Color Harmonies and Contrasts Search in Art Image Collections

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***Abstract* – In this paper a novel and more complete classification of color harmonies and contrasts are presented. It is done on the base of the three main characteristics of the color, which are most closed to the human perception – hue, saturation and lightness. Functions for automatic features extraction from digital images, using MPEG-7 Dominant Color Descriptor are defined. The results of these functions are new high-level features vectors, corresponding to outline color combinations. An experimental software system was developed and experiments were conducted. The system can be used by designers and art students for searching images, having specific harmonies and contrasts in image collections. In future we will use the system as a Web 2.0 service, which could be included in a virtual learning environment.**

Keywords: Content-Based Image Retrieval, Color, Contrast, Color Harmonies

I. Introduction

One of the most felicitous analogies for presenting the existing semantic gap in area of Content-Based Image Retrieval (CBIR) can be found in "The Hitch-Hiker's Guide to Galaxy" by Douglas Adams. In this story, a group of hyper-intelligent pan-dimensional beings demand to learn the "Answer to Life, the Universe, and Everything" from the supercomputer Deep Thought, specially built for this purpose. It takes Deep Thought 7½ million years to compute and check the answer, which turns out to be "42" [1]. The efforts of covering the semantic gap in CBIR are turned to avoid these misunderstanding between human perceiving and the ways of communications and computer manner of low-level representations.

As it is mentioned in [2], the user questions in image search are partitioned into three main levels:

Low level – this level includes basic perceptual features of visual content (dominant colors, color distribution, texture pattern, etc.). Low-level queries and analysis can support the retrieval of art images in order to seek some specifics or common characteristics between artists, schools or movements.

Intermediate level – this level forms next step of extraction from visual content, connected with emotional perceiving of the images, which usually is difficult to express in rational and textual terms. The visual art is area, where these features play significant role. Typical features in this level are color contrasts, because one of the goals of the painting is to produce specific psychological effects in the observer, which are achieved with different arrangements of colors.

High level – this level includes queries according to rational criterions. In many cases the image itself does not contain information which would be sufficient to extract some of the characteristics. For this reason current high-level semantic systems still use huge amount of manual annotation.

Different features' levels imply different ways for communication between the user and the CBIR system. When a system uses low-level properties such as color percentages, color layout, and textures, (see e.g. QBIC, developed by IBM [3]) the queries do not need to be described in words. When working with such systems, the user can select a sample image and the system returns all images which are "similar" to it. For systems, which operate with high level features, only choosing a sample or drawing a sketch and search similar characteristics is not sufficient, even because such system has to "know" which of characteristics are targeted by the user. There are two mutually connected tasks in this area:

- Defining features and terms, which present certain effect or criterion and describing correlation between defined concepts;
- Finding appropriate algorithms for generating metadata, which alone or in combination with present terminal features and terms will allow improved image search as well as proposing adequate methods and tools for establishing belonging of a sample to same concept.

Several big projects addressed the description of the high-level concepts in the art domain:

- *The Getty vocabulary databases* [4] are produced and maintained by the Getty Vocabulary Program. They contain terms, names, and other information about people, places, things, and concepts relating to art, architecture, and material culture. The vocabularies in this program are: The Art and Architecture Thesaurus (AAT), the Union List of Artist Names (ULAN), the Getty Thesaurus of Geographic Names (TGN), and the last the Cultural Objects Name Authority (CONA), which expects to be introduced in 2011;
- *WordNet* [5] is a large lexical database of English, developed under the direction of George A. Miller.

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WordNet is freely and publicly available for download. Although it is not domain-specific, it is a useful tool for computational linguistics and natural language processing especially for English-language texts;

- *Iconclass* [6] is a hierarchical system, developed by the Netherlands Institute for Art History. It includes the following main divisions: Abstract, Non-representational Art; Religion and Magic; Nature; Human being, Man in general; Society, Civilization, Culture; Abstract Ideas and Concepts; History; Bible; Literature; Classical Mythology and Ancient History.

In order to present properly concepts and their correlation between low and intermediate levels as well as the connections to the high level, every system usually creates its own dataset. This allows implementing the specific elements of the used methods and tools. These sets use on their highest level concepts, which are the objects of the domain-specific bases, mentioned before. Some examples follow:

- The "Pictorial Portrait Database" [7] uses a hierarchical database indexing method based on Principal Component Analysis. Its description model is based on the eyes as the most salient region in the portraits;
- The team, headed by R. Jain uses annotation of paintings based on brushwork, where brushwork is modeled as part of the annotation of high-level artistic concepts such as the artist name using low-level texture [8].
- An approach for extraction of low level color characteristics and their conversion into high level semantic features using Johannes Itten theory of color, Dempster-Shafer theory of evidence and fuzzy production rules is suggested in [9].

This article presents an experimental software system for image retrieval, based on intermediate and high level semantic search based on color harmonies and contrasts. In section two we make an analysis of the phenomenon of the impact of one color on the perception of others. In section three we present a hierarchical classification of different types of harmonies and contrasts in order to be used as base for further analysis and extraction tools from image databases. In section four we describe an experimental software system which integrates the described tools. Section five contains experimental results made by the realized system. Finally, conclusions and future work are presented.

II. Human Perception of the Color

From all the senses that connect us to the world – vision, hearing, taste, smell, and touch – vision is the most important. More than 80% of our sensory experiences are visual [10]. When the brain receives a light stimulus it first interprets form as distinct from background. Figure-ground separation or pattern recognition is the first cognitive step in the process of perception. Color plays an important, but secondary role in recognition. Color responses are more tied to human emotions than to his intellect. Just this property makes the colors very powerful source of influence of human perception. The presence of one or more colors in different proportions conveys different messages, which can increase or suppress the perception of the observed objects.

A. Color

The nature of color is in the focus of research by different science disciplines – Physics studies the power essence of the color, Physiology is interested in the process of human eyes perception of specific wavelengths and theirs transformation to color, Psychology examines the problems of colors' perception and theirs influence on the mentality, Mathematics suggests methods for color measurement. The enormous growth of the number of digital images and videos in different application areas explains the extensive interest in developing computer science methods in this area.

Different models for presenting the color have been created from Antiquity. A detailed survey of color models was made by the team of Urs Baumann [11]. Different models serve various domains – from Physics and Colorimetry; through Painting, Architecture, and Design; to Digital coding for printers, monitors and TV. The history and practice show that a perfect color model cannot be created: one is suitable to supply compact coding and transmitting of the color characteristics, another is easy perceived from humans, etc.

From human point of view, it is most easy to define the color as composition of three components – hue, saturation and lightness. Hue means the name of the color – red, orange, etc. Black, grays and white are called achromatic. Saturation measures the hue intensity or brilliance of a sample, its dullness or vividness. Lightness refers to relative light and dark in a sample [10]. Such point of view to the color facilitates the structuring of color contrasts and harmonies are evinced in art images.

B. Harmonies and Contrasts

The contrasts are experienced when we establish differences between two observed effects. When these differences reach maximal values we talk about diametrical contrast. Our senses perceive only on the base of comparison. For instance one segment is short when lays near long segment and vice versa. In similar way color effect becomes strong or weak thorough contrasts.

Many people are observed and examined the influence of the color each other. Aristotle in his "De meteorologica" posed questions about different looking of violet near to white wool and black wool [12]. His questions were systematically examined and explained later by Michel Eugène Chevreul.

In 1772 – the same year that Johann Heinrich Lambert constructed his color pyramid and demonstrated for the first time that the complete fullness of colors can only be reproduced within a three dimensional system [13], another color circle was published in Vienna by Ignaz Schiffermüller. He was one of the first, who arranged the complementary colors opposite one another: blue opposite orange; yellow opposite violet; red opposite green [12].

Leonardo da Vinci had probably been the first to notice that when observed adjacently, colors will influence each other. Goethe, however, was the first to specifically draw attention to these associated contrasts.

Michel Eugène Chevreul had continued resolving the questions for contrast with establishing a law of "Simultaneous Contrast" [12].

Johannes Itten was one of the first to define and identify strategies for successful color combinations [14]. Through his research he devised seven methodologies for coordinating colors utilizing the hue's contrasting properties. These contrasts add other variations with respect to the intensity of the respective hues; i.e. contrasts may be obtained due to light, moderate, or dark value. He defined the following types of contrasts: *Contrast of hue, Light-dark contrast, Cold-warm contrast, Complementary contrast, Simultaneous contrast, Contrast of saturation, and Contrast of extension (proportion).*

Later additional contrasts such as Split-complementary contrast, Double-complementary contrast, Triads contrast, etc. have been suggested by various researchers. Some of them are combinations of previously listed ones.

C. Artists' color wheel

Usually, in accordance of Johannes Itten proposition, the color wheel, which represents relations between hues, is divided in twelve sections. Centers of three equidistance sections correspond to primary colors. Between them secondary colors are posed, which from one side are middle points of two primary colors, and from other side are complementary to the third color. The quantization is expanded with the intermediate colors, which lays at midpoint to adjacent primary and secondary hues.

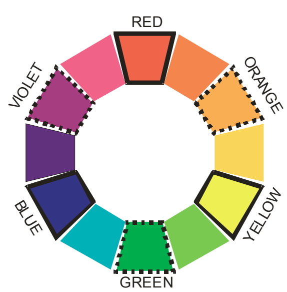


Figure 1. Standard Artists' Color Wheel

In Figure 1 the position of the hues in standard artists' color wheel is shown. This order and correlations between hues is described in RYB (Red-Yellow-Blue) color model, used by the artists. Let us mention that this arranging of hues differs from many of contemporary color models – RGB (Red-Green-Blue), CMY (Cyan-Magenta-Yellow), HSL (Hue-Saturation-Luminance), HSV (Hue-Saturation-Value), based on the defining of colors as primary or secondary in accordance with trichromatic theory [15].

III. Classification of Harmonies

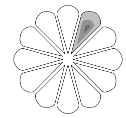
We present one classification of different types of harmonies, from the point of view of the three main characteristics of the color – hue, saturation and lightness.

A. Harmonies from point of view of hue

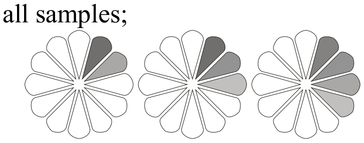
1) Hue harmonies based on the disposition of hues

The figures below shows only relatively disposition of the colors, not the absolute meaning of the color. Some of these combinations are discussed in [10] and [16].

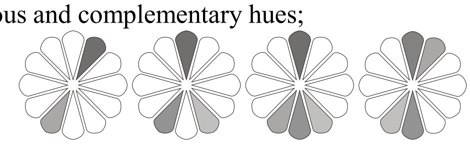
a) Monotone compositions: These compositions use one hue, and image is built on the base of varying of lightness of color. These images are used to suggest some kind of emotion since every hue bears specific psychological intensity;



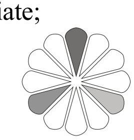
b) Analogous hues: Analogous hues can be defined as groups of colors that are adjacent on the color wheel; contain two, but never three primaries and have the same hue dominant in all samples;



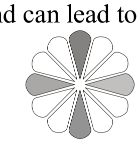
c) Complementary contrasts: Complementary colors are hues that are opposite one another on the color wheel. When more than two colors take part in the composition the harmonic disposition suggests combination between analogous and complementary hues;



d) Triads: Three colors that are equidistance on the color wheel form triad. This means that all colors are primary or secondary, or intermediate;



e) Tetrads: The tetrad includes four colors in equidistance on the color wheel. This contrast produces very complicated scheme and can lead to disharmony;



f) Achromatic compositions: As a special case, images composed by black, grays and white tones or contain colors with very small saturation.

2) Harmonies based on the group of hues (Warm-cold contrast)

Warm and cold are two opposing qualities of hue. Warm colors are hues around red and orange; cold colors are these around blue. The terms warm and cold are helpful for describing families of colors. They can be defined as follows:

a) Warm: The image is warm when composition is built from family of warm colors;

b) Cold: By analogy – the image is cold when it is composed only (or predominantly) with cold colors;

c) Neutral: The composition contains colors mainly from neutral zones;

d) Warm-cold: The composition lays in this category when the percentage of cold family is in some proportion to the percentage of warm family;

e) Warm-neutral: In such compositions there is proportion between warm colors and neutral ones;

f) Cold-neutral: The image contains cold and neutral tones in some proportion.

Unlike of hue, which is circular and continuous, saturation and lightness are linear. That difference determines different definitions of harmonies for these characteristics.

B. Harmonies from point of view of saturation

This harmony appears together with the hue ones. It is used to give different perception when the color is changed. As a whole we can define three big groups of harmonies and contrasts:

a) Dull: An image can be classified as dull when composition is constructed mainly from dull colors;

b) Clear: Clear images have been build mostly from clear (spectral and near to spectral, respectively only with varying in lightness) colors.

c) Different proportion of saturations: Usually in composition of clear colors in combination of dull ones. Depending on content of different saturation and of distance between predominate quantities harmonies can be defined such as *smooth*, *contrary*, etc.

C. Harmonies from point of view of lightness

The construction of these contrasts is similar to the contrasts of saturation. Here also three main contrasts can be examined:

a) Dark: Dark compositions are built mainly from dark colors;

b) Clear: Light images contain mostly colors near white;

c) Different proportion of lightness: Light colors combined with dark ones compose the image. Depending on content of different lightness and of distance between predominate quantities contrasts can be defined as*: smooth*, *contrary*, etc.

IV. Experimental Software System Functionality

An experimental software system for automatic image descriptor annotation corresponds with defined harmonies and contrasts in the frame of a virtual laboratory for semantic image retrieval was created. For obtaining the dominant colors of the images we use MILOS [17] realization of MPEG-7 descriptors [18].

For the purposes of the system we convert RGB-values of dominant colors, calculated from MILOS-system to values in non-uniformly quantized HSL-feature space – twelve hues plus one value for achromatic color, five levels of saturation and five levels of luminance are identified. This numbers are chosen on the base of Itten's color theory.

The system allows user definitions of the quantization of the space. Figure 2 shows the screen where the user can set up quantization for the purposes of further defining of color harmonies. The screenshot is made when quantization of hue is in accordance with artists' color wheel. The displacement between correlation of hues in two color models – RYB and HSL is clearly seen. Current realization of defining hue harmonies is based on RYB color space.

The saturation and luminance are quantized in five levels –{"very dull", "dull", "neutral", "clear", "very clear"} and {"very dark", "dark", "middle", "light", "very light"}. The boundaries can be set up by the user.

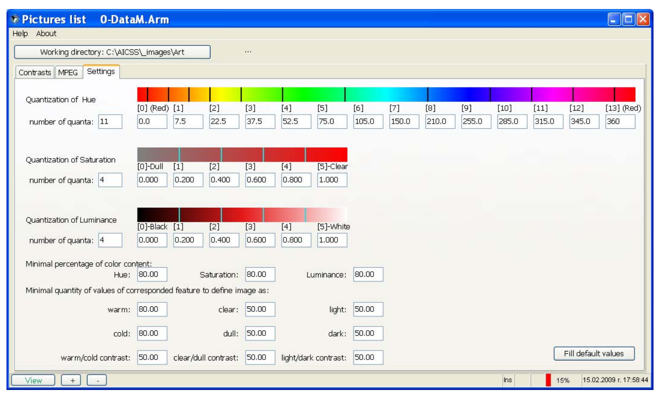


Figure 2. Screen for set up the quantizational parameters and boundaries

The system transforms percentage values of dominant colors, which in MPEG-7 standard are coded in 5 bits to percentage values ranged from 0 to 100.

As a result, every picture is represented with three arrays, containing percentage values of corresponding characteristics in the picture. These arrays are:

- H (h_{-1}, h_0, … , h_{NH-1}) for hues; NH=12. h_{-1} contains percentage of achromatic tones; h_0 to h_{NH-1} contains percentage of colors, ordered as it is shown on Figure 1, starting from reds (h_0) and ending to purples (h_{NH-1});
- S (s_0, …, s_{NS-1}) for saturation. In this example NS=5. s_0 holds percentage of grays and almost achromatic

tones, and s_4 contains percentage of pure (in particular – spectral) tones;

- L (l_0, …, l_{NL-1}) for lightness. It this example NL=5. l_0 holds percentage of very dark colors, and l_4 contains percentage of very light colors.

A. Hue order vector

This vector contains number of dominant hues *nh,* and positions of dominant hues, ordered in decreasing percentage. *nh* can vary from zero for achromatic paintings, to maximal defined dominant colors. For the purposes of defining hue harmonies maximal dominant colors are restricted in this example to 5. When image is not achromatic the value of *nh* is defined as the number of ordered hues, which sum of the percentages exceed some (expert-defined) value *x*.

$(nh; p_1, p_2, \ldots, p_{nh})$,

$nh \in \{0, \ldots, 5\}$

$p_i \in \{-1, \ldots, NH-1\}$ *and* $h_{p_i} \geq h_{p_{i+1}}$, $i \in \{1, \ldots, nh-1\}$

$$nh: \begin{cases} nh = 1 \;\; if \;\; h_{p_1} \geq x \\ nh = n \;\; if \;\; \sum_{i=1}^{n-1} h_{p_i} < x \;\; and \;\; \sum_{i=1}^{n} h_{p_i} \geq x \end{cases}$$

B. Hue harmony, based on disposition

For defining hue harmonies first we define:

$$opposite(p) = \begin{cases} p + NH \; div \; 2 & if \quad p \leq NH \; div \; 2 \\ p - NH \; div \; 2 & if \quad p \geq NH \; div \; 2 \end{cases}$$

$$l\_neighbour(p) = \begin{cases} NH - 1 \;\; if \;\; p = 0 \\ p - 1 \;\; if \;\; p \;\; in \{1, \ldots, NH-1\} \end{cases}$$

$$r\_neighbour(p) = \begin{cases} 0 \;\; if \;\; p = NH - 1 \\ p + 1 \;\; if \;\; p \;\; in \{0, \ldots, NH-2\} \end{cases}$$

$$l\_triad(p) = (NH + p - NH \;\; div \;\; 3) \;\; \mathrm{mod} \;\; NH$$

$$r\_triad(p) = (p + NH \;\; div \;\; 3) \;\; \mathrm{mod} \;\; NH$$

$$l\_tetrad(p) = (NH + p - NH \;\; div \;\; 4) \;\; \mathrm{mod} \;\; NH$$

$$r\_tetrad(p) = (p + NH \;\; div \;\; 4) \;\; \mathrm{mod} \;\; NH$$

The values of the hue harmony depend from the number of dominant hues *nh*:

- *nh*=0:

Achromatic: the composition is constructed by black, white and gray tones. This construction can be examined as special case of monochromatic harmony;

- *nh*=1:

Monochromatic: only one hue predominates in image;

- *nh*=2:

Analogous: when p_2=*l_neighbour*(p_1) or p_2=*r_neighbour*(p_1);

Complementary: when p_2=*opposite*(p_1);

Partial Triad: when p_2=*l_triad*(p_1) or p_2=*r_triad*(p_1);

- *nh*=3:

Analogous: if for one of dominant hues p_i ($i \in \{1, \ldots, nh\}$) is fulfilled that the other two colors are *l_neighbour*(p_i) and *r_neighbour*(p_i) respectively;

Split complementary: if for one of dominant hues p_i ($i \in \{1, \ldots, nh\}$) is fulfilled that the other two colors are *l_neighbour*(*opposite*(p_i)) and *r_neighbour*(*opposite*(p_i));

Triad: if for one of dominant hues p_i ($i \in \{1, \ldots, nh\}$) the other two colors are *l_triad*(p_i) and *r_triad*(p_i);

- *nh*=4:

Analogous: if for one of dominant hue p_i ($i \in \{1, \ldots, nh\}$) is fulfilled that one of the other three colors p_j ($j \in \{1, \ldots, nh\}, j \neq i$) p_j=*l_neighbour*(p_i) or p_j=*r_neighbour*(p_i) and other two colors are *l_neighbour*(p_j) and *r_neighbour*(p_j);

Double Complementary: if for one of dominant hue p_i ($i \in \{1, \ldots, nh\}$) is fulfilled that one of the other three colors p_j ($j \in \{1, \ldots, nh\}, j \neq i$) p_j=*opposite*(p_i) and other two colors are *l_neighbour*(p_i) and *l_neighbour*(p_j) or *r_neighbour*(p_i) and *r_neighbour*(p_j);

Split Complementary: if for one of dominant hue p_i ($i \in \{1, \ldots, nh\}$) is fulfilled that one of the other three colors p_j ($j \in \{1, \ldots, nh\}, j \neq i$) p_j=*opposite*(p_i) and other two colors are *l_neighbour*(p_j) and *r_neighbour*(p_j);

Tetrad: if for first hue p_1 the other hues are *l_tetrad*(p_1), *opposite*(p_1), *r_tetrad*(p_1) respectively;

- *nh*=5:

Multicolor: here can be searched the presence of defined combinations discarding one of the colors. In this realization this section is still open.

C. Cold/warm contrast

For defining cold/warm contrast the system compares percentage value of families of colors p_{warm}, p_{cold}, and $p_{neutrals}$ which is calculate as sums of dominant colors belonging in corresponded regions of hue.

$$p_{warm} = \sum_{i \;\; in \;\; \{0,1,2\}} p_i + \frac{1}{2} \sum_{i \;\; in \;\; \{11,3\}} p_i$$

$$p_{cold} = \sum_{i \;\; in \;\; \{7,8\}} p_i + \frac{1}{2} \sum_{i \;\; in \;\; \{6,9\}} p_i$$

$$p_{neutral} = \sum_{i \;\; in \;\; \{4,5,10\}} p_i + \frac{1}{2} \sum_{i \;\; in \;\; \{11,3,6,9\}} p_i$$

The image is defined as *warm*, *cold*, or *neutral* if corresponding value is greater than some coefficient (expert-defined). If none of these values exceeds this parameter the image is *warm-cold*, *warm-neutral*, or *cold-neutral* according to order of decreasing of corresponded values.

D. Saturation order vector

This vector contains number of dominant saturations *ns* (*ns*∈{*1,…, NS*}), and positions of dominant saturations, ordered in decreasing percentage. The value of *ns* is defined as the numbers of ordered saturations, which sum of the percentages, exceed some value *y*.

$(ns; p_1, p_2, \ldots, p_{ns})$,

$ns \in \{0, \ldots, NS\}$

$p_i \in \{0, \ldots, NS\text{-}1\}$ *and* $s_{p_i} \geq s_{p_{i+1}}$, $i \in \{1, \ldots, ns\text{-}2\}$

$$ns: \begin{cases} ns = 1 \ \ if \ \ s_{p_1} \geq y \\ ns = n \ \ if \ \ \sum_{i=1}^{n-1} s_{p_i} < y \ \ and \ \ \sum_{i=1}^{n} s_{p_i} \geq y \end{cases}$$

E. Saturation combinations

If *ns*=0 the picture is defined as *monointense*.

If *ns*>0 some combinations of presence of dominant saturations can be outlined. For instance if p_0 and p_{NS-1} are in dominant saturations the image can be defined as *contrary*; if saturations are adjoining – the feature is *smooth*, etc.

If *ns*>4 this characteristics is called *variety*.

F. Lightness order vector

This vector $(nl; p_1, p_2, \ldots, p_{nl})$ is defined in the same way as the saturation order vector.

G. Lightness combinations

These values are defined in the equal manner as saturation ones – the same function are used; only corresponding parameters are changed.

V. Experimental Software System Realization

These tools for automated annotation of the images with harmonies' and contrasts' descriptors are realized as part of a virtual laboratory for semantic image retrieval.

The system operates with images in JPEG-format. Images, stored in one directory, form a collection. As metadata storage space a multidimensional database, property of FOI Creative Ltd. [19] is used. The database allows storage and retrieval of different data types.

The user can choose the specific collection, changing the working directory. The system automatically scans the collection and extracts features. The user can refine setting of some parameters or boundaries (see Figure 2), which provoke recalculating of the corresponded descriptors.

The files, used in these collections, contain in theirs names the information about the artist and the name of the stored painting. The system extracts the names of the picture and the artist and, using a small thesaurus with information about the artists (dates of birth and death; countries; movement; periods), connects these metadata, extracted by the context, to information for the pictures.

The extracted descriptors (from the content and from the context) can be observed in a grid. The user can sort it by any selected feature. Pointing on the exact image, the user can see all extracted metadata, connected to this image – an example is given on Figure 3.

The user can set different conditions on the extracted descriptors and receive the images that satisfy these conditions. The results can be obtained in two forms:

- in thumbnail form, where the images can be seen. The example of such result is shown on Figure 4;
- in a file, where selected images can be additionally batched using other features, selected by user.

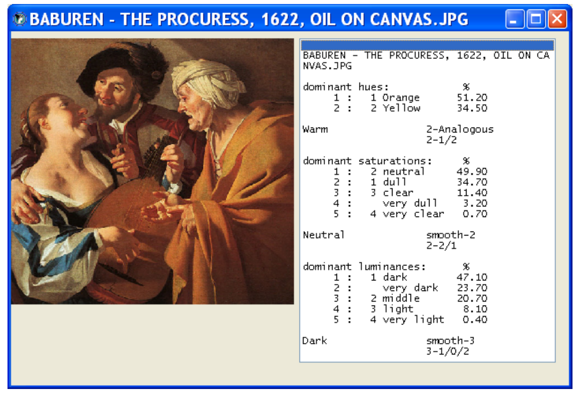


Figure 3. Results of calculating of types of harmonies for the picture "The procuress" by Baburen

Figure 4. Result of retrieval from the image base with parameters: "Hue contrast: *Analogous"; "Warm/cold: Warm"; "Dark/light: Light"

The system allows searching within a collection of images, which has specific combination of the colors, defined by some harmony.

VI. Experiment Results

For our experiments we used a dataset that includes 380 paintings from 27 artists, which work in 9 movements in West-European fine arts, from Gothic to Cubism (Table 1). The paintings were chosen by an art expert reviewer.

He has included in the collection the most valuable paintings for every movement. The pictures were obtained from different web-museums sources using ArtCyclopedia as a gate to the museum-quality fine art on the Internet [20]. We used images describing in [14] presenting different contrasts to tune up our system.

TABLE I. LIST OF THE ARTISTS, WHICH PAINTINGS WERE USED IN EXPERIMENTS, CLUSTERED BY MOVEMENTS

Movement	*Artist (number of images)*
Gothic (46)	Firenze (13), Giotto (21), Lorenzetti (12)
Early Renaissanse (43)	Botticelli (13), Leonardo Da Vinci (9), Filippino Lippi (10), Piero Della Francesca (11)
High Renaissanse (48)	Bruegel (8), El Greco (16), Raphael (9), Titian (15)
Baroque (46)	Poussin (15), Rembrandt (14), Rubens (17)
Rococo (40)	Boucher (12), Fragonard (22), Watteau (6)
Romanticism (41)	Constable (15), Friedrich (11), Turner (15)
Impressionism (46)	Monet (17), Morisot (15), Seurat (14)
Post Impressionism (34)	Gauguin (18), Van Gogh (16)
Cubism (36)	Braque (23), Picasso (13)

Figure 5 shows the distribution of images from different movements, based on cold-warm contrast. It clearly shows the dividing of the painting styles into several groups with similar distribution of cold-warm contrast. Early Renaissance and High Renaissance are with almost equal predominance of warm and cold-warm contrast. Theirs predecessor – Gothic style is similar to them, the higher percentages of warm colors can be explained with presence of paintings with gold coats in icon-like images. The big presence of dark warm colors is specific for the Baroque. Presenting the nature in paintings is typical for the Rococo and Romanticism, which leads to forcing the presence of cold (green and blue) tones. This tendency increases in next styles.

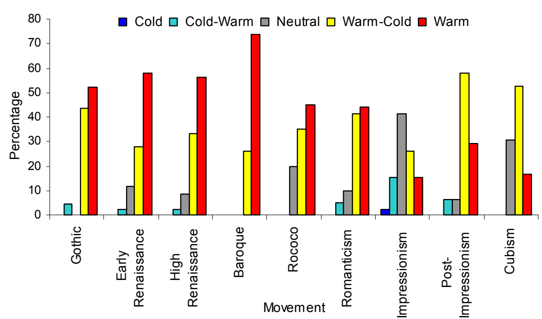


Figure 5. Distribution of of paintings, grouped by movements, based on cold-warm contrast.

Figure 6 shows the splitting of the painting styles in two main groups. The first includes Renaissance, Baroque and Rococo, where almost all pictures can be classified as dark. The second group includes Romanticism, Impressionism, Post-Impressionism and Cubism where dark, middle and light painting are with equal distribution. Many of frescoes in Gothic style are classified as middle because the distemper paints cannot give deep dark colors as oil paints.

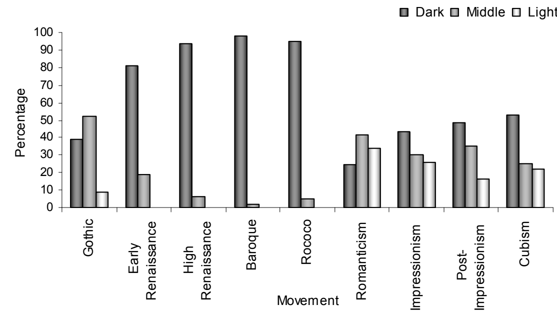


Figure 6. Lightness distribution of paintings, grouped by movements.

Figure 7 shows the distribution of images in different movements, based on the first dominant hue. As we have observed in our previous work [21] the colors around orange are frequently dominant color in the paintings in classic art. An exception to the rule makes Impressionism, where different colors are dominant.

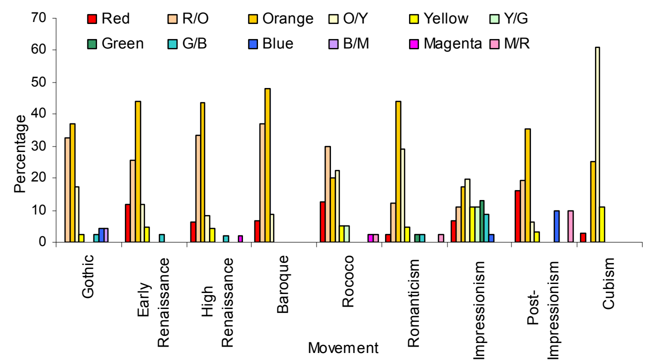


Figure 7. Distribution of of paintings, grouped by movements, based on first dominant hue

Figure 8 shows the distribution of hue contrasts in the paintings, clustered by authors. The order of the artists is on increasing of the analogous contrast, which becomes to be the most frequently used contrast in art paintings.

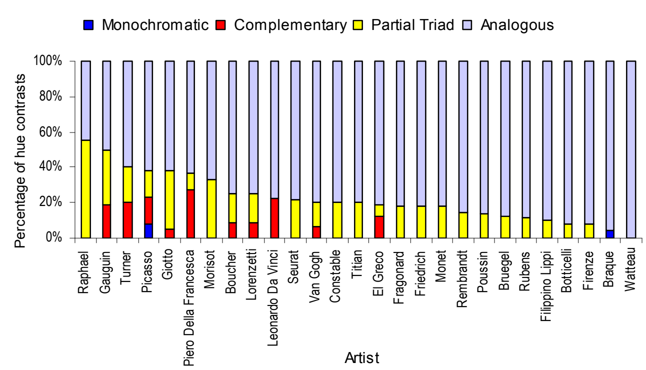


Figure 8. Percentage of different hue contrasts in the paintings of examined artists

Experiments, implemented on the 200 electronic photos, randomly derived from the site of National Geographic [22] showed about 42% presence of Partial Triad, 37% Analogous harmonies, 12% Complementary and about 5% Monochromatic pictures.

Our experiments give us the confident that the observed characteristics can be of help of automatically art movements recognition.

VII. Conclusion and Future Work

In this article we presented a novel and more complete classification of color harmonies by three main characteristics of the color, which is most close to the human perception. We used this classification and develop software system which extracts the defined features from an image. This feature vectors are uses for similar images search within an image collection. Interesting results were found with our experiments. This makes the presented tool a natural component within the virtual laboratory for semantic image retrieval.

The initial work presented here provides a good basis for subsequent developments. We plan to add also texture features, which will allow us to address additional definitions of contrasts, presented in Ittens' theory. In future we will use the system for classifying art painting pictures by artists and movements. We also consider including our system as a Web 2.0 service, which could be included in a virtual learning environment. It will allow art student and designer to search for similar images throw the Internet. It will allow searching using words such as: 'greenish', 'scarlet', 'pale', 'dark', etc.

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