Content-Based Image Retrieval: Color-selection exploited

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Abstract

This research presents a new color selection interface that facilitates query-by-color in Content-Based Image Retrieval (CBIR). Existing CBIR color selection interfaces, are being judged as non-intuitive and difficult to use. Our interface copes with these problems of usability. It is based on 11 color categories, used by all people, while thinking of and perceiving color. In addition, its usability is supported by Fitts' law. The design of the color selection interface provides fast, unambiguous, intuitive, and accurate color selection.

1 Introduction

With a median of 14.38 images on each web page (Lyman and Varian, 2000) the World Wide Web consists to a great extent of images (Lew, 2000). Unfortunately, most Image Retrieval engines are text-based and do not provide the means for searching on image content. Given the exploding market on digital photo and video camera's, the fast growing amount of image content further increases the need for image retrieval engines.

Although query-by-text methods are fast and reliable when images are well-named or annotated, they are incapable of searching in unannotated image collections. Content-Based Image Retrieval (CBIR) methods are capable of searching in such collections. However, present methods used in CBIR are not fully reliable, nor fast enough to handle image databases beyond a closed domain and the techniques used are still subject of development.

The research described here, is part of the research line Eidetic[1]. This line of research is targeted on the integration of five query-paradigms, each of them object[2]-based:

1. Query-by-text, a query is done by way of either a single keyword or a description of an object present in the image.
2. Query-by-example, an example object is used. Its features (e.g. color, texture, and shape), are extracted to facilitate CBIR.
3. Query-by-sketch, this query paradigm was based on the findings of Schomaker et al. (1999), who state that users can sketch the shape of an object and use this as a query;
4. Query-by-color, the color of an object in the image, is defined and used for querying.
5. Query-by-texture, the texture of an object in the image is defined and used for querying.

The query paradigms query-by-text, query-by-example, and query-by-sketch are implemented in the current system Vind(x) (see `http://kepler.cogsci.kun.nl/vindx` and Vuurpijl et al. 2002).

For the present paper, we focus on the fourth query method: query-by-color and in particular on how color can be selected. A color selection interface, based on theories of human color perception, is presented. This is done in such a way, that fast and accurate color selection is promoted.

To satisfy this goal we propose that the user should get a central position in the development of new CBIR engines. This is conform the advice of Rui et al. (1998), who already emphasized, the relevance of user-feedback. However,

[1]Eidetic: Intelligent Content-Based Image Retrieval is a project within the ToKeN2000 research line. See also: http://www.ToKeN2000.nl

[2]An object is defined according to Merriam Webster's online dictionary (http://www.m-w.com) as: A thing that forms an element of or constitutes the subject matter of an investigation or science.

necessary, this is not the only demand that has to be met for a successful CBIR engine, in our opinion. Available information concerning the users cognitive abilities should be considered as well. This holds for all three components of CBIR-engines:

1. Definition of the query *by the user* (i.e. input of *content*)
2. The image retrieval engine, conducting *intelligent* image analyses (i.e. based on and adapted to the *the users' characteristics*).
3. The presentation of retrieval results (i.e. *the output to the user*).

We have conducted the research toward a new color selection user-interface, in which we take into accout human cognitive capabilities.

We will first briefly discuss *human color perception* and practical and technical shortcomings accompanying color perception and selection. Next, color spaces, used in both CBIR and in modeling human color perception, will be discussed. This overview will lead us to a review of existing color selection user-interfaces. After this, we will present the research underlying the new color selection user-interface, followed by the introduction of this new color selection interface. In addition, the importance of using query-by-color is illustrated, especially in relation to shape. We end this paper with plans for future research and the final conclusions.

2 Color perception

Human color perception is a complex function of context, for example: illumination, memory, object identity, culture, and emotion can all take part (Czajka, 2002; Schulz, 1998; Kay, 1999). As already mentioned by Forsyth and Ponse (2002): "It is surprisingly difficult to predict what colors a human will see in a complex scene; this is one of the many difficulties that make it hard to produce really good color reproduction systems. Human competence at color constancy is surprisingly poorly understood. The main experiments on humans (McCann et al., 1976; Arend and Reeves, 1986) do not explore all circumstances and it is not known, for example, how robust color constancy is or the extend to which high-level cues contribute to our color judgments." So, we are not even close to having a good model for human color perception.

Modeling human color perception becomes even more complex due to a range of technical shortcomings. The colors perceived on photographs, for example, can be quite a poor representation of the color of the surfaces when being viewed directly. Furthermore, there is a loss of "color authenticity", due to the compression techniques, used on images that are presented on the Internet. Finally, we want to mention monitor settings (e.g. brightness and contrast) as color disturbing factors. Both the complexity of human color perception and the technical shortcomings are sources of variability, making color a "noisy" source of information.

3 Color spaces

Many attempts have been made to model color perception (Forsyth and Ponse, 2002) by researchers of various fields: psychology, perception, computer vision, image retrieval, and graphics. Some of these resulted in well defined color spaces. The list of color spaces is almost endless. A few of the most important color spaces are:

1. RGB (Red, Green, and Blue)
2. HSV (Hue, Saturation, and Value)
3. HLS (also named HSB)
4. CMYK (Cyan, Magenta, Yellow, and Black (Key))
5. CIE (Centre International d'Eclairage)[3] XYZ
6. Munsell[4]
7. RBW (Red, Blue, and White) (Shirriff, 1993)

In the present research, we adapt the W3C [5] definition of color spaces: "A color space is a model for representing color numerically in terms of three or more coordinates." [6]

Color spaces are needed in:

1. The representation of color-ranges.
2. The manipulation of colors, as is done in the graphics industry.

[3]http://www.cie.co.at/ciecb/
[4]http://www.munsell.com
[5]The World Wide Web Consortium
[6]http://www.w3.org/Graphics/Color/sRGB.html

3. Mixing of colors.

4. The retrieval (i.e. matching) of colors.

So it is evident that CBIR engines, using color as feature, need a color space for color matching. However, often CBIR engines also use a color space in their color selection interface. The color selection interface we developed, has the goal to provide an optimal guidance for the user in the color selection process during querying. Our color selection interface is color space independent, because we have chosen to present a limited number of colors and thus require no color manipulation. Only the advanced features of the color selection interface need an underlying color space, for computing intermediate colors.

Until now, it is still a topic of discussion which color space is the most intuitively one for humans (Douglas and Kirkpatrick, 1996). It is essential that the color space used, follows human color perception as closely as possible because the user is the final judge, of the performance of the system using the color space.

4 Color selection interfaces reviewed

The need for a review of the interfaces of CBIR engines in general is still present. Existing reviews, such as those of Veltkamp and Tanase (2000), Veltkamp et al. (2001), and Venters and Cooper (2000) emphasized the various image retrieval techniques but not their interfaces. Others such as Steiner (2002) did only briefly discuss the usability of 36 freely available web based color selectors. This, despite the fact that a lot of performance can be gained using a well-designed user-interface, improving human-computer interaction.

We did, therefore, conduct a new review on ten online CBIR engines, emphasizing interface aspects and judging human-computer interaction. Ten subjects participated. They were asked to have special attention for the color selection user-interfaces. However, despite the fact that most CBIR engines do use colors, they lack the presence of a color selection user-interface. An exception is, for example, IBM's CBIR engine QBIC[7] [8]. QBIC has reserved a prominent place for color selection facilitating query-by-color.

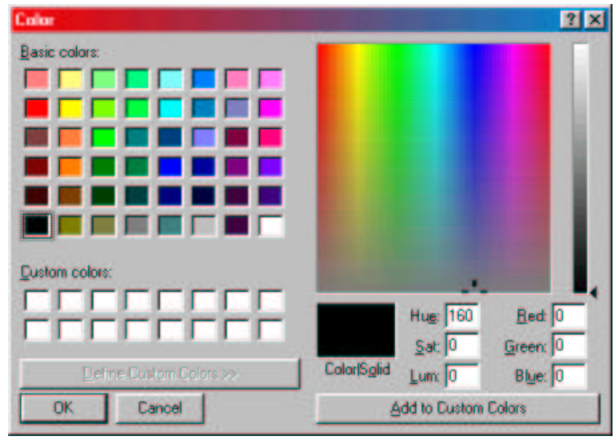

Figure 1: The EditPlus 2 color selector.

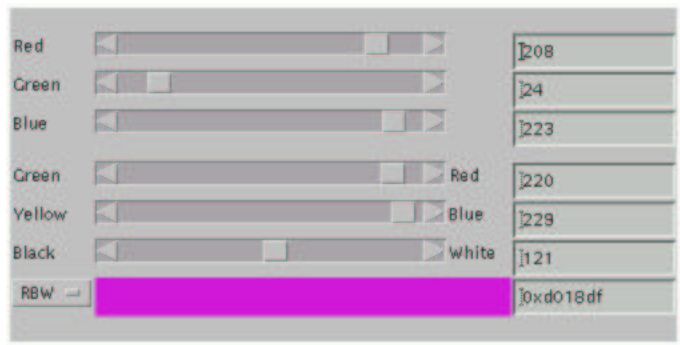

Figure 2: Shirriff's color selector, using solely sliderbars.

The information gathered by the reviews of online CBIR engines did not provide enough information, due to the lack of color selection user interfaces used in CBIR. We, therefore, additionally reviewed several color selection user-interfaces, suitable for online use. An exhausting number of color selection interfaces has been developed in the last 10 years. Some well known, such as the color selection interface of Powerpoint (see Figure 3 and 4), some less familiar such as that of EditPlus (see Figure 1). Others are online Java-applets and applications [9] [10] [11] (see Figure 2).

[7] http://wwwqbic.almaden.ibm.com/
[8] http://www.hermitagemuseum.org/fcgi-bin/db2www/qbicSearch.mac/qbic?selLang=English

[9] http://burtleburtle.net/bob/java/color/color.html
[10] http://www.righto.com/java/colorselector.html
[11] http://java.sun.com/products/jlf/ed2/book/HIG.Dialogs4.html

The reviewed color selectors can be divided into three groups depending on their color definition method.

1. Slider-bars represent the axes of the used color space (see Figure 2 and [12]), providing a way to define a color. In addition, these color selection interfaces present a panel in which the defined color is shown. In some of these interfaces, the sliderbars are combined with numeric fields where the sliderbar position is presented (see Figure 2).
2. A discrete color matrix, with each cell having its own color (see Figures 1 and 3).
3. A square that describes and is perceived as a continuous 2-dimensional representation of the used color space (see Figures 1 and 4). The color of choice, can be directly chosen in the panel. In some color selection interfaces the square is extended with a panel, representing a third dimension of the color space (see Figures 1, 3, and 4).

Some interfaces involve two or three of these color selectors in parallel (see Figures 2, 1, and 4). For example, the use of numeric fields for color selection (see Figures 2, 1, and 4). They can be accessed directly for fast color definition. When the RGB model is used, a user might know the numeric value for a certain color. In such cases, the user can determine which interface to use. Other color selectors provide the possibility to replace the presented colors with a larger set of colors. Hence, the user is often given the choice to use at least two color spaces (see Figures 2, 1, and 4).

We will now discuss a usability study on color selection conducted by Everly and Mason (?), who adapted another method of research then the reviews just discussed. They measured speed, accuracy, and ease of use of four color selection user-interfaces. This was done for four color selection methods: Apple's Crayon (see Figure 5), HSV, RGB, and CMYK color selectors. On *all* three criteria the Crayon color selector, which uses a discrete presentation of colors, outperformed the other three color selectors. With this, experimental proof has been given that the discrete presentation of colors for color selection purposes, is the best choice. The Crayon color selector provided a choice between 60 colors. A small subset of the colors that can be selected, with the other color selection interfaces. However, in the next section we will argue in favor of an even further decrease of the number of colors presented in color selection interfaces.

[12] http://www.righto.com/java/colorselector.html

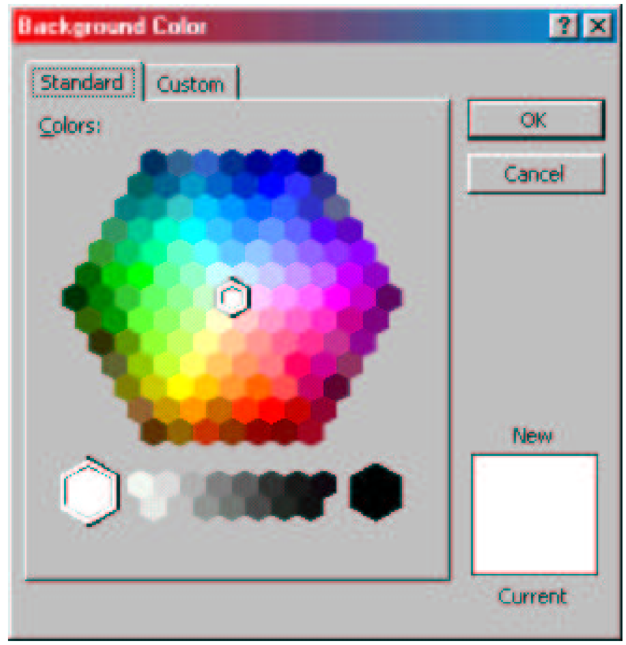

Figure 3: The MS PowerPoint 2000 ”standard” color selector.

The results of the study of Everly and Mason (?) and our review, can be summarized as a triplet of main problems with regard to most of the existing color selection interfaces :

1. Most color selection interfaces require that the user is familiar with the presented color space. Imagine using 3 sliderbars, representing the Red, Green, and Blue axes of the RGB-model, for defining a color such as pink.
2. The users described the color selection interfaces as non-intuitive and often too ”complex” (e.g. The interfaces provide multiple ways to define a color, which is confusing for the users.).
3. The number of variations of colors presented is eye-appealing, but not judged as necessary.

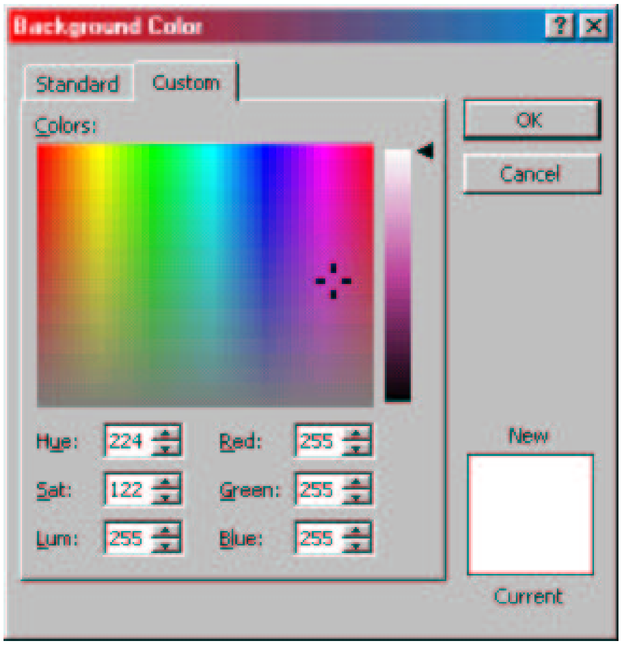

Figure 4: The MS PowerPoint 2000 "custom" color selector.

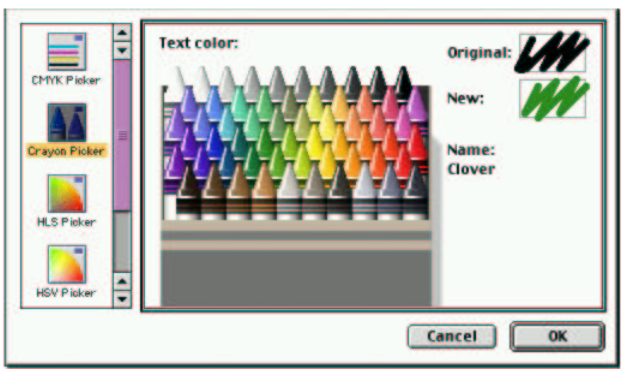

Figure 5: Apple's crayon color selector.

The problems mentioned above are strongly related. The question emerges, why such color selection interfaces have evolved. Color selectors in the graphics industry were present years before the first CBIR engine was born. However, color selectors for the graphics industry do have other demands than color selectors for CBIR. Subtle level crossings for example, do not have to be made in a CBIR context but are very regular in graphics design.

In CBIR no differentiation between more-or-less similar colors is required. The presentation of hundreds or even several thousands of colors was reported as almost overwhelming for the users and with that as being inefficient. Nevertheless, current CBIR engines that allow the user to specify colors (e.g., QBIC), exhibit such an interface.

In the next section of this paper two forms of fundamental research are described, underlying our new color selection interface. In our opinion, are these research forms a very rich source of information, essential in the development of interactive applications, such as CBIR engines.

5 The practical use of fundamental research

We will now guide you through fundamental research in several fields, illustrating two concepts: color categories and Fitts' law, both relevant to the design of a color selection interface.

5.1 Color categories

Humans have a relatively poor color memory over the long term. They tend to remember colors as members of categories. Most people distinguish 11 color categories (Goldstone, 1995; Kay, 1999; Lai, 2000; Shirriff, 1993; Uchikawa and Ikeda, 1986). This set of colors can be divided in 6 *primary colors* (black, white, red, green, blue, and yellow) and 5 *secondary colors* (gray, brown, purple, pink, and orange). Note that this is another division than the often used distinction between the primary colors(red, green, and blue), the secondary colors (yellow, magenta, cyan), and the *none-colors*(black, white, and gray).

There is a range of explanations for the existence of color categories, one of the strongest is the Sapir-Whorf view (Whorf, 1956). According to this view, linguistic categorization can influence non-linguistic perception and cognition. So, the higher frequency of appearance of basic color categories compared to other colors and the names given to these, provide an explanation for the more rapid recognition of these colors.

Basic color categories are relatively insensitive to various sources of variability, such as: illumination, memory, object identity, culture, and emotion. All people tend to categorize colors in the same way.

Both the fast recognition of the 11 basic colors and the fact that they are perceived by *all* people as being "that" color are great advantages, if used in a color selection interface for CBIR.

5.2 Fitts' law

A completely different point of view is that of human motor control. An interface has a certain complexity from the perspective of human perceptual and motor skills. As every computer-user experiences quite regularly, small objects on the computer screen are more difficult to select, than larger are. This intuitive statement is subscribed by Dix et al. (1998): "Since users find it difficult to manipulate small objects, targets should generally be as large as possible". This can be explained, using Fitts' law (Fitts, 1954), which is commonly expressed in the following form:

$$T = a + blog_2(\frac{A}{W} + 1),$$

where T is the selection time of a target of width W, with A as the distance that has to be moved. a and b are empirically determined constants.

Given the constraint of the limited surface of a computer screen, the more colors, the smaller the area available for a color. A color selection interface presenting a small amount of colors would therefore, according to Fitts' law, result in an enormous decrease in selection time, compared to an interface presenting a larger amount of colors.

This is an important advantage for a CBIR color selection interface. As Dix et al. (1998) already stated: "Speed and accuracy of movement are important considerations in the design of interactive systems."

6 The Vind(x) color selector

In the previous sections we have discussed the ingredients necessary to define a color selection user-interface for a CBIR engine. More than anything else, has the complexity of human color perception and human motor skills and its relation to human-computer interaction, been illustrated. A number of issues that have to be taken into account, can be extracted:

1. From the perspective of usability and human motor control, a limited set of colors is sufficient for CBIR color selection.
2. A large variability in human perception of color is present, due to: Human memory, differences between people (e.g. culture and language), and differences in perception within people (i.e., changes in perception over time).
3. Environmental noise is present, due to: Environmental conditions (e.g. lighting) and technical shortcomings (e.g. monitor settings and compression techniques).
4. The lack of a satisfactory color space.
5. Reviews of color selection interfaces.
6. Usability research.
7. People think and perceive colors in terms of the 11 color categories.
8. Human motor skills, e.g. Fitts' law.

Our main concern was to develop a color selection user-interface that was insensitive to the diverse sources of variability in human-computer interaction, concerning color perception, definition of color, and selection of color.

We did not want to depend to heavily on one of the color spaces, because none of them has proven to work correct in all circumstances. We also took human motoric capabilities into account. Furthermore, we did not want to be dependent on environmental variables and technical shortcomings. Above all, we wanted our color selection interface to be of use for all users. So, the interface had to be robust concerning both the variability in color perception within and between people.

We have chosen to exploit the fact that all humans tend to think and perceive colors in 11 basic color categories. Summarizing, we can state that there are four advantages in using the 11 basic color categories:

1. They are robust to variability between people (i.e. All people are different and so is their color perception.).
2. They are robust to variability within people (i.e. People have changing moods and, for example, also changing perceptual abilities.).
3. There is no need for the use of a color space, because we present a limited number of colors and thus require no color manipulation.

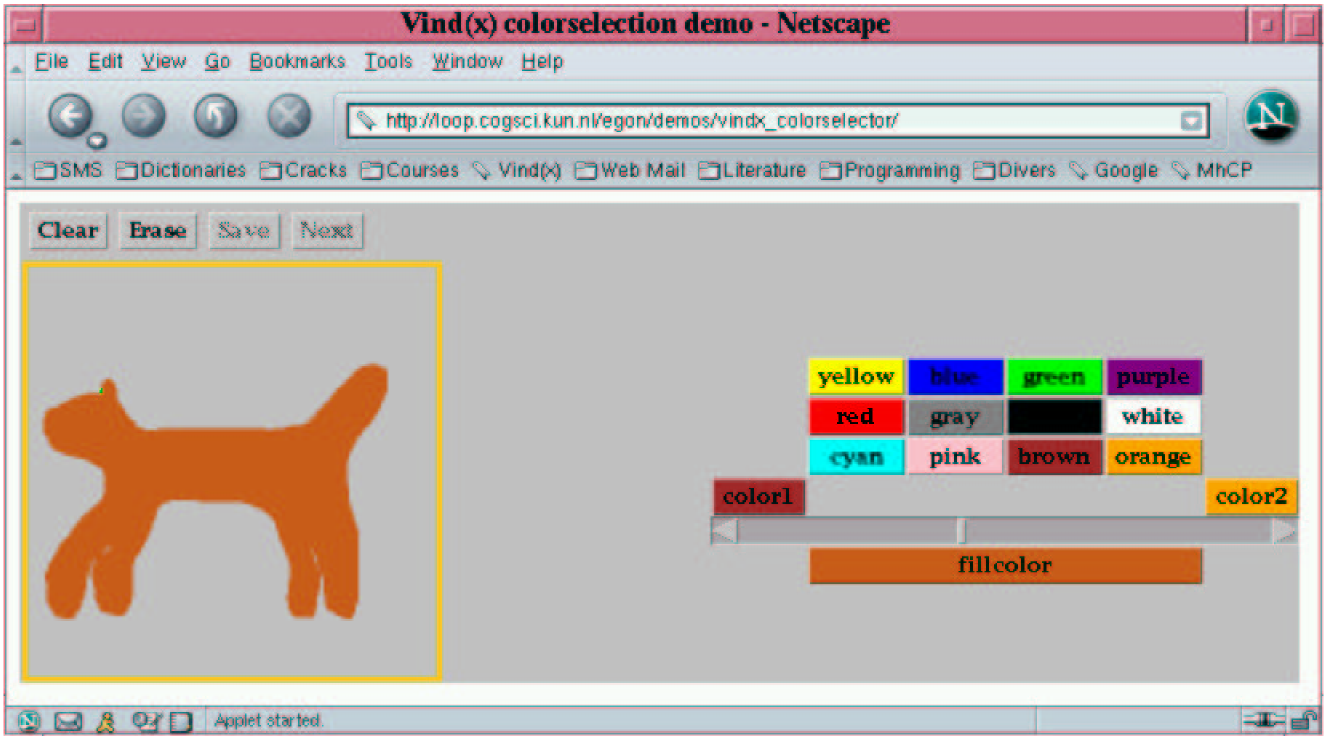

Figure 6: The Vind(x) color selector.

4. An important additional advantage of this limited set of colors, is that there is space for a relatively large area for each of the colors, on the screen.

Based on these four advantages we have chosen to take the 11 basic color categories as the basis for our color selection user-interface. Please note that the classification of the 11 colors in a matrix of 4 by 3, provided space for an additional color. We have chosen to use this additional place. The 11 colors were, therefore, extended with the color ”Cyan”, a secondary color, often associated, for example, with the air and with the sea.

We placed prototypes of each of the basic color categories in this matrix. The RGB-values of the prototypes are determined, using the W3C standards. The resulting color selection user-interface assists in a fast, unambiguous, intuitive, and accurate choice of color.

However, we did also want to take into account that the users may want to specify a particular color that is not one of the 11 basic colors. To cope with this incidental need, our color selection user-interface involves the possibility to mix two colors. With this additional feature, the color selection interface is augmented with the possibility to specify a color of choice. This is in line with the recommendations of Everly and Mason (**?**).

Although the 11 color categories will remain the basis of our color selection, the way they are presented is still a topic of discussion. The ordering of the 11 basic colors is not a trivial problem. The complexity of the design of a user-interface that has to be both functional and eye-appealing remains challenging, due to the lack of formalized design rules (Czajka, 2002). However, we will in the near future conduct a series of experiments, in which a number of alternative presentations of the color selection user-interfaces will be compared.

The fully operational online demo version is currently available at: `http://loop.cogsci.kun.nl/egon/demos/vindx_colorselector/`. In Figure 6 a screenshot of the color selection user-interface is shown.

7 Shape and color

Color is for both human perception and CBIR of great importance and is therefore given much attention by researchers. However, the relation between color and shape has received little attention. This relation is two-folded:

1. Color influences human object recognition.
2. The shape category of an object influences the perceived color of it.

The influence of color perception on object recognition is described by Goldstone (1995) in his article "Effects of categorization on color perception" he states that: "high-level cognitive processes do not simply operate on fixed perceptual inputs; high level processes may also create lower level percepts".

The relation between shape and perceived color is observed by Sacks (1995) who describes the horror people experience when perceiving objects, after they lost their ability to see color. Meadow (1974) described the disabilities his patients had in distinguishing between objects, due to the loss of the ability of seeing color. He further notes that these problems are especially important for the recognition of those objects that rely on color as a distinguishing mark.

So, shape and color influence each other very strongly and can not be separated. Therefore, we have chosen to integrate the described color selection interface, with the sketch pad of CBIR engine Vind(x)[13] (Figure 6). This sketch pad is used to define an object of interest. So, the literature discussed above, illustrates the need for merging image retrieval, using query-by-color, and image retrieval, using query-by-sketch. Both types of interfaces are merged. How to merge both retrieval techniques will probably remain a question for at least several years.

8 Future research

This paper illustrates, the complexity of the design of the first component of CBIR engines: the query definition interface. We have presented guidelines for the design of a part of the first component of CBIR engines: the color selection interface. However, the research toward design-rules for the other parts of the query definition interface, is still in progress. Parallel to this, we are working on the development of the second component of the query-by-color engine: the color matching engine. Here, we again try to adapt the system as much as possible to the user. We aim to embed important human color perception features in the color matching engine (e.g. the principle of color constancy). After the development of this new color matching engine, we will focus on the development of the third component of CBIR engines: The interface presenting the results of CBIR. Such an interface should give the user as much information as possible regarding the processes, underlying CBIR. This facilitates understanding in the use of the features (shape, color, and texture) for CBIR querying and decreases the errors made using them.

Until now, we have discussed the features shape and color, but have not mentioned texture as a feature. Especially, for image retrieval, using query-by-color, texture has to be taken into account as an important additional variable. The integration of texture in query-by-color is an interesting, but also highly complex topic of discussion. For now, we question, if people can define texture, and even if we assume that they can, how an interface providing the facility to define texture, has to be developed?

Both the research toward the user-interfaces, of query definition and presentation of the CBIR results on the one side, and the research toward the color and texture matching engine on the other side, will be used in the adaptation and the extension of the CBIR-engine Vind(x).

9 Conclusions

The present paper has given an overview of a broad range of topics related to color selection. This overview emerged from the research toward a color selection interface for the CBIR engine Vind(x). To fulfill the need for a color selection user-interface for CBIR engines, we, as a first step, conducted three lines of research:

1. Fundamental research
2. A review on color selection interfaces
3. A usability study

[13] http://kepler.cogsci.kun.nl/vindx

From this triplet of research lines a number of issues was extracted:

1. The presentation of a limited set of colors is both sufficient and efficient for color selection in CBIR.
2. People tend to think in terms of 11 color categories and perceive colors as belonging to one of these 11 color categories.
3. People lack the knowledge, concerning color spaces, which is needed in most CBIR color selection interfaces.
4. The size of the surface available on the screen, for each color, influences the amount of time needed for selection of these colors. The larger the surface available for each color the faster the color selection will take place.

These issues revealed a new view on color selection in CBIR. Color selection in CBIR has completely other demands then, for example, color selection in graphics industry, where the users are all experts. Hence, there was a need for the development of a new color selection user-interface, such as presented. The interface presented, is relatively robust toward variability in user-experience and perception, between and within users. It yields three important advantages:

1. A decrease in selection time.
2. High usability, (e.g. intuitively working and unambiguous) compared to existing selection interfaces.
3. Accurate

These advantages are supported by both the 11 color categories and Fitts' law. So one can conclude that the presented interface, facilitates good human-computer interaction.

However, so far we have not taken into account a relatively large group of users. Assuming that in time CBIR engines will be used in a range of settings, by numerous users, the group of users suffering from a form of color-blindness (e.g. red-green or yellow-blue color-blindness) is significant. We have implemented a simple solution for this problem: The colors presented in the color selection interface, are labeled with their name. Such a solution is only possible with a limited set of colors, such as the 11 basic colors. In such a limited set of colors, each of them can have a large enough area available on the screen, to present their label in a readable size of font.

This last advantage of the color selection user-interface illustrates the strength of its simplicity. The color selection user-interface, presented in the current paper, provides fast, unambiguous, intuitive, and accurate color selection. In addition, a number of requirements on color selection interfaces, especially in CBIR are listed in this paper. These requirements can serve as guidelines for the development of color selection interfaces in the future.

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