Automatic Design of Colors for Magazine Covers*

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ABSTRACT

In the design of a magazine cover, making a set of decisions regarding the color distribution of the cover image and the colors of other graphical and textual elements is considered to be the concept of color design. This concept addresses a number of subjective challenges, specifically how to determine a set of colors that is aesthetically pleasing yet also contributes to the functionality of the design, the legibility of textual elements, and the style consistency of the class of magazine. Our solutions to automatic color design include the quantification of these challenges by deploying a number of well-known color theories. These color theories span both color harmony and color semantics. The former includes a set of geometric structures that suggest which colors are in harmony together. The latter suggests a higher level of abstraction. Color semantics means to bridge sets of color combinations with color mood descriptors. For automatic design, we aim to deploy these two viewpoints by applying geometric structures for the design of text color and color semantics for the selection of cover images.

Keywords: Color Design, Automatic Design, Color Harmony, Color Semantics, Color Theories, Color Aesthetics, Color Palette, Color Theme, Design Principles

1. INTRODUCTION

Designers spend their time learning about the concept of color design, which is a fundamental element in visual design. Colors convey moods and emotions to viewers, and they also contribute to the purpose of a design. In fact, when designers attempt to choose colors for any given design, they create a set of colors, called a color palette or a color theme, that conveys the design's purpose. When designers are asked to design a piece such as a magazine cover, poster, brochure, catalog, or webpage, they often start by choosing a good image and then extracting the color palette from that image. A color palette is then used consistently throughout the process of the design. Designers usually choose a 3-color or, at most, a 5-color palette so that their designs are clean and sophisticated in contrast to busy and cluttered [1].

Due to the emergence of automatic design, the concept of color design is one which requires further investigation. The main challenges in the automatic design of colors are: how to determine a color palette that is aesthetically pleasing yet also contributes to the functionality of the design, how to assure the legibility of textual elements, and how to maintain the style consistency of the class of magazine. In order to address these challenges, we study a number of well-known color theories and quantify them in a mathematical framework. These color theories span both color harmony and color semantics. Color harmony is quantified in hue and tone geometric structures by Itten's color contrasts and Matsuda's harmonious templates. We deploy these geometric structures to design a color palette for textual elements, including the masthead and the cover lines. Color semantics, on the other hand, deals with how to relate sets of color combinations with color mood descriptors, for example, when a set of colors conveys a mood such as "nostalgic" or "elegant." For color semantics, we study Kobayashi's Color Image Scale. We employ Kobayashi's scale to select an image for the magazine cover that is representative of the design's color mood. Our solutions have been implemented on top of the Automatic Design of Magazine Covers (ADoMC) system introduced in [2].

*Research supported by Hewlett-Packard Laboratories, Palo Alto, CA.

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2. WELL-KNOWN COLOR THEORIES

In this section, we overview the contemporary and well-known color theories about color harmony and color semantics. The concept of color harmony is based on psychophysical experiments on the physical attributes of colors and how viewers perceive the aesthetics of colors that occur together. Color semantics, on the other hand, relates color combinations with color mood descriptors. For instance, a set of color combinations may represent a "sporty" mood. In the two following two subsections, we discuss these theories in more detail.

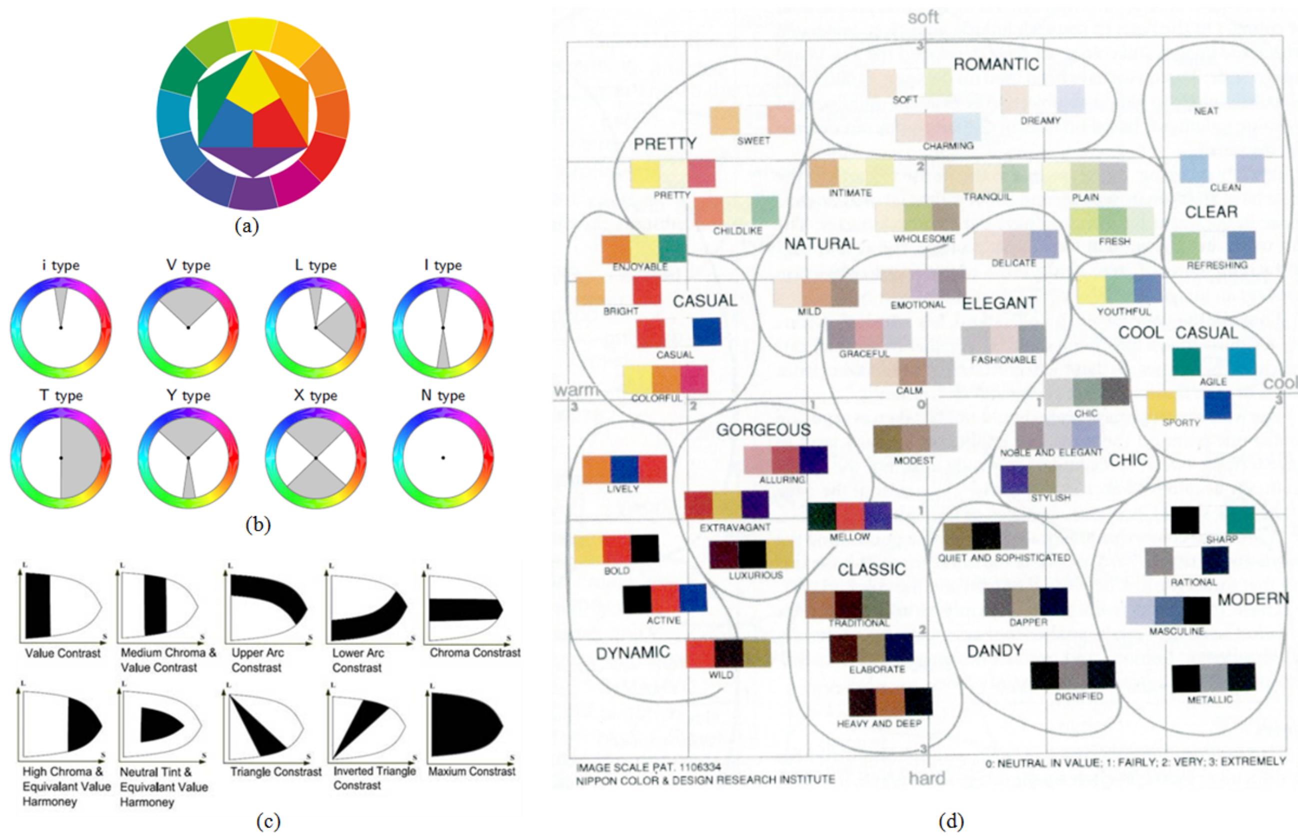

Figure 1. Well-known color theories. a) Itten's hue wheel [3]. Colors on opposite sides of the wheel are considered complementary. b) Matsuda's hue templates [4]. Colors in the shaded sectors are considered harmonious. Image reproduced from [5]. c) Matsuda's tone templates [4]. Colors in the black regions are considered harmonious. Image reproduced from [6]. d) Kobayashi's Color Image Scale [7]. Some 3-Color Combinations with their associated Labels are depicted in this scale. Note that Kobayahsi has defined 1170 3-Color Combinations, in total. The contours show 15 Patterns, labeled by all-capital letters. Image reproduced from [7].

2.1 Geometric Structures for Color Harmony

One of the most significant works in the area of quantifying aesthetics of colors is Itten's color harmony concept. Itten defines seven kinds of color contrast: contrast of hue, light-dark contrast, cold-warm contrast, complementary contrast, simultaneous contrast, contrast of saturation, and contrast of extension [3]. Among these contrasts, complementary contrast is widely used for color harmony. Itten's complementary contrast concept is based on physiological laws of afterimage and simultaneity. These laws suggest that our eyes are satisfied when they perceive a balance in colors, or in Itten's words, "complementary colors." Itten then defines a hue wheel as shown in Figure 1.a, which presents complementary colors in opposite directions. A more comprehensive investigation of this color harmony concept is later suggested by Matsuda's harmonious templates. In a nine year study of colors through psychophysical experiments, Matsuda came up with a number of hue and tone templates illustrating which colors are considered harmonious together [4]. Figure 1.b illustrates Matsuda's hue and tone templates. It is important to note that harmonious geometric structures are context-free. In other words, they are not devised to suggest what colors could be used for a specific purpose or mood in a visual design, and so the need for color semantics is observed.

2.2 Color Semantics

Because a design is meant to convey a purpose to its audience, high level features that describe a design and its color mood become necessary. This viewpoint on colors, which is also called color semantics, is studied by some color theorists. Among these theorists, Kobayashi has proposed a semantic view on the aesthetics of colors in a color scale, called the Color Image Scale, to relate colors with objects, lifestyles, and human preferences. Kobayashi's Color Image Scale investigates the meanings that people may interpret from colors and color combinations. These descriptors were determined from a number of psychological, systematic, and pragmatic approaches. Kobayashi associates the physical attributes of the colors – hue, value, and chroma – to a higher level of abstract attributes of colors – warm-cool and soft-hard. Kobayashi and his institute, Nippon Color and Design Research, have conducted more than a decade of psychophysical experiments on colors. They asked individuals and groups of people to match a color and a combination of three colors with an adjective. Through factor analysis, a semantic differential method, and cluster analysis, Kobayashi came up with a list of adjectives as color descriptors or "color-images." Kobayashi then applied his scale to different color designs, for example, clothes, food, and several other industrial design applications [8]. Kobayashi first defines 130 Basic Colors. He then defines 1,170 3-Color Combinations and associates them with 180 adjectives (called color-images) or Labels. The Labels are later classified into 15 Patterns. These Patterns represent a number of selected terms in fashion and lifestyles. Kobayashi positions his 3-Color Combinations on a scale of warm-cool and soft-hard, and based on this arrangement, defines the boundaries of each Pattern. Figure 1.d illustrates Kobayashi's Color Image Scale with the 15 Patterns and some of his 3-Color Combinations [7].

3. RELATED WORK

Geometric structures for color harmony have been studied by color theorists [9–11]. Deployment of these structures in mathematical frameworks, however, has been recently practiced by computer scientists and engineers. Tokumaru et al. applies Matsuda's hue and tone templates in a color design system that suggests harmonious color combinations to the user based on an input color and keyword [6]. Cohen et al. also employs Matsuda's hue templates for color harmonization of images [5]. In visualization techniques, Wang et al. applies both Itten's complementary hue wheel and Matsuda's hue templates for illustrative visualization of volume rendering [12]. Li et al. defines a set of features for aesthetics assessment of impressionist paintings based on both Matsuda's hue and tone templates [13]. O'Donavan et al. tested Matsuda's hue templates via crowdsourcing. They compared the hue templates with a large scale data set of color palettes that were designed by amateur and professional designers, available at th Adobe Kuler website [14]. There are also several tools for color design that work based on these geometric structures. Meier et al. applies Itten's complementary hue wheel in an interactive color palette tool to support users with a set of harmonious color combinations [15].

The emergence of color semantics in the literature is observed [16–20]. The most significant work on color semantics is perhaps Kobayashi's Color Image Scale, which has been applied in interpretation of user input image color keywords by the color design support system described in Tokumaru et al. [6]. Solli et al. applied Kobayashi's scale for image retrieval [21]. Finally, we employed Kobayashi's Image Scale to select cover images for the design of magazine covers in a recommendation system. This system, called R-ADoMC [22], recommends and personalizes the design of magazine covers based on user preferences.

4. COLOR DESIGN FOR TEXTS

Designers use vivid colors as well as white and black for the text found on magazine covers. These color choices are meant to stand out from the background image, which supports the design's functionality. Accordingly, we limit the color selection for text to meet this form of color design. In this section, we describe how the geometric structures are used to design colors for the magazine cover text, including the masthead and cover lines.

4.1 Masthead and Cover Lines Color Palette

For the masthead color, we employ Itten's concept of color harmony, which is illustrated in Figure 1.a. Itten has chosen ten colors to represent hues. Our hues that we have chosen to use are defined in the HSV – Hue, Saturation, Value – color space. Our hue wheel is, however, distorted as illustrated in Figure 2 (the outer ring of the hue wheel). This modification is aligned with designers' intuition in design of colors. Such intuition, for instance, suggests to pick yellow with purple rather than with blue. As observation has been reported in [14]. Figure 2 provides some examples of before and after applying our modified hue wheel. We choose to use the HSV color space because it has been defined to provide an intuitive color space for designers. We also choose colors that are completely saturated because designers use vivid colors for their magazine cover text. In other words, we choose colors with the maximum amount of saturation and value in the HSV color space.

(a) (b)

Figure 2. Computation of complementary color harmony for masthead and cover lines. a) The modifed hue wheel. b) A comparison between results, before and after applying the modified hue wheel. Photos courtesy of Amir Gharachorlou and Andy Jessop.

To compute the color of the masthead, the cover image is first converted from the sRGB color space to the HSV color space. Then, the opposite hue of the most repeated hue in the image histogram is chosen for the masthead color. Given the hue of the masthead, we obtain the color of the cover lines, namely the headline and byline, by choosing two more colors that are near the masthead's hue. This allows us to achieve the idea of similar hues in V type and Y type templates, as seen in Matsuda's harmonious hue templates (Figure 1.b). For the rest of the cover line colors, we alternate between these two colors. This helps us to adhere to the 3-5 color palette rule that designers construct to keep the cover clean and sophisticated.

4.2 Color Aesthetics and Text Legibility

In the previous section, we discussed how we design a 3-color palette for text colors. However, there are some dilemmas that limit our color choices. The main challenge is that the color palette design must be aesthetically pleasing yet also simple. Therefore, we should limit the palette to two or three colors. This can be a difficult constraint because sometimes these two or three colors are not legible when placed over a background image; and so we have to create a better color that is subject to a readability criterion. The text color is likely to be illegible when the absolute difference between either the hue (in HSV) or the lightness (in CIELab) of the text and its local background is less than perceptually noticeable color distance.

One way of to solve this problem is to expand our use of color to include the variation of Saturation and Value in the color's design. Going back to the geometric structures, we observe that Matsuda has defined tone templates as seen in Figure 1.c. These tone coordinates are composed of Chroma versus Value. Here, Chroma and Value are representative of Chroma and Value in Munsell's color system. The colors seen in the shaded regions are considered to be harmonious. In our design, we use the Upper Arc Contrast and Lower Arc Contrast tone templates (the middle column in Figure 1.c). More specifically, we choose two points in these two black regions: the tip and the tail of the arc. The reason for this decision is that in our contemporary design, professionals tend to use white and black for text colors. Similarly, in our designs we use a pure or highly saturated color with

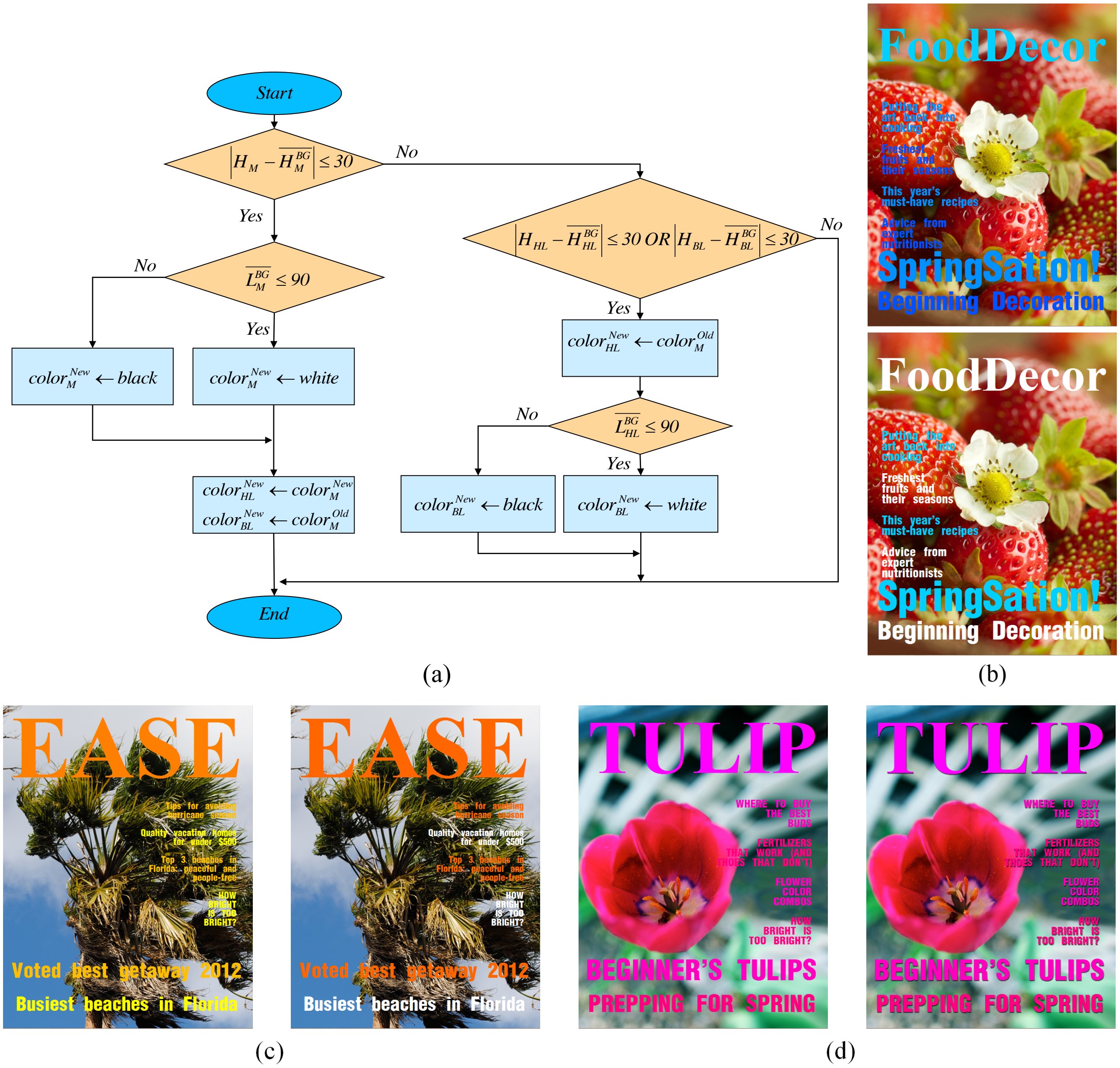

Figure 3. Text legibility solution and results. a) Flowchart representing color modifications for text when the lightness (in CIELab) of the text and its local background are too close. In this flowchart, the lightness of masthead is denoted by L_M, and the mean lightness of the masthead's local background by $L_M^{\overline{BG}}$. Also, HL and BL indicate headline and byline, respectively. The numerical thresholds are based on psychophysical experiments, some described in [23]. b) Before (top image) and after (bottom image) applying the flowchart in (a). c) Results (before and after) of color modifications for the case where hue (in HSV) of text and its local background are too close. d) An alternative solution to improve text legibility by applying shadow effects to the text. Photos courtesy of Andy Jessop (b,d) and Amir Gharachorlou (c).

white or black. In order to choose between white and black, we first consider the local background lightness of the text. If the lightness of the local background is less than a threshold, we use white. Otherwise, we use black. This process is implemented in the flowchart found in Figure 3.a. It is important to note that the comparisons in Figure 3.a are computed in CIELab color space because this color space is perceptually uniform and is a useful system for representation of lightness and just noticeable contrast to the human viewer. Also, the numerical values of the thresholds in Figure 3.a are based on psychophysical experiments, some described in [23].

Another approach to solving the text legibility problem is applying shadow effects on the text. This approach is often taken by designers to mitigate the problem in an aesthetically pleasing fashion. Similarly, in cases where the illegible text colors are raised, we provide an alternative design that includes text shadow effects for the user. Figure 3.d illustrates alternative designs generated by the system.

5. COLOR SEMANTICS FOR COVER IMAGES

Computational aesthetics of photos is one of the recent interests in computer science and engineering. However, most of the related work is focused on a number of low level features in a photo, such as color distribution, texture, and objects [24]. These features are part of the aesthetics of photos, but they are context-free. Since a design is meant to convey a purpose to the audience, we also need a set of high level features to be able to describe a design and its color mood. Our solution to this challenge is inspired by the work on the Color Image Scale by Kobayashi. We have employed color semantics to select an image for the cover based on the color mood that the user wants to convey in his/her design. Accordingly, we have developed a recommendation system, called R-ADoMC, which personalizes magazine cover designs based on user preferences. [22] describes this system, including the design of a set of user interactions for the purpose of automatic visual design. In this section, however, we reiterate the mathematical framework deployed from [21] to implement Kobayashi's scale. Furthermore, sematic color extraction of magazine covers as well as cover image selection is discussed.

In order to map an image to Kobayashi's scale, we first quantize the sRGB color space to a smaller space with 8 levels of R, 8 levels of G, and 8 levels of B. This leads to 512 sRGB colors or bins. We obtain Kobayashi's histogram of an image, denoted by h_K from the sRGB histogram of the image, denoted by h_{RGB}, according to $h_K = h_{RGB} \cdot T$. Here T is the transformation matrix. We construct T by first converting both the quantized sRGB space and the 130 Basic Colors to CIELab color space. This space is perceptually uniform, and so we measure the distance between each pair of colors converted from these two color spaces in terms of their Euclidean distance in CIELab, denoted by $\triangle E_r$. We can then define the elements of the transformation matrix T:

$$t_{rl} = \begin{cases} 1 - \frac{\triangle E_r}{10} + 0.1 & \text{if } \triangle E_r \leq 10 \\ 0 & \text{otherwise} \end{cases}$$

where $r = 1, ..., 512$, and $l = 1, ..., 130$.

Hence, we obtain Kobayashi's histogram h_K of an image. The next step is computation of the distribution of any 3-Color Combination in the given image from its corresponding h_K. To do so, we first define the following notation to refer to a 3-Color Combination: $c_n^{(3)} = \left\{b_n^1, b_n^2, b_n^3\right\}$, where $0 \leq b_n^i \leq 130$ denotes the index of a Basic Color. Now we define h_σ as the distribution of the all 3-Color Combinations in a given image by $h_\sigma = [\sigma_1, ..., \sigma_{1170}]^T$ where $\sigma = \min(h_K(b_n^1), h_K(b_n^2), h_K(b_n^3))$ for $n = 1, ..., 1170$.

Next, we define matrix L as an index matrix to associate the 180 Labels to the 1170 3-Color Combinations:

$$L = \left[\vec{l_1} \ldots \vec{l_{180}}\right]$$

where L is a 1170 $\times$ 180 matrix and

$$l_{ij} = \begin{cases} 1 & \text{if label } j \text{ is associated to Color Combination } i \\ 0 & \text{otherwise} \end{cases}$$

Also, we define the diagonal matrix R, which contains the ratings of each 3-Color Combination. Hence, we obtain the distribution of each Label in an image by h_L as:

$$h_L = h_\sigma \cdot R \cdot L$$

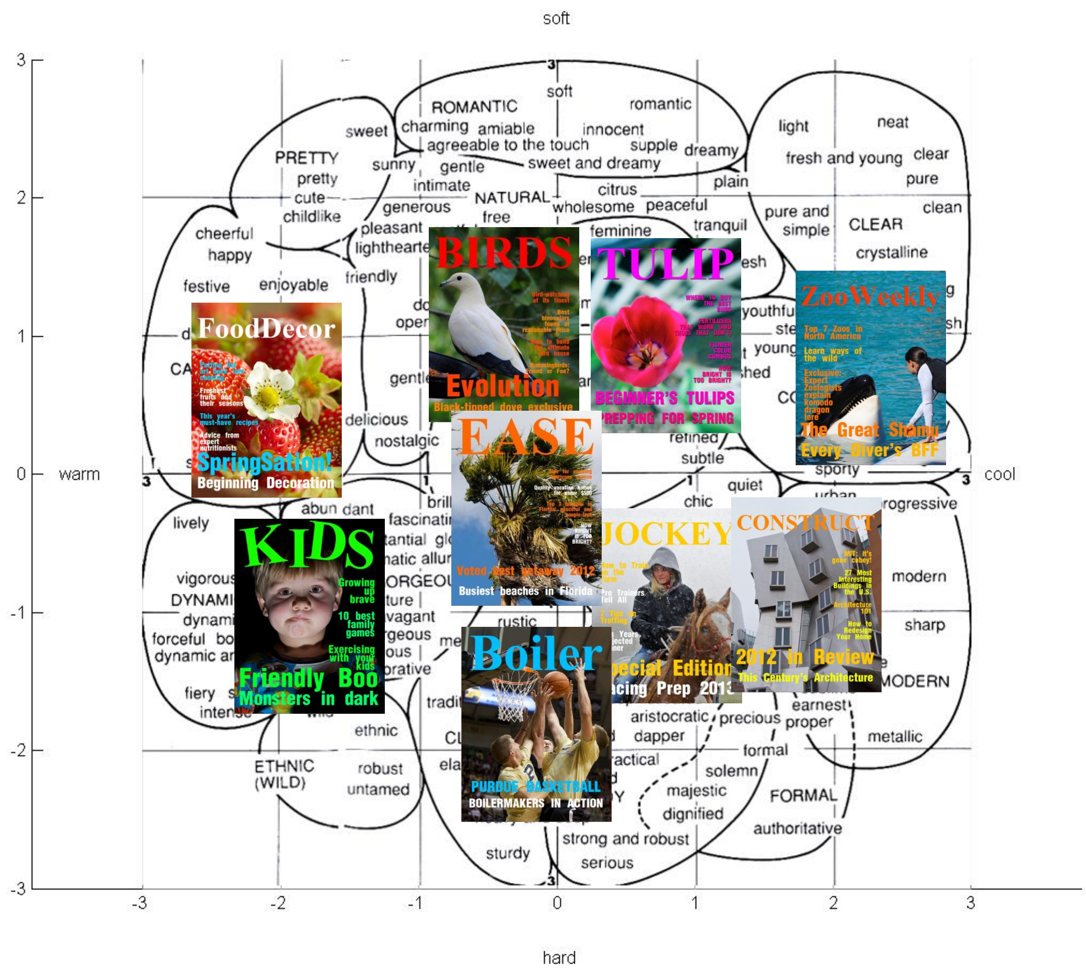

Figure 4. Illustrations of magazine covers that were automatically designed on Kobayashi's Color Image Scale. The cover images of these designs have been selected according to Kobayashi's Patterns to represent the mood of the magazine cover designs. Photos courtesy of Andy Jessop (FoodDecor, BIRDS, TULIP, KIDS, Boiler, JOCKEY, and CONSTRUCT) and Amir Gharachorlou (ZooWeekly and EASE).

Similar to the matrix L, we can define the matrix U as an index matrix to associate the 15 Patterns to the 180 Labels. Hence, we obtain the distribution of each Pattern in an image as follows:

$$h_P = h_L \cdot U$$

For an album of images, one can find an image with the highest value for any of these 15 Patterns. For instance, for an album with N images, the image that is the best match for "NATURAL" (Pattern 7) and "CLASSIC" (Pattern 10) is retrieved from:

$$\underset{j}{\operatorname{argmax}}\{h_{P_{j,7}} + h_{P_{j,10}}\}$$

for $j = 1, ..., N$.

Finally, given the location of all the 180 Labels on the scale from the matrix E, we can obtain s, the location of the given image on the scale, from:

$$s = h_L \cdot E^T$$

Figure 4 depicts a set of magazine covers generated by our system. It is important to note that the cover images are categorized according to Kobayashi's scale before adding text.

6. CONCLUSION

In the design of a magazine cover, making a set of decisions regarding the color distribution of the cover image and the colors of other graphical and textual elements is considered to be the concept of color design. This concept addresses a number of subjective challenges, specifically, how to determine a set of colors that is aesthetically pleasing yet also contributes to the functionality of the design, the legibility of textual elements, and the style consistency of the class of magazine. Our solutions to automatic color design includes the quantification of these challenges by deploying a number of well-known color theories. We discussed Itten's concept of color harmony, Matsuda's harmonious hue and tone templates as the geometric structures for color harmony. We then emphasized the notion of color semantics. We described Kobayashi's Color Image Scale and illustrated how we utilized this scale to convey a design's color mood. We believe the suggested framework of automatic color design can be expanded to color design for other types of media such as document collaterals, webpages, and videos. Also, the notion of color semantics can be applied in various applications, including semantic color extraction from images, color mood transfer, computational aesthetics of images, image annotation and retrieval, image enhancement techniques, recommendation and personalization, and design by examples. This notion can also provide more sophisticated sets of user interactions and user interfaces.

ACKNOWLEDGMENTS

We gratefully thank David Sigman, Head of The Patti and Rusty Rueff School of Visual and Performing Arts at Purdue University, and Petronio A. Bendito, Assistant Professor of Visual Communication Design, The Patti and Rusty Rueff School of Visual and Performing Arts at Purdue University, for their input on our automatic design. Also many thanks go to Elana Cutter, recent graduate of the English Secondary Education program at Purdue University, for editing this manuscript.

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