A Color Coordination Support System based on Color Image

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Abstract: Color selection plays a vitally important role in creating impressions of individuals or companies. This is largely because colors have sensibility aspects, which relate, in part, to images and, in part, to associations. Based on theories of color harmony and sensibility ergonomics, we have developed quantitative and systematic metrics for color images. In this paper, we suggest a color coordinate system that supports color analysis and color harmony functions using color images, which can be captured by corresponding adjectival words. We focus on a prototype system for graphical logo design to exemplify our concepts. The system can be applied to a wide variety of design domains.

Keywords: Color Coordination System, Color Image, Color Harmony, Design Support System

1. Introduction

Much of our perception of physical things includes identifying objects using vision, and in this process, color is particularly essential. Colors have perceiver-dependent properties; in this respect, this can be considered as a kind of subjective attitude. Nevertheless, according to Itten (1970)[1], the concept of color harmony can be removed from the subjective into a realm that reflects an objective principle. For example, people mostly think of the color red as representing a warm or hot feeling, and similarly, of the color blue as representing a cool or cold feeling. This fact reveals that most people have a common sense notion towards colors. That is, colors have an objective essence. If we take into consideration theories of color harmony and sensibility ergonomics, we can develop quantitative metrics.

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[1] Itten (1970). *The Elements of Color*. New York: Van Nostrand Reinhold. pp59-62.

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Since the early 1990s the rapid widespread use of the color monitor as an output device and advancements in digital technology have allowed designers to move from more traditional paper-based work to computer-aided design (CAD). Current software with color related facilities provide color palette functions for easier selection of desired colors. Simple color picker software is generally built into operating systems; there may also be a choice of different color palette systems to select from, for example, RGB, HSB, CMYK, etc. However, a major problem in handling color has to do with data that contains ranges in color — for instance, when designers want to coordinate colors with one or another color they have to deal with delicate variations in the data. So much so, the resulting color coordination depends on designer training and ability. At times, designers are pushed to having to spend time just referring to and comparing large numbers of colors. And, just providing a traditional color picker may not suffice to help designers with color coordination; it is neither intelligent nor faster or nor more efficient.

In this paper we develop a color coordination system that supports designers by matching sensibilities with groups of colors during the color coordination process. Designer sensibilities are represented using color images, each captured by corresponding adjectival words. The system recommends, to the designers, a set of color palettes that match with color images. To achieve color coordination, functionally, we use an "area ratio" theory for color harmony. The designer can then select and even modify colors from a set of color palettes to apply with some given user preference function. The system exhaustively generates the results of the color harmony analysis so that the designer can inspect alternatives to find one that "best" matches with the designer's intentions.

We consider the following process comprising the following tasks taken in order:

1. The designer selects a new bitmap picture (.jpg or .gif format).
2. From the color analysis knowledge base and color image database, the system automatically analyzes the color information in the picture and suggests other color images similar to the picture.
3. The designer can select either an image from the system suggestions or an entirely new color image.
4. The system displays a set of colors that matches with the color image.
5. The color(s) in the set can be modified according to designer preference.
6. When the designer sets up a set of color from a color image, the system then offers, exhaustively, color coordination alternatives from the color harmony knowledge base
7. When the designer is satisfied with the result, the colors are accepted and applied to the original bitmap picture.

We focus on a prototype system for graphical logo design to exemplify our concepts; we claim that this system can be applied to other kinds of design products.

2. Background

2.1 Color Image

Sensibility ergonomics is a form of engineering that integrates emotional agreement into human-computer interface (HCI) design[2]. Sensibility ergonomics can be used to understand the relationship between the factors associated with designer feelings and design elements. Because of the fuzzy nature of a color image, using language is a most convenient method of selecting color — one that can be most readily agreed upon by people[3]. One of the more efficient ways of describing color is through ***adjectives***. We use the term "color image" as the adjectival description for a group of colors which correspond to the same feeling.

Valuable research has been done in Japan by Nagumo (2000)[4]. He uses a questionnaire method to gather some 500000 investigative data points collected over 40 years. The data points are arranged in an x-y coordinate system in order to categorize colors using color images (see Fig.1); the vertical axis represents colors from soft to hard, and the horizontal axis from dynamic to static. Nagumo classifies 160 color images, each of which has between 9 to 24 colors.

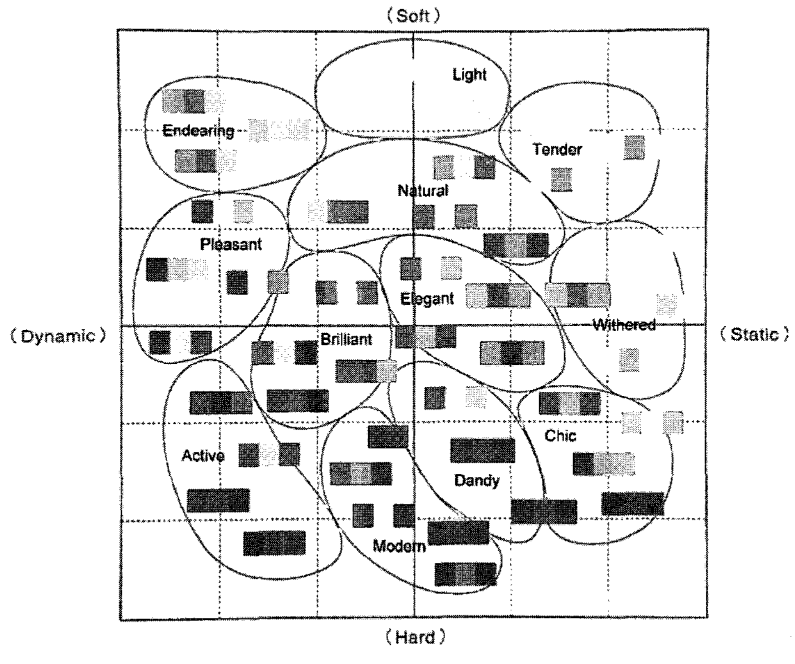

Fig.1 Color image scale (source: Image Research Institute Inc., 2003[5])

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2 Lee, J.-H. and W. Qian (2004) 'Color Your Feeling –Design Support System for Color Coordination-', in *Recent Advances in Design and Decision Support Systems in Architecture and Urban Design* (J.P. van Leeuwen and H.J.P. Timmermans eds.). The Netherlands: Kluwer Academic Publishers. pp113-125.

3 Nagumo, H. (2000). *Color Image Chart.* Taipei: Long See International Book Co Ltd. (in Chinese)

4 Ibidem, pp2.

5 Image Research Institute Inc. (2003). Web Color Design. Taipei: DrMaster Press Co Ltd. (in Chinese)

2.2 Color Harmony

Alone, a color is neither beautiful nor ugly — it becomes meaningful only when it is placed next to another color. Perception of color is influenced by area, in particular, by different area ratios. For example, in general, a larger area of a bright color looks brighter than a smaller area. Likewise, a dark color looks darker in a larger area. This relative ratio of areas can also be used to indicate its visual effect on both brightness and color saturation. In this section we consider exemplar relationships between color harmony and their relative areas[6].

For instance, Goethe obtained the following proportions for the brightness of each hue:

Yellow	:	Orange	:	Red	:	Violet	:	blue	:	Green	
9	:	8	:	6	:	3	:	4	:	6	(1)

Each number represents a measure towards the proportion for the relative brightness of two colors. For the following complementary color pairs: orange-blue, red-green, and yellow-violet, we obtain, respectively the corresponding ratios 2:1, 1:1, and 3:1. Based on this, Itten suggests that the goal should be achieving balance among complementary color pairs through the area ratio[7]. The quantities that Itten uses in calculating the area ratio for primary and secondary colors are the following:

Yellow	:	Orange	:	Red	:	Violet	:	blue	:	Green	
3	:	4	:	6	:	9	:	8	:	6	(2)

Formulae (1) and (2) only deal with brightness and not with saturation. Furthermore, the definitions only apply to pure colors and a few at that too. As such the formulae are of little practical value.

Munsell improves on Goethe's formula. He calculates an area ratio that accounts for both brightness and saturation. His formula for the harmonious area ratio between colors A and B satisfies:

$$\text{Brightness A} \times \text{Saturation A} : \text{Brightness B} \times \text{Saturation B} = \text{Area B} : \text{Area A} \quad (3)$$

Munsell's formula can be used to solve variations in brightness and saturation for different area ratios. In other words, a strong color has to be used in a smaller area whereas a weak color in a larger area balances color harmony.

2.3 Color Difference Formula

The "color difference" between two colors can be calculated. Notionally, as a quantifiable measure, it can be applied to color tolerance, color fidelity, metamerism, etc. Color difference has been used to accurately control color tolerance, to determine pass/fail in all applicable industry color domains[8].

Calculations for color difference require good color models. In 1976, CIE (Commission Internationale de l'Eclairage) published two color models: "CIE 1976 L*a*b* (CIELAB)" and "CIE 1976 L*u*v* (CIELUV)", which experiments on 10°view angle. However, the uniformity for CIE 1976 L*u*v*and CIE

6 Kao, S.-L. (2004). A Study of the effect of changing size and shape of colored area on cognition in color combination. Master Thesis, Graduate School of Visual Communication Design, National Yunlin University of Science & Technology, Yunlin, Taiwan. (in Chinese)

7 Itten (1970). *The Elements of Color*. New York: Van Nostrand Reinhold. pp59-62.

8 Li, X.-Y., J.-Q. Xu, Y.-Z. Liu and H.-Y. Zheng (2002) 'Research on the White Balance of Digital Camera', *Hwa Kang Graphics Communication Journal* 33: 62-70. (in Chinese)

1976 L*a*b* are not perfect, and color difference is calculated by linear distance[9].

For this reason, CIE developed a new color difference formula, CIDED 2000, based on CIE L*a*b*. The formula sets not only a weighting function for hue, brightness, and saturation, but also an interactive term between hue and saturation differences for improving the performance for blue colors, and a scaling factor for the CIELAB a* parameter for improving the performance for gray colors. This formula refers to four reliable color discrimination databases: RIT-Dupont, Witt, Leeds, and Bradford[10]. The formula was tested with the other advanced formulae; it outperformed them by a large margin. The CIEDE 2000 formula is considerably more sophisticated and computationally more involved than its predecessors, CIELAB and CIE94. CIE has been extensively tested and verified to ensure accuracy[11].

2.4 Related Researches and Software

There has been much research and Commercial-Off-The-Shelf (COTS) software in the past 5 years.

Hsiao and Ou (2000)[12] execute consultative glossaries from consumers' perceptional demands for color planning. The result of their system is a set of colors determined according to measures of fuzziness under different consultative conditions. However, the system lacks a color harmony function making it hard for users to achieve color harmony from amongst the suggested colors. Tokumaru et al. (2002)[13] proposed a system that automatically composes color schemes. They make fuzzy rules to evaluate the harmony of color schemes. In their proposed system, effective judgments of color harmony and color image are executed and suitable color schemes acquired by the system. However, the color schemes ignore considerations of size, especially as specific colors in different areas have different color effects. Moreover, the system does not directly apply a color scheme to the target objects so that the designer still has to go through a trial-and-error process to compare each color combination. Ueki and Azuma (2003)[14] developed methods and a system that support Web page designers to decide upon appropriate color combinations for specified images. They applied their system to background color coordination of Web pages by the use of an analysis. In this system, designers know the combination of colors for the intended Web page impression. The designers need have neither sensibility nor knowledge of colors. However, the system only deals with backgrounds of simple types of web page layouts — it is still not capable of handling realistic web page color coordination. In addition, the system lacks color harmony functions.

We compared the advantages and disadvantages of several color harmony applications like Color Wheel

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9 Da, T.-D. (2003). *Introduction to Color Reproduction Technology*. Taipei: Quan-Hua Technology Book Inc. (in Chinese)

10 Luo, M.-R., G. Cui and B. Rigg (2001) 'The Development of the CIE 2000 Colour-Difference Formula: CIEDE 2000', *Color Research and Application* 26: 340-350.

11 Sharma, G., W. Wu and E.-N. Dalal (2005) 'The CIEDE 2000 Color-Difference Formula: Implementation Notes, Supplementary Test Data, and Mathematics Observations', *Color Research and Application* 30.

12 Hsiao, S.-W. and H.-Y. Ou (2000). A Study on the Application of the Spatial Color Image to Design. Master Thesis, Department of Industrial Design, National Cheng Kung University, Tainan, Taiwan. (in Chinese)

13 Tokumaru, M., N. Muranaka and S. Imanishi (2002). 'Color Design Support Considering Color Harmony', in *Proceedings of the 11th IEEE International Conference on Fuzzy Systems*, Hawaii, USA, pp378-383.

14 Ueki, H. and M. Azuma (2003). 'Background Color Coordination Support System for Web Page Design', in *Proceedings of the 2nd IEEE International Conference on Cognitive Informatics (ICCI '03).*

Expert[15], ColorImpact[16], Color Wheel Pro[17], etc. Each provides theory-based basic color harmony types, and also provides the capability for user defined color harmony to make the systems flexible and extensible. Most software use default templates to which to apply their color harmony types, because it is relatively easy to make a harmonious system fit to a chosen shape, size, and set of colors. However, the use of fixed templates limits these systems. Should a designer require a totally different kind of design from any of the default templates – and unfortunately, such situations happen often enough – these systems will not be of much help.

Based on our survey of related research and software applications, we can conceive a more beneficial and enhanced system. First, we note that an analysis of color information is needed to acquire designer concepts. Second, providing a color harmony function is useful for color coordination. Finally, if the system can provide a function to get pictures from outside, it will be more flexible; only dealing with fixed templates or just support recommends colors are not satisfied.

3. Methodology

3.1 Establishing Color Image Data

We use Nagumo's color image data, described in section 2.1, to build a color image database that includes 160 color images each of which has between 9 to 24 colors.

3.2 Establishing Color Coordination Method

Our system generates color coordination based on the concept of a corresponding color image. In order to achieve harmonized color coordination among the colors in a color image, we employ Munsell's color harmony area ratio formula (3) (see section 2.2). Fig.2 outlines the procedure for our color coordination system. The detailed descriptions are as follows:

1. **Step 1: Set a threshold of tolerance for the area ratios.** We need to set tolerances because when the system analyzes area ratios each color, the proportions for colors do not always occur exactly in a harmonious ratio.
2. **Step 2: Calculate relative area ratios of colors in a picture**. The system analyzes area ratios for each color in the picture. The color with the largest area is chosen as the base color and the system then calculates relative area ratios of the other colors with respect to this base color. It helps that the colors are sorted according to decreasing area (see steps 7 and 8).
3. **Step3: Suggest similar color image(s) to the picture**. The system automatically suggests one or more color images that are similar to the given picture to be chosen.
4. **Step 4 – step 6: Calculate relative area ratios of colors in the selected color image**. As in step 2 the system calculates relative area ratios of colors based on the color with the largest area as the base color. Again, the colors are sorted according to decreasing area.
5. **Step 7 and step 8**. Since color area ratios are relative proportions, both base colors from step 2 and step 6 are relatively equal (at 100%), which implies that these do not have to be compared. Therefore the comparison of colors starts with colors with the next largest areas.

[15] Color Wheel Expert Website, http://www.abitom.com/ (last visited on May 16, 2006)

[16] ColorImpact Website, http://www.tigercolor.com/ (last visited on May 16, 2006)

[17] Color Wheel Pro Website, http://www.color-wheel-pro.com/ (last visited on May 16, 2006)

6. **Step 9 – step 11: Calculate the difference of area ratios for the two colors from step 8**. If the difference is smaller than the threshold, record the pair of colors. If not, we shift to the next one and compare repeatedly.
7. **Step 12 – step 14**. The comparisons are continued until the result includes all sets of colors from the given picture. Upon finishing a set of color coordination, we record the results and continually keep finding other sets of results.

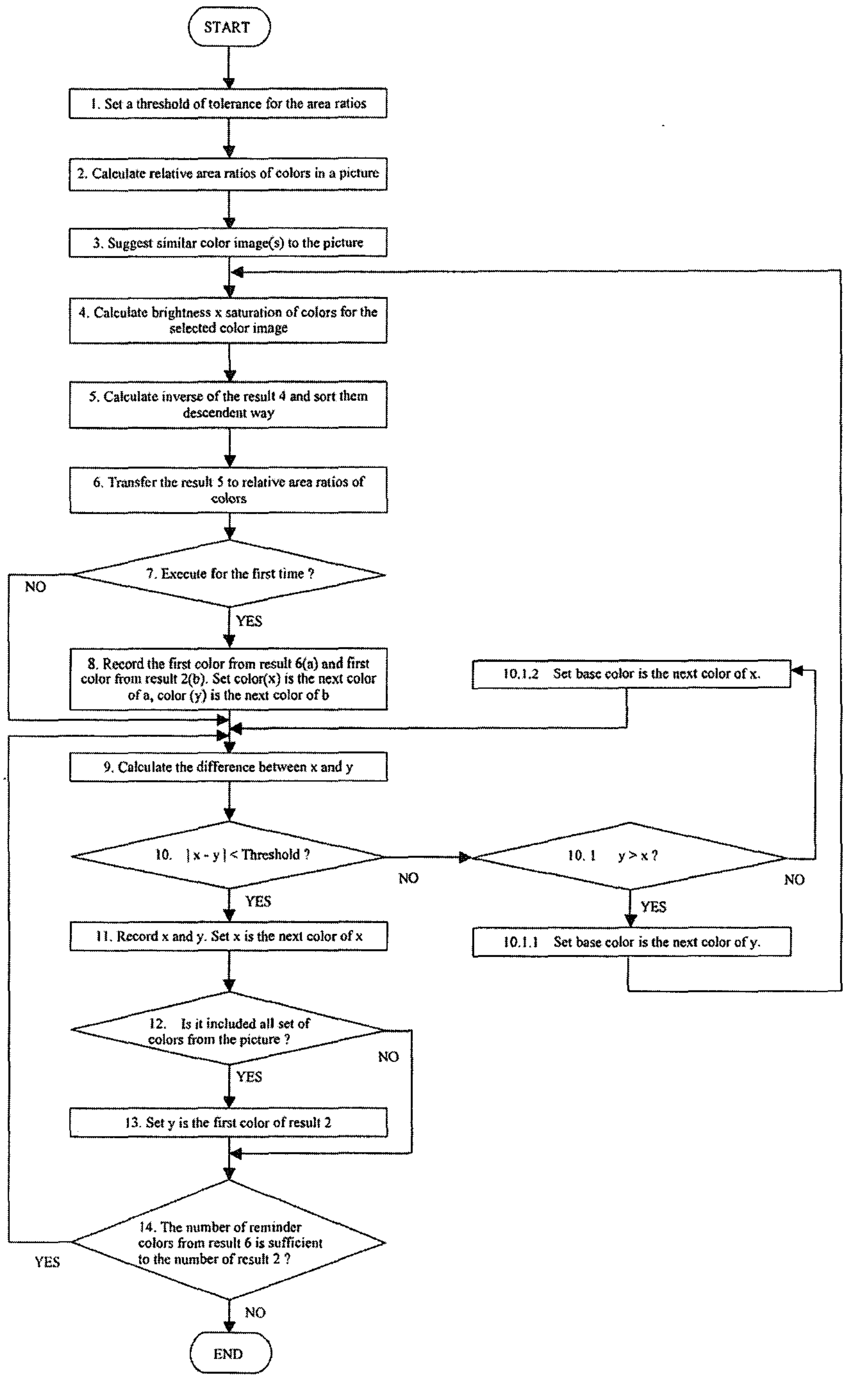

Fig.2 Flowchart of color coordination in our system

3.3 Calculating Color Difference

There are two parts that are needed in order to calculate color difference. These are described as follows:

1. **Color image analysis in a picture**: When the system analyzes the number of colors and the area ratios of the colors in the given picture, it compares these colors with the colors in the color image data using a color difference formula, and selects similar color images to the given picture.
2. **User preference evaluation**: A user can modify colors from the default color in a color image. After that, the system compares user preference colors with the default colors, calculate color difference and record the information in HSV mode. Where the color difference is smaller than "slight", the system ignores the difference and it is not recorded. Otherwise, the system saves up to three modified colors.

Our system adopts the latest color difference formula – CIEDE2000 to calculate color difference as was explained in section 2.3. The reference level for value of color difference is given in Table 1.

Table 1 Reference level of color difference(△E)

Level	$\triangle E^*_{ab}$	Evaluate of color difference(△E)
1	0 ~ 0.5	Trace
2	0.5 ~ 1.5	Slight
3	1.5 ~ 3.0	Noticeable
4	3.0 ~ 6.0	Appreciable
5	6.0 ~ 12.0	Much
6	12.0 above	Very much

4. Prototype Implementation

4.1 System Architecture

The system architecture is shown in Fig.3. A picture can be loaded in the system. The 'Color Analysis' component automatically analyzes color information in the picture including the number of colors and the area ratio for each color. The analyzed result is compared with the 'Color Image' database for similar color images which are then suggested to the user. The 'Color Selection' component shows all colors that correspond to the selected color image. Those colors are displayed in a three-dimensional color space for users to compare and observe. The 'User Preference' database has specific user color modification information from the default as mentioned in section 3.3. The 'Color Harmony' component calculates and sorts all possible combinations of color coordination. Lastly, the 'Color Viewer' component shows all color coordination alternatives for the user to select from.

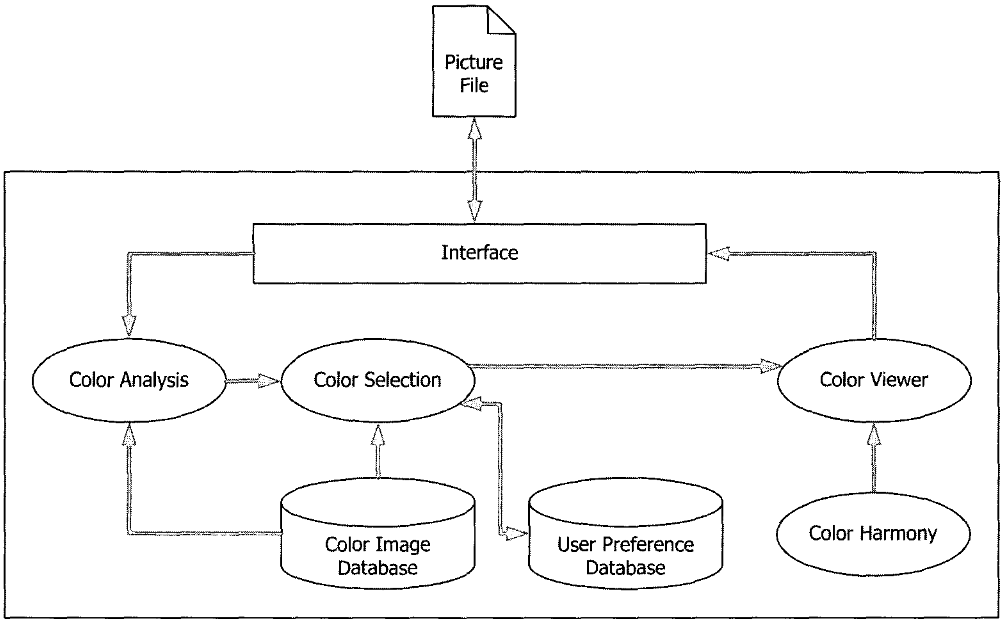

Fig.3 System architecture

4.2 Interfaces and Functions of the Prototype

The system has three phases: (1) Loading a picture from a file, (2) Color adjustment by user preferences, and (3) Composing color coordination. The user starts in the first phase. Fig.4 shows the initial window of our system prototype.

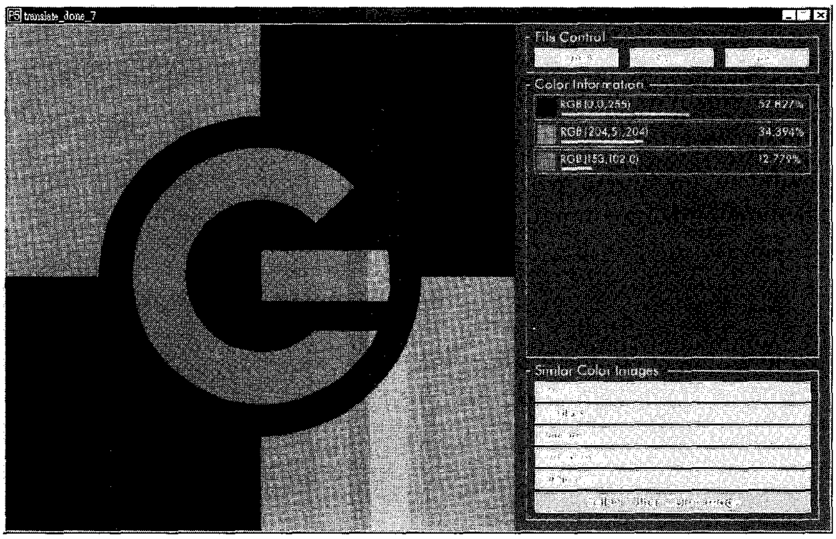

Fig.4 Loading a picture from a file

The user selects "Open File" to load a picture from a file. The system then automatically shows its color information in terms of the number of colors and for each color, its RGB information and area ratio. The system also automatically calculates and suggests one or more color images similar to the picture. The user can select one of these color images or choose 'Select Other Color Image' to find a new color image. If the user selects one of the suggested color images, the system goes to the second phase. Otherwise, the system goes to Fig.5.

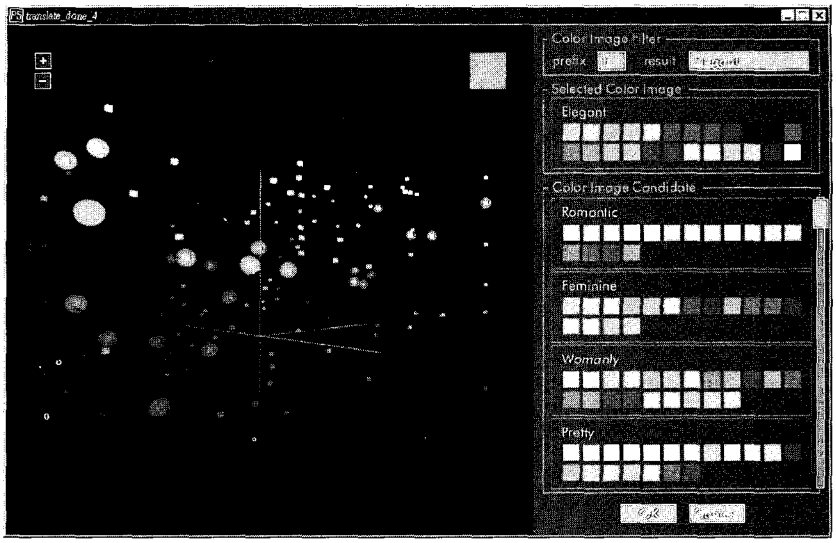

Fig.5 Interface of color image selection

Here, the user can select a color image either from the 3D color picker or from the adjectival names associated with the color images. The 3D color picker is based on the HSB color space: the red-white axis represents saturation; the black-white axis represents brightness; and the color axis represents hue. All colors from each color image are displayed in the 3D color picker. The emphasized colors are those from the selected color image, especially, the largest one, displayed in the right square, which is the user selection color. The color images including the colors are displayed in the right side panel. Using direct mouse manipulation, the user can zoom in, zoom out, and rotate the 3D color picker. When the user selects a color image by its adjectival name, the adjectives are sorted by the prefix character to be chosen. The user clicks "OK" to go to the second phase, or clicks "Cancel" to return to the initial interface.

In the second phase, the system adjusts colors according to the user preference (Fig.6).

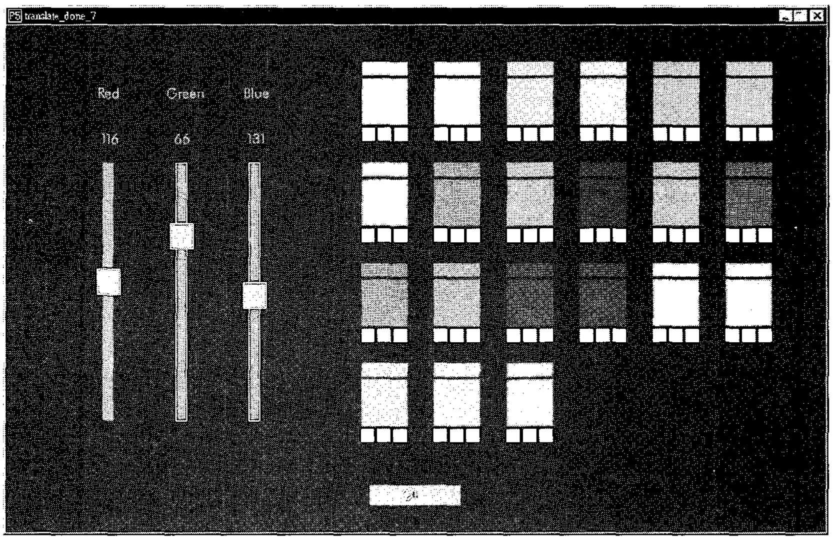

Fig.6 Interface of color adjustment

The system displays each color of the selected color image. If the user has an experience to use the system and adjusts colors from the color image, the history will be recorded and displayed in the bottom of three squares sorted by recent order. The user can adjust colors using color adjustment bars, which are shown immediately to the right side color. The user can also select a color from the history squares, or go back to the default color, which is originally given by the color image, by clicking the top of the square.

After adjusting colors by user preference, the user is able to select the most appropriate color coordination from amongst generated alternatives (Fig.7). The system calculates all possible combinations of color coordination as explained in section 3.2, and displays all alternatives of color combination. The system also displays the original for purposes of comparison. The user can select the most appropriate color coordination from amongst the alternatives or cancel to start the procedure all over again.

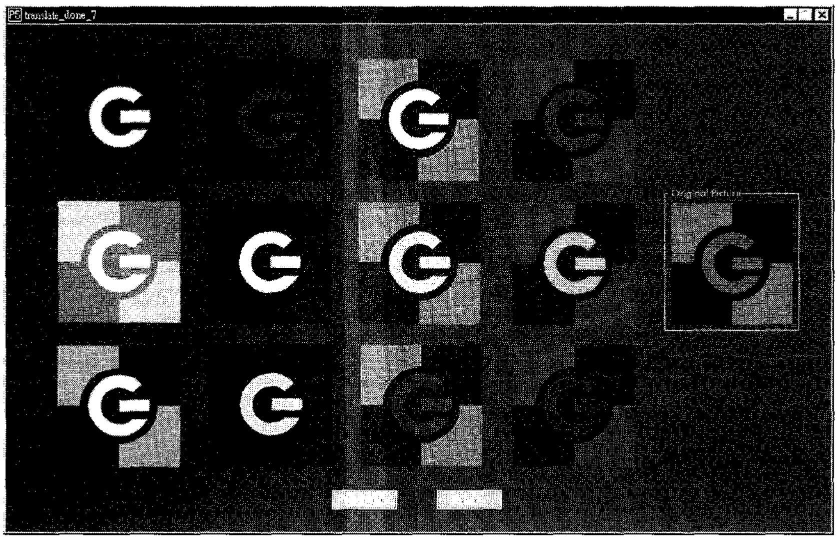

Fig.7 Interface for all alternatives of color coordination

5. Conclusions

This paper describes a color coordination support system based on color image. This new system is not only a "smart e-palette", but is able to overcome traditional rough combinations of RGB values, in a "purpose-oriented" way through the use of knowledge- and databases. Designers can breakthrough deficiencies in their color knowledge in finding the ideal colors, be more efficient, especially in time wise, and, perhaps, more accurate with their *feelings*. With current computer *speeds*, it is now possible work with huge amounts of data based on a complicated color difference formula, CIEDE2000, to be able to preview the results in real-time and thus, achieving a useful and viable computational technology. Moreover, since the system is implemented using Java technology, it is web-based and platform independent. The system also offers a user preference function to support different users.

Future research directions include i) extending the work to increase the number of input file formats. Now the system only accepts the .jpg and .gif formats; ii) making the system server-based will make it more powerful since it can then be linked much larger and more distributed color knowledge and databases; and iii) research into and expanding color image data to support local people's feelings about colors.

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