Adaptive Subtitle and Caption Coloring Using Fuzzy Analysis

Mohsen Davoudi
Zanjan University
mohsen.davoudi@gmail.com

Mehdi Davoudi
Zanjan University
mehdi.davoudi@gmail.com

Nima SeifNaraghi
Eastern Mediterranean University, Turkey

Abstract

In this paper, a novel approach is proposed for automatic adaptive subtitle color changing based on fuzzy logic. Fuzzy analyzer, the core of this system, changes the color of the subtitle/caption to a 'pleasant' color according to color harmony and the visual perception of the image background colors. Using RGB histograms of background image, the fuzzy analyzer computes the R, G and B values for the color of the subtitle or caption based on fuzzy rules which are designed to satisfy complementary color and subtitle-background color harmony conditions.

1. Introduction

Subtitles are textual versions of the dialog in movies and television programs, usually displayed at the bottom of the screen. They can either be a form of written translation of a dialog in a foreign language or a written rendering of the dialog in the same language with or without added information intended to help viewers to follow the dialog.

The use of subtitling to represent audio dialogue of film and television presentations is well known and understood. In context of learning technologies, deaf and hearing-impaired students also use subtitles to read dialogue and identify characters. Some simple manipulations such as the increasing of text sizes and the changing of color are often made available.

Subtitling is included with Analogue and Digital Video Broadcasts, DVD, CD-ROM movies and other multimedia platforms. Additionally, subtitles are produced to enable hearing audiences to watch foreign language films and television [1].

Till now, the subtitled movies, pictures taken by camera and TV shows had a constant color subtitles in white, yellow, green, etc. It caused an unpleasant view of subtitles on the images when the background color was the same with the subtitle color or they were not matched together psychologically.

In the proposed approach the system using some algorithms changes the color of the subtitle to a pleasant color based on visual perception of background view and color psychology concerns. They are included in the fuzzy rules has been applied to fuzzy analyzer structure. The concept of this approach is depicted in the block diagram of figure 2.

The main idea is to compute the subtitle color while it is contrary to overall color of the averaged summation of the image background colors on the color wheel (see figure 1). But the rigid color opposition may not cause a pleasant combination of subtitle and background image color. In the proposed method using color harmony rules the fuzzy analyzer selects a pleasant opposite color for the subtitle. The pleasant opposite colors may not be opposite directly on the color wheel. The selected color will be somehow cooler/warmer dependent on the image (see figure1).

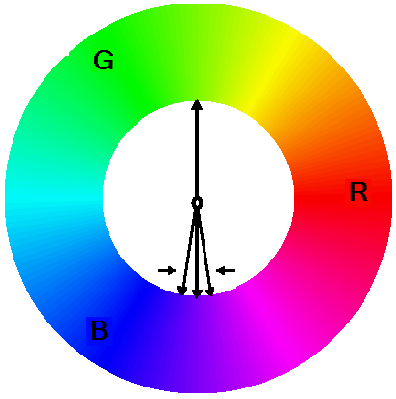

Figure 1: The opposite pleasant colors on the color wheel (A: a sample color of overall averaged summation of the image background colors, B: the rigid opposite color, C: a cooler opposite color and D: a warmer opposite color)

The rest of the paper is organized as follows. In the first section we develop the assumptions and image pre-processing. The structure of the fuzzy analyzer is explained in the second section and the last section demonstrates the simulation results.

978-0-7695-3507-4/08 $25.00 © 2008 IEEE
DOI 10.1109/CSIE.2009.841

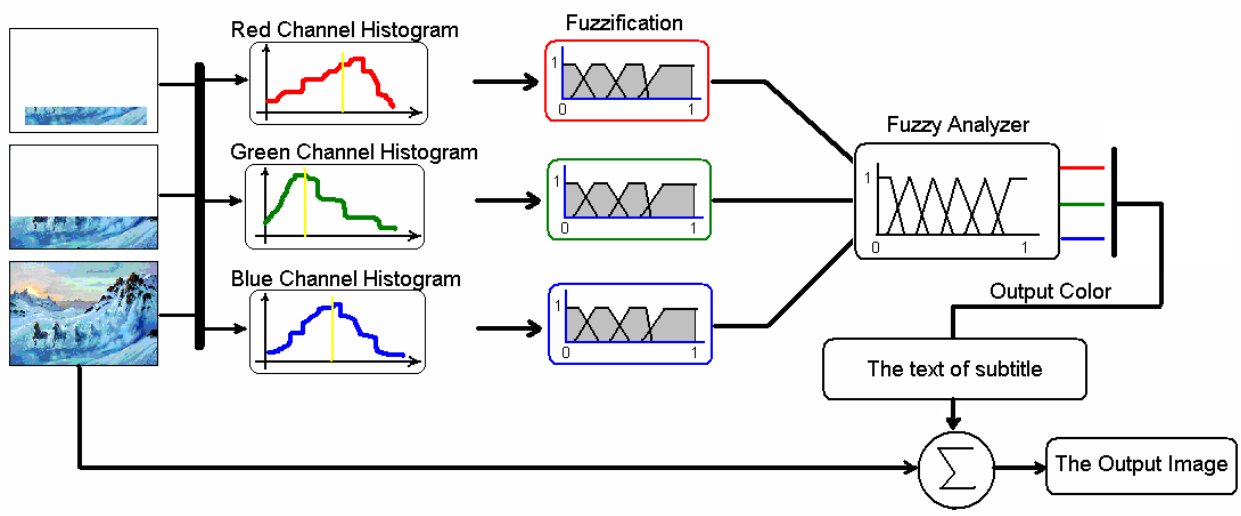

Figure 2: The block diagram of automatic adaptive subtitle color changing based on fuzzy logic

2. Image pre-processing

The aim of this section is to prepare information needed for fuzzy analysis. For sake of visibility of the subtitle, the closer image pixels to the subtitles should affect more on the color of subtitles. Assuming that the subtitle is captioned in the below part of image, we divide an image screen into three regions: 1) full screen image (F) which contains all pixels of the screen, 2) below part of the image (B) which is the below part of the screen and 3) subtitle region (S) which is a rectangular space in which the subtitle will be put (see figure 3).

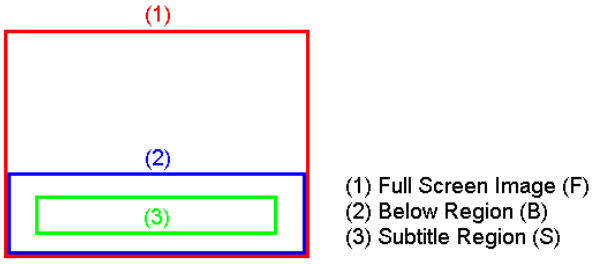

Figure 3: The image is divided into three regions

The regions F, B and S are weighted differently regarding to the importance of the regions:

$$W(S)>W(B)>W(F) \quad (1)$$

where $W(x)$ is the weight of region X. For sake of subtitle visibility, the background color of S region is more important than the F and B regions. The regional weighting results in a subtitle color which is more opposite to the S region rather than F and B regions.

For simplicity, the weights are assumed to be constant (a, b, c). The weights are:

$$W(F)=\frac{A_F}{A_F}, W(B)=\frac{A_F}{A_B}, W(S)=\frac{A_F}{A_S} \quad (2)$$

where A_F, A_B and A_S are the image areas of F, B and S regions of the given image.

According to the block diagram shown in figure 2, the gray level histograms of the Red, Green and Blue channels of the image are computed and weighted separately for F, B and S regions based on inequality of (1). Then, the weighted histograms of each channel for all of the regions are summed:

$$R_w = W(F)*hist_r(F)+W(B)*hist_r(B)+W(S)*hist_r(S) \quad (3)$$

$$G_w = W(F)*hist_G(F)+W(B)*hist_G(B)+W(S)*hist_G(S) \quad (4)$$

$$B_w = W(F)*hist_B(F)+W(B)*hist_B(B)+W(S)*hist_B(S) \quad (5)$$

where R_w, G_w and B_w are summation of regional weighted histograms for red, green and blue channels respectively. $hist_x(y)$ is defined as *x-channel histogram of the y region*.

The mean value of the R, G and B summed histograms are the values to be given as the inputs to the fuzzy analyzer which is discussed in the following section.

3. Fuzzy analyzer

In this section the fuzzy analyzer and its membership functions, fuzzy rules and defuzzification method are discussed briefly. Three fuzzy variables

(mean values of red, green and blue histograms of the background image) are inputs of the subtitle fuzzy analyzer. After fuzzification of inputs, the rules of subtitle color selection are applied and the output matrix (R, G and B values of subtitle color) is generated and defuzzified using the *centre of area* defuzzification method.

The block diagram of the fuzzy analyzer is depicted in figure 4 which the left blocks are the mean values of *Red*, *Green* and *Blue* histograms of the background image are the inputs of the fuzzy analyzer and the right blocks are the Red, Green and Blue channels of the selected color for subtitle.

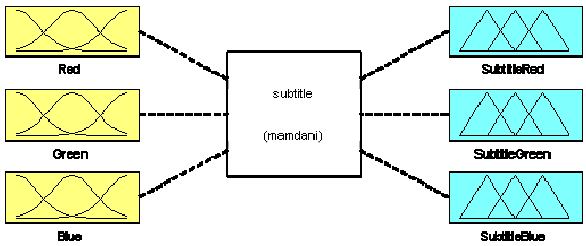

Figure 4: The block diagram of subtitle fuzzy analyzer

The fuzzy sets of the RGB channels for data input fuzzification on RGB cube are shown in figure 5.

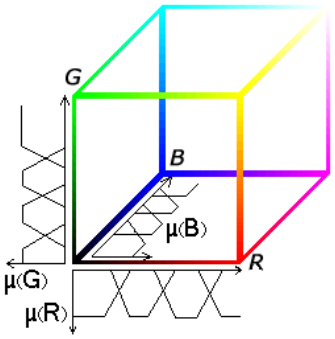

Figure 5: Fuzzy sets of the RGB channels for data input fuzzification

The fuzzy analyzer consists of 48 fuzzy rules which are derived from our visual perception, color psychology and color harmony between subtitle color and image background colors. We used three principles for forming the rules:

1) the color of subtitle should be opposite to the averaged summation of the image background colors,
2) in an image with warm colors (Red, Orange or yellow) do not use very cool colors like blue as subtitle color and vice versa,
3) in a dark image do not use very bright subtitle colors (and vice versa).

The 3-D visualizations of some rules are shown in figure 6. Some samples of these rules are given below [2, 3].

R_R^1 : *If (Red* is L*) and* (*Green* is L) *and* (*Blue* is L) then (*SubtitleRed* is H)

R_R^2 : *If (Red* is M*) and* (*Green* is M) *and* (*Blue* is L) then (*SubtitleRed* is ML)

R_R^3 : *If (Red* is H*) and* (*Green* is L) *and* (*Blue* is H) then (*SubtitleRed* is L)

where Zero, low (L), medium (M), high (H) are linguistic values of fuzzy sets for the averaged summation of *red, green* and *blue* histograms of the image. The fuzzy set of generated subtitle color is: zero (Z), very low (LL), low (L), low-medium (LM), medium (M), medium-high (MH) and high (H). We use a general form to describe the fuzzy rules:

R_R^i : *If (*Red *is* X_{1i}*) and (*Green *is* X_{2i}*), and (*Blue *is* X_{3i}*), then (*SubtitleRed *is* Y_i*), i =1… 48*

R_G^i : *If (*Red *is* X_{1i}*) and (*Green *is* X_{2i}*), and (*Blue *is* X_{3i}*), then (*SubtitleGreen *is* Y_2*), i =1… 48*

R_B^i : *If (*Red *is* X_{1i}*) and (*Green *is* X_{2i}*), and (*Blue *is* X_{3i}*), then (*SubtitleBlue *is* Y_3*), i =1… 48*

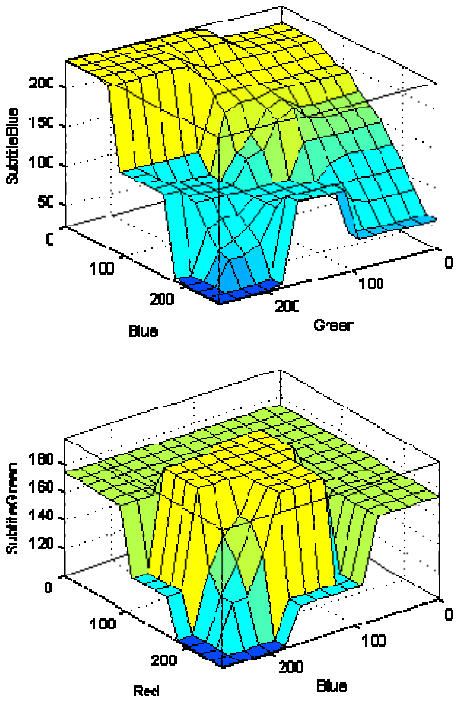

Figure 6: 3-D surfaces shaped by fuzzy rules

where X_{1i}, X_{2i} and X_{3i} are triangle-shaped fuzzy term sets and Y_i is a fuzzy singleton.

Let X and Y be the input and output space, and P, V be arbitrary fuzzy sets in X. Then a fuzzy set, $[P,V]\circ R^i$ in Y, can be determined by each R^i.

We use the sup-min compositional rule of inference:

$$m^i_{R^i} = \mu_{\mathrm{Re}\,d^i}(X_{11}).\mu_{Green^i}(X_{21}).\mu_{Blue^i}(X_{31}) \quad , i=1...48$$
$$m^i_{G^i} = \mu_{\mathrm{Re}\,d^i}(X_{12}).\mu_{Green^i}(X_{22}).\mu_{Blue^i}(X_{32}) \quad , i=1...48$$
$$m^i_{B^i} = \mu_{\mathrm{Re}\,d^i}(X_{13}).\mu_{Green^i}(X_{23}).\mu_{Blue^i}(X_{33}) \quad , i=1...48$$

Where $\mu_{\mathrm{Re}d^i}(X_1), \mu_{Green^i}(X_2), \mu_{Blue^i}(X_3)$ membership functions of Red, Green and Blue histograms are averaged summation of the image respectively.

By using the *center of area* (centroid) method in the defuzzifier, the crisp outputs can be obtained*:*

$$SubtitleRED = \frac{\sum_{i=1}^{48} m^i_R \cdot \overline{y}_1{}^i}{\sum_{i=1}^{48} m^i_{R^i}} \quad (6)$$

$$SubtitleGREEN = \frac{\sum_{i=1}^{48} m^i_G \cdot \overline{y}_2{}^i}{\sum_{i=1}^{48} m^i_{G^i}} \quad (7)$$

$$SubtitleBLUE = \frac{\sum_{i=1}^{48} m^i_B \cdot \overline{y}_3{}^i}{\sum_{i=1}^{48} m^i_{B^i}} \quad (8)$$

where $\overline{y}_1{}^i, \overline{y}_2{}^i, \overline{y}_3{}^i$ are the centre of the R^i, G^i, B^i areas respectively [4].

4. Simulation results

A simulation has been developed in MATLAB to demonstrate the proposed method. The codes developed for image pre processing and fuzzy analysis get the image file and text of the subtitle and produce the output image on which the colored subtitle is mounted. The RGB histograms of the image are shown as well as R, G, B values of the subtitle color. The following photos have been subtitled using the approach proposed in this paper in which the subtitles are colored according to the input images.

There are two sorts of comparison can be done for evaluation of the proposed approach: 1) comparing the colored subtitle with the fixed color subtitle (white, yellow, etc) and 2) comparing with solid opposite color subtitle computed using equation 9 for given R, G, B centroid values for the background image.

$$(SubtitleRED, SubtitleGREEN, SubtitleBLUE) = (255, 255, 255) - (R, G, B) \quad (9)$$

We use the second comparison method which is particularly for precise comparing. To compare the fuzzy logic based approach and mathematical approach the Peak Signal-to-Noise Ratio (PSNR) parameter is used for comparison (10).

$$PSNR = 20.\log_{10}\left(\frac{MAX}{\sqrt{MSE}}\right) \quad (10)$$

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} \| F(i,j) - M(i,j) \|^2 \quad (11)$$

where *F (i, j)* and *M (i, j)* are the subtitled images that are colored with fuzzy and mathematical approaches respectively. In equation 10, MAX is the maximum value of a pixel in the image. For an 8-bit image format MAX is 255.

The higher value of PSNR, the lower level of similarity between two images in subtitle color which are generated first using fuzzy logic and second, using mathematical approach. Typical value for the PSNR in image comparison is *PSNR> 32.83dB*.

The centroid of the histograms of the RGB channel for the figure7 are *R=129, G=121* and *B=133*. The R, G and B values of the subtitle color are (*SubtitleRED, SubtitleGREEN, SubtitleBLUE)=(*149, 215,196*).* The *R, G* and *B* channels of exact opposition color are*: (126, 134, 122). PSNR(R, G, B)=(32.83, 32.83, 32.83)* dB. The fuzzy coloring according to the minimum values of PSNR for each channel and the background colors of the figure 7 is more visible.

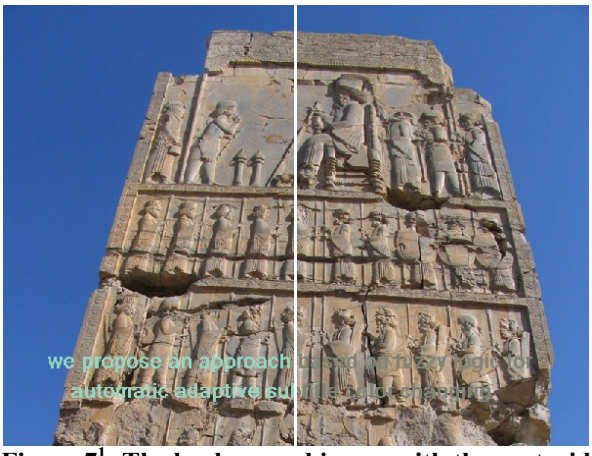

Figure 7[1]: The background image with the centroid values: R=129, G=121 and B=133.

For sake of simplicity in visual comparison and saving space, the remaining figures are divided into

[1] The Glory of Persepolis built in about 500 BC, Iran

two parts: left part demonstrates the subtitled image using fuzzy approach and right part demonstrates the same image subtitled with solid opposition color.

The centroid values of the histograms for the RGB channel in figure 8 are (56, 44, 9). The *R, G* and *B* values of the fuzzy subtitle color are (214, 198, 234). The *R, G* and *B* channels of exact opposition color are*:* (199, 211, 246). *PSNR(R)*=33.37*dB*.

Figure 8[2]: The background image with the centroid values: R =56, G = 44 and B = 9.

According to the warm colors of the background image the fuzzy subtitle color is so warmer than exact opposite color. *PSNR (R)* shows that the reddish in fuzzy subtitle is more than mathematical subtitle.

The centroid values of the histograms for the RGB channel in figure 9 are *R=137, G=146* and *B=111*. The *R, G* and *B* values of the fuzzy subtitle color are *(149, 199,196)*. The *R, G* and *B* channels of exact opposition color are*:* (*199, 211, 246). PSNR(R, G, B) = (32.83, 32.83, 32.83) dB*. According to the cool colors of the background image in figure 9 the fuzzy subtitle color is cooler and brighter than exact opposite color.

5. Conclusion

An approach has been introduced for adaptive subtitle and caption coloring using fuzzy logic. The main objective of the paper has been to give a direction on how to determine the color of subtitles and captions for photos and movies according to the visual perception of background image colors and color psychology concerns. Fuzzy analyzer in this system uses information extracted from images to select the R, G and B values for coloring the subtitle using some perceptional fuzzy rules based on principles discussed in section III. A set of codes in MATLAB environment have been developed and tested for some photos to demonstrate how the proposed fuzzy analyzer functions. This idea can be developed in different types of subtitling using other information like context of subtitle and emotional concerns as well.

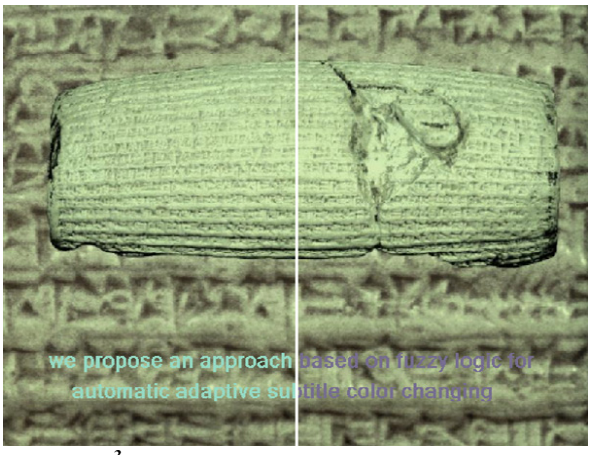

Figure 9[3]: The image with the centroid values: R =137, G = 146 and B =111.

6. References

[1] James Ohene-Djan, Rachel Shipsey, "Emotional Subtitles as a Technology to assist the Deaf and Hearing-Impaired when Learning from Television and Film", *Proceedings of the Sixth International Conference on Advanced Learning Technologies (ICALT'06)*, IEEE, July 2006, pp. 464-466.

[2] B. G. Buchanan, E. H. Shortliffe, "Rule-Based Expert Systems", *The MYCIN Experiments of the Stanford Heuristic Programming Project,* Addison-Wesley, Reading, MA, Menlo Park, CA, 1984.

[3] V. Novak, I. Perfilieva, J. Mockor, "Mathematical principles of fuzzy logic", Kluwer Academic Publishers, Boston/Dordrecht, 1999.

[4] V. Kreinovich, G. C. Mouzouris, H. T. Nguyen, "Fuzzy rule based modeling as a universal approximation tool", In: H. T. Nguyen, M. Sugeno (eds.), Fuzzy Systems: Modeling and Control, Kluwer, Boston, MA, 1998, pp. 135-195.

[5] P. Bonissone, "Fuzzy Logic and Soft Computing: Technology Development and Applications", General Electric CRD Publication, Schenectady NY 12309, USA, 1997, pp. 1-68.

[2] The "si-o-se pol" bridge, Isfahan, Iran

[3] Cyrus Cylinder, The First Charter of Human Rights, 539 BCE