Fuzzy Color-Based Semantic Characterization of Animation Movies

Bogdan Ionescu*[1,2], *Patrick Lambert*[2], *Didier Coquin*[2], *Vasile Buzuloiu*[1]; [1]*The Image Processing and Analysis Laboratory, University "Politehnica" of Bucharest, Romania, Email: BIonescu,Buzuloiu@alpha.imag.pub.ro;* [2]*Laboratoire d'Informatique, Systemes, Traitement de l'Information et de la Connaissance, Universite de Savoie, Annecy, France, Email: Patrick.Lambert,Didier.Coquin@univ-savoie.fr.

Abstract

In this paper a fuzzy statistical color–based approach for semantic characterization of animation movies is proposed. Color is a major feature of animation movies: each movie has its own color distribution. Deriving semantic information about the used color artistry concepts or about the sensation induced by the movie's color distribution should be an ideal analysis-tool for the animation experts. First, the movie is divided into shots and a movie abstract is then automatically generated. Color reduction is applied on each retained frame using an error diffusion algorithm with a predefined color palette. Then, a global weighted color histogram of the movie is computed by taking into account each shot relevance. It serves as a basis of computation for relevant color-based statistics, such as the elementary colors distribution or the light/dark color ratios. Using a fuzzy representation, meaningful color–based semantic information is then derived from the obtained parameters, namely: light–dark contrast, cold-warm contrast and contrast of saturation schemes, the color variations/diversity and the adjacent/complementary colors. The proposed approach was tested on several animation movies.

Introduction

During the last years, the video indexing approaches focused mainly on the semantic analysis, as video indexes get closer to the human perception. Thanks to "The International Animated Film Festival" [1], that takes place yearly since 1960 in Annecy (France), a very large database of animation movies is available. An automatic tool that allows artists or ordinary people to analyze or to access the movies at a semantic level, is required.

Animation movies differ from natural ones in many respects:

- the events do not follow a natural way,
- objects or characters emerge and vanish without respecting any physical rules,
- the characters can have any shape,
- the movements are not continuous,
- a lot of visual color effects are used,
- artistic concepts are used: painting concepts or theatric concepts.
- different animation techniques are used: 3D graphics, paper drawing, etc.

Understanding the movie content is sometimes impossible, some animation experts say that more than 30% of the animation movies from [1] are almost impossible to be resumed and thus understood. One major characteristic is that every animation movie has its own **particular color distribution** (see Figure 5), contrary to natural movies which share almost all the same color distribution. Colors are selected and mixed by the artist using various color artistry concepts in order to express particular feelings or to induce particular sensations.

The semantic characterization approach proposed in this paper continues the work presented in [13] and is based on the approach proposed in [9]. It uses a movie's global weighted color histogram and a fuzzy semantic characterization in order to determine the semantic meaning of movie's color distribution in terms of used color artistry concepts and human color perception.

Very little research has been done in this working field. In [9], color artistry concepts are extracted for the indexing of artworks images and the relationships between image colors are analyzed in a perceptual color space (namely, LCH, which is the transformation of Lab color space into polar coordinates). Another system where art images and commercials are analyzed at emotional and expressional levels is proposed in [10], where various features are used, not only color information, but also motion, and distribution of video transitions.

The purpose of the proposed approach is to provide the animation artists, or ordinary people as well, with detailed information regarding the *movie color content* and the used *color techniques*. First, the movie is divided into shots by detecting the video transitions (cuts, fades, dissolves etc.) using the algorithms proposed in [3] [4], that were specifically developed to overcome the difficulties raised by the peculiarity of the animation movies. Each shot is then summarized by retaining a percentage, $p\%$, of its frames. Then, the color distribution for the entire movie, is captured by the use of a **global weighted color histogram**, computed as a weighted sum of each shot mean color histograms. As frames are represented in true color, a color reduction step is required.

We propose the use of an error diffusion color reduction on a particular prefixed color palette proposed in [8]. The fixed palette color reduction step aims to avoid the difficulty of comparing different color sets which are usualy obtained by using an adaptive color reduction method (for several approaches on evaluating color distances see [6]). Also, the proposed color palette overcome the lack of computational automation of existing color naming systems [7], by proposing an efficient color naming system. A color name is associated to each color within the palette, according to its hue, saturation and brightness. As color names allows everyone to create a mental image of a given color, they will be an important feature for the semantic color analysis.

Several statistical measures are computed on the obtained global weighted color histogram: the elementary color statistics, the light/dark color ratio, the hard/weak color ratio, the warm/cold color ratio, the complementary/adjacent colors ratio, and the color diversity/variation ratio. From the obtained low-level parameters a semantic characterization of the movie is extracted using a fuzzy approach. The proposed semantic color information is regarding the *color perception*, some of the *the Itten's colors contrast* [12] and *the color harmony scheme*, namely: the **light–dark contrast**, the **cold-warm contrast**, the

contrast of saturation, the **color variations and diversity** and the **adjacent-complementary contrast**.

The proposed approach

The fuzzy color–based semantic characterization is performed by the classification of the statistical color parameters obtained from the movie's global weighted color histogram by using a fuzzy-based representation. The proposed approach uses different analysis steps. The method's diagram is illustrated in Figure 1.

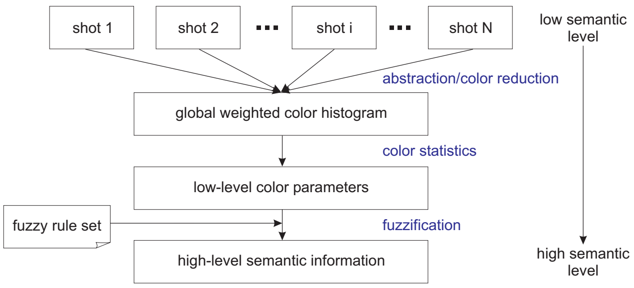


Figure 1. *The proposed fuzzy color-based semantic characterization method.*

Movie segmentation

First, the movie is divided into its fundamental video units or **shots** by detecting the video transitions. Specially designed detection algorithms (proposed in [3] [4]) that were developed to manage the difficulties raised by the peculiarity of animation movies, are used. The following transitions are detected: cuts, fades, dissolves and the "short color changes" or SCC which is a color effect particular to animation movies, corresponding to explosions, thunders, lightening, etc. (see Figure 2). Some of the animation movies share a large amount of SCC color effects, having a particular color distribution, thus detecting this color effect is important.

Figure 2. *SCC exemples (from the movie "Francois le Vaillant" [2]).*

Shots are determined by fusing the detected video transitions and then by removing less relevant frames as they do not contain meaningful color information (i.e. black frames between fades or transition frames). In order to summarize the movie content, some key frames are extracted for each shot. As action takes most likely place in the middle of the shot, key frames are extracted as a centered subsequence of $p\%$ time–continuous frames (more detail will be captured for the longer shots as they contain more color information). The choice of the parameter p is discussed later on the next chapter.

Movie global weighted histogram

For each retained frame of the shot, the color histogram, $h^j_{shot_i}$ where i is the shot index and j is the frame index, is computed. Frames are color reduced using the Floyd–Steinberg error diffusion filter [11] applied in the XYZ color space, with colors being selected in the Lab color space from an predefined color palette (for a literature survey on color reduction techniques see [5]).

For the choice of the color palette, the most important criterion is the availability of a color naming system in order to be able to analyze the human color perception. After analyzing and testing a number of several pre–labeled color palettes, the optimal color palette in terms of number of colors and color naming algorithm has proven to be the webmaster non–dithering 216 colors palette [8]. It contains 12 elementary colors, namely: Orange, Red, Pink, Magenta, Violet, Blue, Azure, Cyan, Teal, Green, Spring and Yellow and 6 gray levels including white and black. Each color is named according to its elementary color origin, degree of hue, saturation and brightness. For example the color defined by $R = 255$, $G = 255$ and $B = 51$ is called *"Light Hard Yellow"* (see Figure 3).

Another advantage of using such a color palette is that it corresponds to the color wheel proposed by Itten [12] which is a perceptual–based color representation.

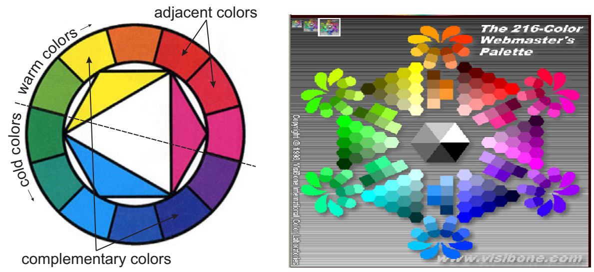


Figure 3. *The proposed color palette (the left image corresponds to Itten's corrected color wheel and the right image corresponds to the proposed non–dithering 216 colors palette [8]).*

The movie's **global weighted color histogram** is defined as the weighted sum of all shots mean color histograms:

$$h_{movie}(c) = \sum_{i=0}^{M} \sum_{j=0}^{N_i} \frac{h^j_{shot_i}(c)}{N_i} \cdot w_i \tag{1}$$

where M is the number of shots, N_i is the number of the retained frames for the $shot_i$ representing a percentage of $p\%$ of its frames, $h^j_{shot_i}$ is the color histogram for the frame j of the $shot_i$, w_i is the $shot_i$ weight, c is the color index, $c \in \{0,..,215\}$. A shot weight is defined as:

$$w_i = \frac{N_{shot_i}}{N_{shots}} \tag{2}$$

where N_{shot_i} is the total number of frames for the $shot_i$, N_{shots} is the total number of movie shot frames. The longer the shot, the more important the contribution of its histogram to the movie's global histogram.

Regarding the best choice of the percentage of retained frames for a given shot, $p\%$, we found that $p \in [15\%, 25\%]$ has proven to be a good compromise between the achieved processing time and the resulting histogram quality [13].

Color statistical parameters

The next step towards the semantic characterization of the movie content is the computation of several **color–based statistical parameters** using the available "webmaster" palette color naming system. First, an elementary color histogram is extracted from the global weighted color histogram (white and black are considered independently), which is computed as:

$$h_{12+3}(c_b) = \sum_{i=1}^{216} h_{movie}(c_i)\big|_{\{Name(c_b)\ \textbf{in}\ Name(c_i)\}} \tag{3}$$

where c_b is an elementary color index (from the total of 12 elementary colors + gray, white and black), $h_{movie}()$ is the movie global weighted histogram, c_i is the current color index from the ”webmaster” 216 color palette.

Using $h_{12+3}()$, several statistical color parameters are computed:

- **the color diversity** (P_{div}),
- the percentage of **complementary colors** (P_{compl}),
- the percentage of **adjacent colors** (P_{adj}).

The complementary and analogous color relationships are defined on the Itten’s color wheel, see Figure 3.

For example the color diversity parameter, P_{div} is computed as the proportion of the significant different elementary colors (having an apparition percentage of more than 4%, empirically determined) from the total of 13 (12 colors + gray, where white and black are considered as gray levels):

$$P_{div} = \frac{Card\{c_b/h_{12+3}(c_b) > 4\%\}}{12+1} \quad (4)$$

where $Card\{\}$ returns the number of elements for a data set, $h_{12+3}()$ is the elementary color histogram, c_b is an elementary color index.

The other proposed parameters are computed on the movie global weighted histogram, $h_{movie}()$ using the same reasoning:

- **the color variations** (P_{var}),
- the percentage of **light colors** (P_{light}),
- the percentage of **dark colors** (P_{dark}),
- the percentage of **hard colors** (P_{hard}),
- the percentage of **weak colors** (P_{weak}),
- the percentage of **warm colors** (P_{warm}),
- the percentage of **cold colors** (P_{cold})

The warm/cold colors are defined using the Itten’s color wheel (see Figure 3) where *the warm colors* are distributed on the one half of the wheel, starting with Spring, continuing with Yellow and ending with Magenta and contrary to the warm colors, *the cold colors* are distributed on the other half of the Itten’s color wheel, starting with Violet, continuing with Blue and ending with Green.

Color hue, saturation and lightness are reflected in color names with specific words. For example the percentage of light colors, P_{light}, is computed as:

$$P_{light} = \sum_{i=1}^{216} h_{movie}(c_i)|_{\wp} \quad (5)$$

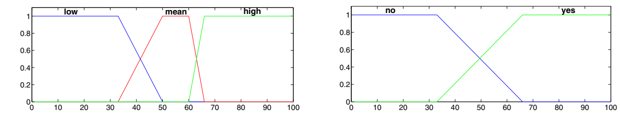
where $h_{movie}()$ is the movie global color histogram, c_i is the color index from the ”webmaster” 216 color palette with the property ($\wp$) of its name containing one of the following words: ”light”, ”pale” or ”white”.

Semantic color information

The higher-level color characterization is derived from the proposed low-level color parameters by using a **fuzzy-based** representation. The interest in this representation is twofold: first, it allows us to represent the low-level color information in a human-like manner and secondly, it provides normalization between 0 and 1 of the proposed parameters which facilitates the data fusion task.

The proposed semantic color information is regarding the *color perception*, *the Itten’s colors contrast* and *the color harmony scheme*, namely: the **light–dark contrast**, the **cold-warm contrast**, the **contrast of saturation**, the **color variations and diversity** and the **adjacent-complementary contrast**.

First a fuzzy symbolical description is associated to each of the enumerated statistical color parameters. The *light color* concept is associated to the P_{light} parameter as being related to the bright colors movie content. The light color is described by using three symbols: **”low light-colors”**, **”mean light-colors”** and **”high loght-colors”**. The fuzzy meaning of each symbol is characterized by its membership function. The design of these functions is performed in a classical way using piece-wise linear functions. This definition is based on the choice of four thresholds $(30, 50, 60, 66)$ which were empirically determined by the manual analysis of several animation movies from [1] (see figure Fig. 4.a).



(a) Light colors (b) Complementary colors

Figure 4. *Example of fuzzy symbolic color descriptions: (a) the oX axis corresponds to P_{light}, (b) the oX axis corresponds to P_{compl}.*

In a similar way the *dark color* concept is associated to P_{dark}, the *weak color* concept to P_{weak}, the *hard color* concept to P_{hard}, the *warm color* concept to P_{warm}, the *cold color* concept to P_{cold}, the *color variation* concept to P_{var}, the *color diversity* concept to P_{div}, the *complementary color* concept to P_{compl} and the *adjacent color* concept to P_{analog}.

In what concerns the *complementary colors* and the *adjacent color* concepts they describe the binary property of the animation movies of sharing a complementary or respectively an adjacent color scheme. Hence only two symbols are associated, namely: **”yes”** and **”no”**. An example of a membership function for the *complementary color* concept is depicted in Figure 4.b.

Using the proposed symbols, new higher-level semantic concepts are built using a fuzzy rule-based system, namely: *light–dark contrast, warm–cold contrast, contrast of saturation and complementary–analogous contrast*. For example the light-dark contrast information is defined by the following rule:

$$\textbf{If } (\text{”}light\ colors\text{” } \textbf{is } \text{”}mean\text{”}) \textbf{ and}(\text{”}dark\ colors\text{” } \textbf{is } \text{”}mean\text{”}) \\ \textbf{then } there\ is\ a\ \text{”}light-dark\ contrast\text{”}$$

The fuzzy description for the proposed symbols is obtained by an uniform mechanism according to the combination/projection principle using a conjunction and a disjunction operator which are the Zadeh min and max operators [14]:

$$\mu_{ld-cont}(P_{light}, P_{dark}) = min(\mu_{P_{light}}, \mu_{P_{dark}}) \quad (6)$$

where $\mu_{ld-cont}$ is the membership function for the *light-dark contrast* concept and $\mu_{P_{light}}$, $\mu_{P_{dark}}$ are the membership functions for the *light colors* and respectively *dark colors* concepts.

Experimental results

Several tests were performed on an animation movies database from [1], containing 52 movies with a total time of 7 hours and sharing a large variety of animation techniques. As the results are subjective and rely on the human color perception, their validation was performed by several persons.

We present the obtained results for 4 animation movies, namely: ”Casa” (6min5s), ”Le Moine et le Poisson” (6min), ”Circuit Marine” (5min35s) and ”Francois le Vaillant” (8min56s)

[2]. Several frames for the enumerated movies are illustrated with Figure 5. The obtained global weighted color histograms, $h_{movie}()$ are depicted with Figure 6. Also, the elementary color distributions which correspond to the elementary color histograms, $h_{12+3}()$, are depicted with Figure 7.

Figure 5. *Several frames of the animation movies (from top to bottom): 1. "Casa", 2. "Le Moine et le Poisson", 3. "Circuit Marine" and 4. "Francois le Vaillant".*

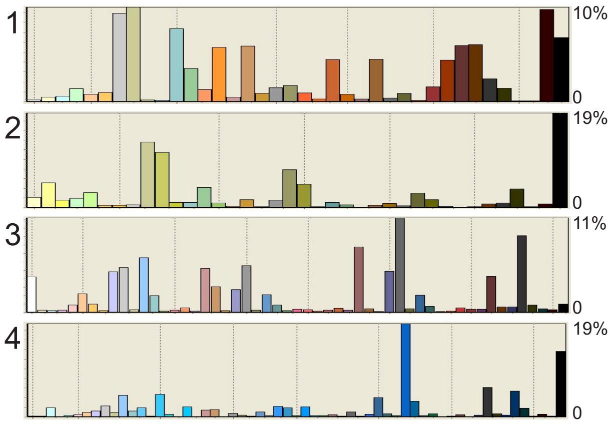


Figure 6. *The obtained global weighted color histograms for the 4 movies, movies order from top to bottom (oY axis corresponds to the colors occurrence with $p = 25\%$).*

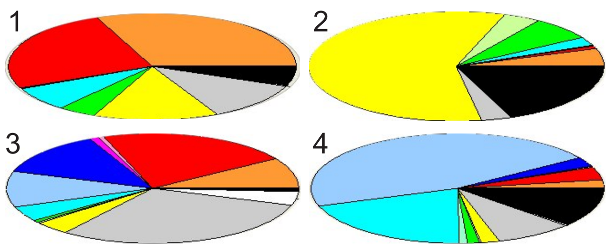


Figure 7. *The obtained elementary color distributions for the 4 movies, movies order from top to bottom and from left to right.*

The following semantic color characterizations are obtained, where the number in the brackets corresponds to the colors amount (%) and to the fuzzy membership degree (μ):

- movie **"Casa"**:
  - predominant colors Orange (35.4%) and Red (28.3%),
  - moderate color diversity ($\mu_{P_{div}} = 1$), dark-light contrast ($\mu_{ld-cont} = 0.9$), warm colors ($\mu_{P_{warm}} = 1$), weak colors ($\mu_{P_{weak}} = 0.8$).
- movie **"Le Moine et le Poisson"**:
  - predominant color Yellow (60.3%),
  - moderate color diversity ($\mu_{P_{div}} = 1$), dark-light contrast ($\mu_{ld-cont} = 0.9$), warm colors ($\mu_{P_{warm}} = 1$), weak colors ($\mu_{P_{weak}} = 1$) and adjacent colors ($\mu_{P_{adj}} = 1$).
- movie **"Circuit Marine"**:
  - predominant colors Red (22.3%), Blue (13.3%) and Azure (10.9%),
  - moderate color diversity ($\mu_{P_{div}} = 1$), dark-light contrast ($\mu_{ld-cont} = 0.9$), weak colors ($\mu_{P_{weak}} = 0.78$).
- movie **"Francois le Vaillant"**:
  - predominant colors Azure (54.6%) and Cyan (24.1%),
  - reduced color diversity ($\mu_{P_{div}} = 0.87$), dark colors ($\mu_{P_{dark}} = 1$) and cold colors ($\mu_{P_{cold}} = 1$).

Using the fuzzy semantic characterization instead of using crisp decisions, as presented in [13], the obtained results are improved by adding a degree of confidence on the result, thus the unreliable characterizations are disregarded. On the other hand using crisp decisions will often lead to false characterizations when dealing with incertitude situations where the parameter values are close to the quantification threshold.

Conclusion

In this paper we have presented an approach for the color–based semantic characterization of animation movies from [1]. The movie color distribution is encapsulated in one global weighted color histogram. The use of an Itten's–color–wheel–based fixed color palette allow the extraction of some color artistry concepts which are being related to the Itten's color contrast and color harmony schemes. Semantic information is derived from low-level color parameters using several fuzzy classification rules. The proposed method performed very well on various animation movies. Future improvements consist in performing additional, region–based color analysis.

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Author Biography

Bogdan Ionescu received an engineer degree in applied electronics (2002) and an MSC degree in computing systems (2003) both from University "Politehnica" Bucharest - UPB, Romania. Since 2003 he is Ph.D student in image processing and informatics with LAPI "Image Processing and Analysis Laboratory", UBP, and LISTIC "Laboratoire d'Informatique, Systèmes, Traitement de l'Information et de la Connaissance", "Université de Savoie", Annecy, France. His scientific interests cover electronics engineering, artificial intelligence, image processing and computer vision, software engineering, computer science.

Patrick Lambert graduated in electrical engineering from the Grenoble National Polytechnic Institute (INPG), France, in 1978. He received the Ph.D. degree in signal processing in 1983. He is currently an Assistant Professor of electrical engineering at the Savoie University (Technological Academic Institute) and works in the Informatics, Systems, Information and Knowledge Processing Laboratory (LISTIC), Annecy, France. His research interests include image and video indexation, data fusion, and fuzzy logic.

Didier Coquin received the Ph.D. degree in signal processing and telecommunication from University of Rennes I, France, in 1991. He is currently an Assistant Professor of telecommunication and network engineering at the Savoie University (Technological Academic Institute) and works in the Informatics, Systems, Information and Knowledge Processing Laboratory (LISTIC), Annecy, France. His research interests include image processing, pattern recognition, image and video indexation, data fusion, and fuzzy logic.

Vasile Buzuloiu is a professor with the Department of Applied Electronics and Information Engineer. He also heads the "Image Processing and Analysis Laboratory" at the University "Politehnica" Bucharest - UPB, Romania, and he is research associate with CERN Geneva, Switzerland. His scientific interests cover mathematical modeling, statistical decisions, encryption, digital signal processing, image processing and analysis systems, image processing applications. He is a member of IEEE, SPIE, Color Group (Great Britain) and of the Romanian Society for Applied Mathematics.