUE
THEN QUALITY IS POOR

IF COLOR_OF_OUTER_SPOT IS RED
THEN QUALITY IS POOR

IF COLOR_OF_IMPACT_ZONE IS LIGHT_RED
THEN QUALITY IS POOR

This set of rules can be evaluated using standard fuzzy techniques in combination with the described methods to calculate the membership values of colors. Any fuzzy system that allows to add new functions for the calculation of membership values can be extended to benefit from fuzzy color processing.

5 SUMMARY AND OUTLOOK

Soft computing for color processing is a powerful approach. Problems with the generation of the corresponding fuzzy sets can be solved using the two mentioned methods. Only few rules are needed to solve complex problems. In our example, the evaluation of a total of seven rules is enough to distinguish between welding points with a good and those with a bad quality. The computational demand is low, so cheap microcontrollers can be used to solve this task. The ideas of linguistic modifiers can be integrated, to generate other color definitions like *light_red*, *dark_red* or *more_or_less_red* automatically from the definition of the color *red*. This will reduce the development time for new applications.

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