Affective Color Theme Generator for Visual-Textual Design: The Exploration of 3-Color for Banner Design

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Abstract: Color design is a crucial component in creating an appealing media presentation. Designers always prepare many color themes in their design work, while it is not an easy work for non-designers to obtain suitable colors. In this paper, we propose an affective color theme generation approach for exploring of 3-color themes. Banner design acts as an initial application. First, we create a color form with overlapped blocks for the evaluation samples of color theme, and conduct the evaluation experiment to gain the affective data for color themes which are created by designers. Second, we analyze the relationships between color features and impressions, and create the estimation model. Then, we propose to generate new color themes corresponding to specified impressions based on the affective color model. A recommender system is developed to create banners with different colors corresponding to specified impressions. Moreover, we implement the mechanism of color unification with input image and text color legibility checker in the design system.

Keywords: Color Theme; Affective Design; Hue & Tone; Visual-Textual Design; PCCS

1. INTRODUCTION

People are very sensitive to color and effective use of color is extremely important in graphic design. Choosing suitable colors is a difficult task and it even confuses professional designers to use appropriate color in their design works. In practice, there are many online color design services, such as Adobe Kuler or known as Adobe Color, and COLOURLovers [1, 2], offering abundant user-provided color sets, called color themes, i.e., ordered combinations of 1-5 colors. These color themes have related ratings. The rating data only express the preference of users. A well-known research of colors and various human impressions, Kobayashi’s art work, maps color themes to a color image-scale space [3]. Many researchers adopt this image-scale space in their works, such as the affective image colorization and adjustment [4, 5, 6], semantic image indexing [7]. These color themes are originally designed for image presentation, without considering textual description.

Nowadays, people are creating greater amounts of rich-media content on the Web than ever before. One of the fundamental challenges is how to create a visual design object consisting of multiple media elements, e.g., image and textual description [8]. The design object combining image and text contents, is called visual-textual presentation media, e.g., poster, magazine cover, banner, and any other rich media. The automatic colorization for visual-textual presentation media is becoming ubiquitous in both commercially printed publications and online digital advertisements. Generally, color themes are extracted from well-designed images and photographs, or created by designers, and applied for image colorization. To our knowledge, there are less researches and applications about the colorization for visual-textual design which is referring to image color, text color, and background color of text contents.

For color system, modern color theory began with Isaac Newton, who devised hue wheel by arranging seven spectral colors into an incomplete circle [9]. Subsequently, many psychologists and artists devoted to developing a color space. In the first decade of the 20th century, a true color system, Munsell Color System was developed in 3-dimensional space of hue, lightness, and chroma, known as saturation. With the development of color theory, many industrial color standards have been produced. Practical Color Co-ordinate System (PCCS), developed from 1964 by the Japan Color Research Institute, is a color-order system similar with Munsell’s system. The color space in this system is indexed by hue and tone, and tone is the mixing of lightness and saturation. PCCS color chart is set with 288 colors for practical use and it is widely used for color investigation, color recording, and color education [10]. We use PCCS to help extract color features and generate color themes in this study.

In this paper, we explore the approach for affective color theme generation for visual-textual design. 3-color theme are set as the first trial and it is applied to web banner design which requires personalized design for millions of users and frequent updating for new contents. We first conduct an evaluation experiment to gain the affective
data for color themes which are created by designers. Different from the general color themes with ordered color bar, the colors are shown as overlapped blocks with different color areas in our work. Then color features based on PCCS are extracted, and the estimation model of affective color features is learned by a multiple linear regression. Based on this model, we propose to generate new color themes corresponding to specified impressions, and develop a recommender system for automatic colorization for banner design.

2. AFFECTIVE EVALUATION OF COLORS

2.1 Color themes for evaluation

Considering that people prefer in themes which are neither too simple (i.e., monochromatic), nor too complex (more than 2-3 different hues) [1], the color theme in our study contains 3 colors and the 3 colors in a theme almost have different hues. Generally, color themes in online communities and related researches are shown in the form of ordered homogeneous bars. Considering of visual-textual presentation media that texts overlay on the background color or image, the samples of color themes in our study are designed with several overlapped blocks with different areas as shown in Figure 1. In our form, each 2 colors have adjacent edges for easier comparison and evaluation. The arrangement of overlapped color blocks brings more intuitive feelings to an actual visual-textual presentation. These 3 colors are called as base color, assort color, and accent color [10]. The base color is expected to be used as the background color with largest area in a design. The assort color, or called main color, is used to enrich the whole design with relative less area. The accent color aims to be used to capture people’s attention with least area. For the areas of 3 colors, there are some popular design principles for color ratios, such as 70-25-5 rule [11], and 60-30-10 rule [12]. These rules are derived from the experience of designers and adjusted in practical application scenarios. After the discussion with color coordinators and seasoned designers, we set the final proportion nearly as 74-22-4 with best color balance for evaluation samples.

We ask designers to create 232 color themes for several specified design images, as pretty, dynamic, etc., which are well-distributed in Kobayashi’s Color Image Scale [3]. The colors in the evaluation samples contain different hues, and different segments of saturation and lightness.

2.2 Affective evaluation experiment

We extracted 30 kansei words including 26 affective words based on color image scale and 4 seasonal words. All these words can be found in Table 1 in section 3. The evaluation experiments for these 232 color themes were conducted for 109 designers. These color themes were divided into 8 groups and each group of them was evaluated by 12 to 15 participants with 30 kansei words. The evaluation experiment was executed through online questionnaire survey by 5-scale method and entrusted to a research company, Macromill. In this experiment, all participants are ensured without color deficiency and their monitors are larger than 20-inch. The age of these participants have a distribution in twenties, thirties, forties, fifties, and sixties.

3. PREDICTION MODEL OF 3-COLOR

This section describe method for learning the affective models by color features and evaluation data. As a widely used multiple linear regression model in Kansei Engineering (KE), Quantification Theory Type 1 (QT1), is used to analyze the quantitative relationships between kansei words and color features.

3.1 Feature vectors

For an input color theme \( \lambda \), we define a vector \( x_i \) where \( i \in \{1, 2, 3\} \) which are corresponding to base, assort and accent colors. A vector \( x_{1i} \) expresses the presence or absence of hue and its categories. We extract 13 categories for each color hue, that is \( i \in \{1, 2, ..., 13\} \). The categories for hue H include 12 interval hues from 24 hues and the neutral one in PCCS, that \( H \in \{2, 4, ..., 24, N\} \). A vector \( x'_{1j} \) expresses the presence or absence of tone and its categories. 12 tones are extracted as categories for each tone, as vivid (v), bright (b), strong (s), deep (dp), light (lt), soft (sf), dull (d), dark (dk), pale (p), light grayish (ltg), grayish (g), dark grayish (dkg), that is \( j \in \{1, 2, ..., 12\} \), and \( T \in \{v, b, s, dp, lt, sf, d, dk, p, ltg, g, dkg\} \). The tone of neutral color is represented by its closest color tone for analysis. Besides hue and tone of each color, we add hue relations of 3 colors, and tone relations of 3 colors into learning model which are defined as \( Q(x_{1i}, x_{2i}, x_{3i}) \) and \( Q'(x_{1j}, x_{2j}, x_{3j}) \).

Figure 1: Parts of 3-color evaluation samples
For hue relations, there are several common definitions for 2 hues, as identical, adjacent, similar, ambiguous, contrast, split complementary, and complementary types, shown in Figure 2. In this study, we clarify them into 4 groups, signed as, I: Identical hues; S: Similar hues, including adjacent and similar types; M: Ambiguous hues, or called Intermediate hues; C: Contrast hues, including contrast, complementary, split complementary types.

The relations of 3 hues \( \varphi \) are the unordered combination of the relations of base-assort colors, base-accent colors, and assort-accent colors. Then, 14 categories are collected shown as Figure 3, that \( \varphi(H_1, H_2, H_3) \in \{CCC, CCM, CMM, CS, CMS, M, MSS, ISS, CN, MC, SN, IN\} \) and \( h \in \{1, 2, ..., 14\} \). N means having a neutral color.

For tone relations, tone is consisted with two concepts of lightness and saturation. The lightness and saturation are both divided into 3 groups, signed as high, medium, and low. As Figure 4 shows, high lightness contains p, lt, and b. Medium lightness contains ltg, g, sf, d, s, and v. Low lightness contains dkg, dk, and dp. Meanwhile, b, s, dp, and v belong to high saturation. Lt, sf, d, and dk belong to medium saturation. P, ltg, g, and dkg belong to low saturation. The relations between high and low groups are defined as contrast (C), and the relations between medium and high groups or medium and low groups are defined as similar (S). In this definition method, the relations of lightness for 3 tones are signed as, 1L: 3 tones correspond to 1 lightness group; 2L_S: 3 tones correspond to 2 similar lightness groups; 2L_C: 3 tones correspond to 2 contrast lightness groups; 3L: 3 tones correspond to 3 lightness groups. The relations of saturation for 3 tones are signed as, 1S: 3 tones correspond to 1 saturation group; 2S_S: 3 tones correspond to 2 similar saturation groups; 2S_C: 3 tones correspond to 2 contrast saturation groups; 3S: 3 tones correspond to 3 saturation groups.

The relations of 3 tones \( \varphi'(T_1, T_2, T_3) \) are the combination of lightness and saturation, such as 1L&1S. For the evaluations in this study, there are 15 categories extracted for the relations of 3 tones, that \( t \in \{1, 2, ..., 15\} \). Here, 2S_S and 2S_C are merged as 2S for 2L_C.

3.2 Regression model

Given an objective variable for an evaluation with a kansei word \( y_\lambda \) for each sample \( \lambda = 1, ..., m \).

\[
y_\lambda = \sum a_{ij} x_{ij\lambda} + \sum b_{ij\lambda} x'_{ij\lambda} + \sum c_{ij\lambda} x_{ij\lambda} x_{2ij\lambda} x_{3ij\lambda} + \sum d_{ij\lambda} x'_{ij\lambda} x'_{2ij\lambda} x'_{3ij\lambda} + \varepsilon_\lambda
\]

where,


\[ x_{li} = \begin{cases} 
0 & (H_{li} \neq H_l) \\
1 & (H_{li} = H_l) 
\end{cases} \]  
\( (2) \)

\[ x'_{lj} = \begin{cases} 
0 & (T_{lj} \neq T_l) \\
1 & (T_{lj} = T_l) 
\end{cases} \]  
\( (3) \)

\[ Q_h(x_{1l}, x_{2l}, x_{3l}) = \begin{cases} 
0, r_h \notin \phi_h(H_1, H_2, H_3) \\
1, r_h \in \phi_h(H_1, H_2, H_3) 
\end{cases} \]  
\( (4) \)

\[ Q'(x'_{1l}, x'_{2l}, x'_{3l}) = \begin{cases} 
0, r_l \notin \phi'_l(T_1, T_2, T_3) \\
1, r_l \in \phi'_l(T_1, T_2, T_3) 
\end{cases} \]  
\( (5) \)

Only a variable assigned as a category of an item is set to 1, otherwise be set to 0. \( a_{li} \) denotes for the coefficient of hue of color \( l \) with categories \( i \). \( b_{lj} \) denotes for the coefficient of tone of color \( l \) with categories \( j \). \( c_h \) denotes for the coefficient of hue relations of 3 colors with categories \( h \). \( d_{i} \) denotes for the coefficient of tone relations of 3 colors with categories \( i \). \( r_{h} \) denotes the relation of 3 color hues, and \( r_{l} \) denotes the relation of 3 color tones.

### 3.3 Estimation precision

The multiple correlation coefficient \( R \) determines how well the estimation model fits the observed data. In the long experience of KE, \( R^2 \) should be more than 0.6 [13]. As a preliminary attempt, we built models with CC-features [4] including 10 hues, 12 tones for 3 colors, and 6 color patterns with some decision rules. We found that the decision rules for color patterns is ambiguous to classify color themes. Then we built affective models with our features including 13 hues and 12 tones for each color, 14 hue relations of 3 colors, and 15 tone relations of 3 colors. The Table 1 shows the results of \( R^2 \) for the evaluation data of 3-color themes. It is found that the estimation models with CC-features are reliable for 23 kansei words, that is 7 kansei words have a result of \( R^2 \) which is less than 0.6, and the estimation models with our features are reliable for 27 kansei words. Our method is precise and scalable for classifying hue relations and tone relations, and the decision rules in our work have better performance than the rules of CC-features.

### 4. COLOR THEME GENERATION IN PRACTICE

#### 4.1 Color generation method

The coefficients in regression model, which are called category scores in QT1, denote the degree of relevance with kansei words. Generally, we can get a color theme with maximum of categories scores, that is, the best result is \( \{a_{1max}, a_{2max}, a_{3max}, b_{1max}, b_{2max}, b_{3max}\} \). Then the hues and tones for 3 colors should be set as \( \{H_{1max}, H_{2max}, H_{3max}, T_{1max}, T_{2max}, T_{3max}\} \). However, when \( c_{max} \) is larger than \( a_{max} \) and the relation of selected hues does not fit \( \phi_{max}(H_1, H_2, H_3) \), the result has conflict and the hues should be adjusted. Similarly, when \( d_{max} \) is larger than \( b_{max} \) and the relation of selected tones does not fit \( \phi'_{max}(T_1, T_2, T_3) \), the result has conflict and the tones should be adjusted. The process for adjustment is to keep the categories which have larger coefficients and change other categories which are fitting the relation of hues or tones.

Moreover, we create several color themes in order. The pseudo code is shown as follows:

#### Table 1: Multiple correlation coefficients R-squared of estimation models for 3-color themes

<table>
<thead>
<tr>
<th>Emotions</th>
<th>CC-features</th>
<th>Our features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretty</td>
<td>0.827</td>
<td>0.834</td>
</tr>
<tr>
<td>Casual</td>
<td>0.770</td>
<td>0.806</td>
</tr>
<tr>
<td>Dynamic</td>
<td>0.759</td>
<td>0.793</td>
</tr>
<tr>
<td>Romantic</td>
<td>0.783</td>
<td>0.870</td>
</tr>
<tr>
<td>Mild</td>
<td>0.842</td>
<td>0.858</td>
</tr>
<tr>
<td>Feminine</td>
<td>0.837</td>
<td>0.818</td>
</tr>
<tr>
<td>Natural</td>
<td>0.783</td>
<td>0.838</td>
</tr>
<tr>
<td>Elegant</td>
<td>0.599</td>
<td>0.693</td>
</tr>
<tr>
<td>Gorgeous</td>
<td>0.548</td>
<td>0.641</td>
</tr>
<tr>
<td>Wild</td>
<td>0.696</td>
<td>0.745</td>
</tr>
<tr>
<td>Classic</td>
<td>0.757</td>
<td>0.780</td>
</tr>
<tr>
<td>Formal</td>
<td>0.733</td>
<td>0.780</td>
</tr>
<tr>
<td>Dandy</td>
<td>0.800</td>
<td>0.841</td>
</tr>
<tr>
<td>Chic</td>
<td>0.789</td>
<td>0.842</td>
</tr>
<tr>
<td>Fresh</td>
<td>0.745</td>
<td>0.791</td>
</tr>
<tr>
<td>Clear</td>
<td>0.722</td>
<td>0.773</td>
</tr>
<tr>
<td>Modern</td>
<td>0.436</td>
<td>0.515</td>
</tr>
<tr>
<td>Pop</td>
<td>0.754</td>
<td>0.789</td>
</tr>
<tr>
<td>Retro</td>
<td>0.648</td>
<td>0.757</td>
</tr>
<tr>
<td>Noble</td>
<td>0.567</td>
<td>0.631</td>
</tr>
<tr>
<td>Friendly</td>
<td>0.760</td>
<td>0.811</td>
</tr>
<tr>
<td>Contemporary</td>
<td>0.386</td>
<td>0.485</td>
</tr>
<tr>
<td>Expressive</td>
<td>0.460</td>
<td>0.561</td>
</tr>
<tr>
<td>Readable</td>
<td>0.503</td>
<td>0.627</td>
</tr>
<tr>
<td>Attractive</td>
<td>0.686</td>
<td>0.722</td>
</tr>
<tr>
<td>Spring-like</td>
<td>0.820</td>
<td>0.817</td>
</tr>
<tr>
<td>Summer-like</td>
<td>0.661</td>
<td>0.802</td>
</tr>
<tr>
<td>Autumn-like</td>
<td>0.679</td>
<td>0.758</td>
</tr>
<tr>
<td>Winter-like</td>
<td>0.671</td>
<td>0.733</td>
</tr>
<tr>
<td>Beautiful</td>
<td>0.676</td>
<td>0.702</td>
</tr>
</tbody>
</table>
Algorithm: Color theme generation in order

Require: Kansei k, ThemeNumber N
1: Define<Object> colorThemes
2: Define<Object> allScores = GetKanseiDB(k)
3: Define<Object> bestCat = GetBest(allScores)
4: Define<Object> restCat = GetRest(allScores)
5: sortDescending(restCat)
6: for n = 1 to N step 1 do
7:   if n == 1 then
8:     catSet = bestCat
9:   else
10:    catSet = bestCat.replace(restCat [n-2])
11:   end if
12: if catSet has conflict then
13:    adjustCategories(catSet)
14: end if
15: if 3 colors are all not same then
16:    colorThemes.add(catSet)
17: end if
18: end for

4.2 Color unification with input image

In our study, color themes are applied for design objects that have image contents and text contents. It is known that designers always extract colors in image and unify the text colors or background colors with the colors of image. Hence, in the design case that have image and text contents, we extract the main colors of the input image, and select unified color themes from generated color themes in order. The main colors of picture are mapping to PCCS colors. If the generated color theme has a color which has same or similar hue and same tone with main colors of picture, the color theme is selected. If there is no suitable color theme for the input picture, it denotes that the picture has a conflict with the specified impression, and it will be suggested to change the kansei word or input a new picture.

4.3 Text color legibility checker

In our design scenarios, the legibility of text color on background color should be ensured. We extract all 144 colors and 9 neutral colors in PCCS color chart, and settle them as text color and background color. There are 23409 pairs of combinations in total. We asked people without color deficiency to label the legibility of these color combinations with 6-scale method. The evaluation score being larger than 4 means the text color is readable on the background color. We create a color legibility checker based on these evaluation data. Universal color design has not been concerned in our current work.

4.4 Color recommender system

Based on the results of affective color models, we implemented a color generation engine in our automatic design system. The color generation engine could be used in many fields of graphic design, as card design, poster design, web design, etc. In this study, we explore the color recommendation for affective web banner design. Once the user chooses a kansei word, the colors for the design will be reset corresponding to the selected impression. Text colors are adjusted to be readable by color legibility checker. Hence, we just extracted 3 pairs of outputs shown in Figure 5 which are corresponding to pretty, formal, clear, elegant, dynamic, natural, fresh, and dandy.

Figure 5: System outputs for pretty, formal, clear, elegant, dynamic, natural, fresh, and dandy

5. CONCLUSION

In this paper, we describe the study for 3-color theme generator and a trail application in banner design. The key contribution of our work is to break the regular form of color bars and create a form with overlapped blocks to show the color theme for visual-textual design. Our
proposed color form in blocks is considered with an appropriate area ratio for 3 colors which brings more intuitive feelings to an actual visual-textual presentation media. For analyzing the affective evaluation data of created color themes, we make the decision rules for classifying hue relations and tone relations to optimize the estimation model for the relationships between color features and impressions. Then we develop a recommender system for generating color themes and colorizing web banner automatically. Additionally, we implement color unification with input picture and text color legibility checker. Next we will conduct verification experiments to explore the effect of unification of text and text-background colors to picture’s colors. We hope to have a further study about the unification rules of picture colors and other colors in design.

As we know, the legibility is important in text design, while the adjustment of text legibility may change the emotional expression of design. Our current adjustment method is to change the color to its closest legible color in PCCS chart. We will explore some other methods and verify their affective effect in our future work.

Our current study has some limitations that the evaluated samples are 3-color themes and the main application scenario is for a simple design work with a small number of colors and contents. Moreover, when input picture is disharmonious with color theme, how to adjust the colors of elements should have an in-depth consideration in our future work. Though our prototype is only initial explorations, we hope that further works will yield tools or systems for industrial cases and business scenes that help non-expert work easier.

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