A Color Schemer for Webpage Design Using Interactive Mood Board

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Abstract. In this paper, we present a web tool called Webpage Color Schemer (WCS), which enables people to easily redefine an existing webpage's color scheme. WCS can adapt the webpage's color scheme towards a new visual effect expressed nonverbally with an interactive mood board, which is actually a collage of sample images or design examples reflecting designer's preference.

WCS is simple and fun to use. It has two major functionalities: an interactive mood board with a color quantization algorithm for extracting color themes; A genetic algorithm for generating best assignment of the theme colors from the mood board to the web page, with respect to necessary design objectives. The objectives are formulated as fitness functions for the evolutionary optimization. Our initial experiments show that three fitness functions are essential for the color scheme optimization: histogram evaluator, contrast evaluator and harmony evaluator, to make sure the scheme has a preferable color tone, legible contrast ratio and harmonious color matching, respectively. The evaluators are generally devised in the light of some well-established color design theories. Some efforts of this research, however, has moved towards using computational model to uncover design knowledge depositing in large set of design cases. WCS uses a kind of RBF network predicting proper contrast ratio of certain class of page elements, regarding its measurable features and context. The performance of the model is encouraging.

Keywords: Website color, Adaptive webpage scheme, CSS.

1 Introduction

Color is undoubtedly the essential means to touch the emotions of website viewers[1]. Our visual and cognitive systems have adapted to perceive and process color information, which is contained in every visual stimulus we encounter, calm or excite, arouse plenty of feelings and stimulate to actions [2]. Color scheme is an important aspect of designing a visually pleasing website. Quite a lot empirical methods and theories of color have been presented in design literatures [3, 4].

Choosing the right color combinations for a website can be difficult even for professional designers. Some efforts have been made to use computational models to support color designs of graphics and websites [5-8] . In this paper we present a tool

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called Webpage Color Schemer (WCS), which enables people to intuitively redefine a webpage's color scheme online. The tool we developed has two major functionalities:

The first is an interactive mood board that allows people interactively to create a color palette (color theme). Mood boards are often used by graphic designers to illustrate the direction of visual style, which they are pursuing[9]. A mood board is usually a rough collage of colors, textures and pictures to evoke specific feelings. It is extremely useful for establishing the aesthetic feel of a web site. Things that can be explored in the mood board include photography style, color palettes, typography, and the overall look and feel of the site. In WCS, a digital mood board is firstly devised to enable a user interactively produce and refine a color theme. The second, more importantly, WCS recolors a targeting webpage by transferring the color theme to the web page. That means to generate a color scheme based on the wireframe of the page by intelligently assigning the colors from the palette to certain figural or background areas of the page. The process is a multi-objective combinational optimization led by some aesthetic and accessibility criteria, such as rules of color harmony and contrast. And the recolored webpage must also approximate the color tone of the mood board as closely as possible. The mood board and its resulting color palette are interactively editable. It enables the user to seek intuitively for a desirable color theme and then a satisfactory color composition of the webpage. For those web pages with pre-specified color contents, such as pictures and logos, WCS is especially useful approach to find harmonic colors compatible with them.

1.1 Related Work

Modern color theory, which was developed at the beginning of the 20th century, deals mainly with visual design in which color is relevant. Itten inductively elaborated the principles of color contrast and harmony using musical chord metaphors to explain harmonious principles of chroma [10]. Munsell's color space based on pigment and dye color [11]. Colors in isolation or unrelated to a layout composition will fail to provide all the necessary information to make a color choice[5]. People rarely deal with a single color in isolation. Most of the time, they deal with a composition of colors, also called color scheme. The colors in the scheme are seldom haphazard, usually they have to fulfill some constraints like being in harmony or contrasting[12]. Kagawa et al. proposed a color design supporting method that help users to obtain various color patterns from pictures[6]. The method implements an interactive evolutionary algorithm. The users can easily find a new color pattern by selecting a picture with most pleasant color design in a database or from web. Hu et al. presented an interactive visualization tool for generating color schemes for novice designers based on two color harmony principles from conventional color theories[8]. The interactive tool enables users to efficiently generate color palettes containing harmonic color combinations in the HSL (hue, saturation, and lightness) space.

There are a number of online tools that can help people to create or share their color themes, such as the websites: Adobe Kuler, COLOURlover, ColorSchemer, ColorExplorer and so on. Most of them provide tools that can abstract color themes from images or graphics. All the researches so far are mainly focusing on the problem of color harmony, which is undoubtedly one of key issues of generating a color scheme. Most of them adopt the idea of color quantization[13], a simple approach using images to generate color sets, in the belief that main colors extracted from a beautiful image must be harmonious anywhere else. This is actually not always true. A color palette from a harmonious image does not always assure a harmony when it is applied to different situations. One problem existing in present researches and tools is that the color scheme creation isolated from its context of use, therefore may be difficult for designers to make right decisions and fine tunings.

2 The Framework of WCS

To solve this problem, we developed a new tool WCS, which supports the evaluation of a color scheme in a real composition of webpage. The tool enables designers to create and edit color theme in a mood board and meanwhile to view the feedback of the consequent visual effect on the web page. The system is illustrated in Fig. 1. It consists of client zone (the upper block) and a server zone (the lower block). The communication between client and server is xmlrpc. The client zone has an interactive Mood Board and a browser for a webpage waiting for recolor. The server zone has three major modular: the evolutionary design module GA, which reproduces better color combinations (schemes) for the webpage; the color quantizer, which extracts a color theme from the Mood Board, therefore defines an available color set (palette) for the webpage; the Style Analyzer, which parses the webpage's CSS file to get all existing variables of colors for change.

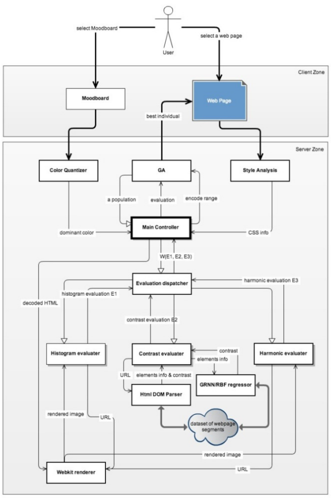

Fig. 1. WCS system framework

The user creates a desirable mood on the Mood Board by interactively pasting certain effects of images on the board (see Figure 2). Quantizing representative colors from the mood board, the system generates a palette of colors using the K-means algorithm in the HSV color space. More details of the Mood Board are given in Section 3. The Main Controller encodes all solutions to assign some of the colors on the palette to the color variables in the CSS. With the encoded solution set, the Genetic Algorithm keeps regenerating new color style definitions of the web page, and sends them to the Main Controller. The Main Controller uses JavaScript simulator to rewrite the web page with new color styles, and saves the page into MEMCACHE. Evaluation Dispatcher fetches every new page in MEMCACHE and sends it to three fitness evaluators: Histogram Evaluator, Contrast Evaluator and Harmony Evaluator.

The detailed explanations of the evaluators are given in Section 4. The fitness evaluations will be fed back to GA for further selection and reproduction. After a number of iterations, The GA will converge to an optimum solution of color scheme. And the best solution of the recolored webpage will be presented to the user.

2.1 The Interactive Mood Board

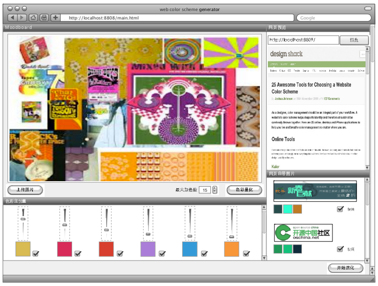

Fig. 2. The interactive Mood Board

The mood board (fig. 2) provides an intuitive way for designers to visualize and refine the “mood” of color. The board also provides an interface for users to interactively abstract the mood board to be a color theme, a row of color patches. The color theme are extracted using k-means color quantization algorithm [13]. Designers can interactively sample the color points on the mood board to pick color clusters he want, specify the number of total clusters in a quantization process, delete unfavorable colors, and merge some color patches to be a blended one.

2.2 Transfer the “Mood” to a Webpage

The ultimate goal of WCS is to transfer the “mood” to a webpage. As we mentioned in last section, the color theme can only be evaluated in its context of use. Thus we need an efficient approach to quickly apply the color theme, a palette of color samples from the Mood Board onto the webpage that we intend to design. Traditionally, designers do the process in trial and error based on their experience and sensitivity. In WCS, a genetic algorithm is devised to complete this work automatically. To implement the algorithm, the WCS need to complete following two key tasks:

Encode All Possible Solutions. WCS style analyzer automatically goes through the html DOM tree to sort out all existing the tags of color values that are editable. Colors on the color palette of the mood board are indexed with a series of binary numbers. Suppose the palette has n colors on it, and the webpage has m tags of color value, then the size of solution set is n^m. The chromosome of the genetic algorithm is constructed with a binary string, which consists of m serial numbers (genes). Every time a legal gene randomly generated at a certain position in the chromosome, the value of a corresponding color tag on the DOM tree will be defined. The n colors are encoded respecting to their relative positions in HSV color space.

Evolve under a Number of Fitness Functions. In real design activities, adjusting of a website color scheme usually follows designers’ intents, obeys some design rules and constraints. In WCS, to find an optimum solution, the evolution should also follow some objectives, which are concluded from interviews and discussions with some professional graphic designers:

- The recolored webpage must have an overall color tone as close as possible to the original mood board. That means the componential colors of both are roughly in same proportion
- The recolored webpage must follow some harmony rules of color matching.
- To be accessible, the webpage must have proper color contrast ratio between background and foreground items, such as texts, buttons, images, etc.

To fulfill those objectives, several fitness functions are formulated for the genetic algorithm.

3 Fitness Functions

There are three fitness functions in respect to three objectives mentioned above.

3.1 Histogram Evaluator

The Main controller calculates both the color histograms of the webpage and the Mood board. The two histograms are discrete bins indexed with the color palette. By comparing the two histograms, we can evaluate how similar the two color tones are. The difference between two histograms can be calculated using Earth Mover's Distance [14] or Histogram Intersection Distance. Here we simply use intersection of two normalized color histograms

$$E1 = \sum_i \sum_j \min\left(\frac{Hcmb_i}{|Hcmb|}, \frac{H_j}{|H|}\right) / D_{i,j}^3 \quad , i,j \in (1, \dots k) \tag{1}$$

Suppose there are k colors on the palette. $Hcmb_i$ and H_j are heights of ith and jth bin in the color histograms of the mood board and the web page correspondingly. $|Hcmb|$ and $|H|$ gives the magnitude of each histogram, which is equal to the number of samples.

3.2 Contrast Evaluator

Contrast ratios of colors on a web page are relevant to visual saliences distribution. To set proper contrast ratios for different elements on a web page is important for both visual pleasure and accessibility. Strong Contrast Insures Legibility and proper contrast is important for harmony [15]. Graphical elements such as menus and page headers usually use more notable color, which can either be a stronger tint or a contrasting color on a neutral background. High contrast ratio is used for elements that require more attention. Text has high contrast ratio leads to greater readability. For the main body of the content frame, it should be clear but calm, rather than with an active tint. Designers believe that contrast ratios for different kinds of elements on a webpage have some regular patterns. And the contrast as one property of the elements has relation with their other properties like: type, location, occupied area, content and on.

Therefore, in this research, we try to formulate a model of contrast ratio, so that WCS can predict proper contrast ratios for different kinds of elements on the page. A large set of design cases are collected. (So far we have collected and analyzed the pages of Fortune 500 companies.)

To distinguish different elements on a web page, we first need to segment a web page into a set of blocks. Our method for web page segmentation is a DOM tree based segmentation[16]. By parsing the DOM tree, the method divides the webpage into a number of visible blocks. From calculated styles of every block, we extract the properties like: ID, tag, class, position, scrollWidth, scrollHeight, parent node, number of siblings, and some color properties: background-color, background-image, color etc. the contrast ratio of each element is defined as a vector, which is calculated from four consecutive color pairs: P1: color/background-color; P2: color/parent node's color; P3: background-color/1px border color; P4: background-color/parent node's color.

Contrast ratio C = (L1+ 0.05) / (L2 +0.05) , where L1 is brighter color of the pair, while L2 is dark one. L = 0.2126 * R + 0.7152 * G + 0.0722 * B. it is brightness value calculated from weighted linear combination of RGB channels.

A data set of samples of webpage elements is established. All samples can be represented with data pairs (X, C) where X is the normalized feature vector represents measurable properties and C is the corresponding color contrast ratio.

A kind of neural network is adopted to learn the general contrast ratio models. The model, once be trained, must has an desired output Ce that approximates the conditional mean of the response C, that is, the regression of C conditioned on X.

$$Ce = E [C \mid X] \tag{2}$$

Ce is expected C conditioned on X.

With this model, WCS can evolve a webpage's color following some expected local contrast ratios. Here is a fitness function of contrast ratio

$$E2 = \sum_{i=1}^{n} \frac{\|Ce_i - Cr_i\|}{n} \tag{3}$$

where, Cr is current real contrast ratio of ith element on the webpage. Ce is expected contrast ratio predicted with the regression model. The n is total number of elements on the webpage.

The regressor is Radial basis function (RBF) network. RBF network places Gaussian kernels centered at some clusters of the samples. The number of kernels, center of the kernels, and weights of connections to output layer must been optimized in offline learning process. As a special type of RBF network, General Regression Neural Network (GRNN) simplifies the learning by placing a Gaussian at every sample point x and with connection weight equal to corresponding output C

$$\text{Ce(x)} = \frac{\sum_i C^i \exp\left(-\left\|x - x^i\right\|^2 / 2\sigma^2\right.}{\sum_i \exp\left(-\left\|x - x^i\right\|^2 / 2\sigma^2\right.} \tag{4}$$

where x is a new case, x^i is ith sample in training dataset X, C^i is ith sample's C. Both networks are testified in our experiments. The RBF network has much more fast response speed while GRNN is more safe and reliable to predict.

3.3 Harmony Evaluator

Besides the contrast, harmony is also important for pairwise matching on a webpage. To sort out harmonic colors from the color palette, a harmony evaluator would be necessary. Harmonious colors are sets of colors that provide a pleasant visual perception. Harmony among colors is not determined by specific colors, but rather by their relative position in color space[17].

The notion of color harmonization in this work compromises the Moon-Spencer model and the schemes developed by Matsuda [18]. Color harmony is mainly affected by the hue channel. Matsuda's model presents nine templates of color distributions on the hue wheel. The harmonic templates may consist of shades of the same colors (types i, V and T), possibly with complementary colors (templates I, Y, X) or more complex combinations (template L and its mirror image). Among those templates, O'Donovan's research further shows that monochromatic, analogous, and complementary templates are the most popular[19]. This statement are coincident to the Moon-Spencer model which induces three types of color harmonic relations of any color pair: 'Contrast,' a state the two color are significantly different from each other, 'Similarity,' a resembling state, and 'Identity,' a state with an identical hue.

Based on the notions of the three basic types of color harmony, we formulated a color compatibility measurement for a color pair. Suppose we have a color pair P, then the compatibility measurement

$$H(P) = \text{argmin}_{\alpha}\big(\big|\|h(P)\| - \alpha\big| \cdot S(P)\big), \alpha \in \left\{0, \frac{\pi}{4}, \pi\right\} \tag{5}$$

where H denotes the hue channel. $\|h(P)\|$ denotes the arc-length of the color pair P on the hue wheel. The angle α represents three harmonious templates: monochromatic α =0; analogous α $=\frac{\pi}{4}$; and complementary $\alpha = \pi$. The argmin determines the template that best fits the color pair, and the difference is regarded as the deviation from the harmonic state. The less the deviation is measured, the more harmony the pair has.

Note that the above formula also take into account the channel of saturation denoted with S, since the hue distances between colors with low saturation are perceptually less noticeable than the distances between those of high saturation. The S(P) represent the sum of two colors' saturations in [0 ,1.0]. Also note that the formula implies that two colors with same hue value are absolutely harmony. And two colors along the gray pole (with S=0) are absolutely harmony. That is reasonable from designer's point of view.

Then, by summing up all local color pairs' harmony values of a webpage, the overall color harmony of the page can be roughly assessed.

$$E3 = \sum_{j=1}^{n} \sum_{i=1}^{4} H_j \ (P_i) \tag{6}$$

Suppose there are n visual segments on the webpage. And each segment has four layered fore-background color pairs as we mentioned in contrast evaluator. Probably some of the pairs have identical colors and therefore score zero.

M. Nishiyama et al [20] demonstrated that the sum of the color harmony scores computed from local regions of an image is positively correlated with the overall aesthetic quality of the image. An image with high (low) aesthetic quality often contains a large number of local color patterns with high (low) color harmony scores. The harmony model they adopted is the Moon-Spencer model.

3.4 Multi Objective Optimization

With three fitness functions: E1, E2 and E3 and a well-encoded solution set, we cast web color scheme creation as a constrained multi objective optimization problem, which tries to strike a balance among the desirable color "mood", the spatial harmonious pairwise color combination as well as necessary figural-background color contrast for legibility and saliency. The energy function is defined as

$$E = \alpha E1 + \beta E2 + \gamma E3 \tag{7}$$

where α, β and γ are the weighting coefficients of E1, E2 and E3 respectively. The changes of the coefficients shift the minimum of the energy function. To determine the proper values of them, we fix one of them and manually adjust the other two, meanwhile, to observe the resulting outcomes of the evolutionary algorithm. In our experiments, we set α to -1, γ and β are varies in between 5~10. These three terms altogether make the system converge to an expected state, fulfilling all the three objectives.

4 Results and Application

We conducted an informal experiment to test the usefulness of the WCS in the context of a webpage design. We found that most color schemes generated by the tool are aesthetically preferable. Sometimes the evolution may be stuck in a local optimum, with one or two parts of the webpage not so well settled. With the proper weights of the energy function and a well-encoded solution set, the optimal color schemes produced by evolutions in different sessions are pretty consistent.

Initial experiments show that the three fitness functions are all essential for the optimization of the color scheme. Removing any one of them, the results of the evolution are not so acceptable, especially the E1 and E2. Changing the weights of the functions, the resulting schemes could be slightly different. The interactive Mood Board is easy and intuitive to use. WCS demonstrates that novice users can compose desirable color schemes for webpages as easily as professional designers do.

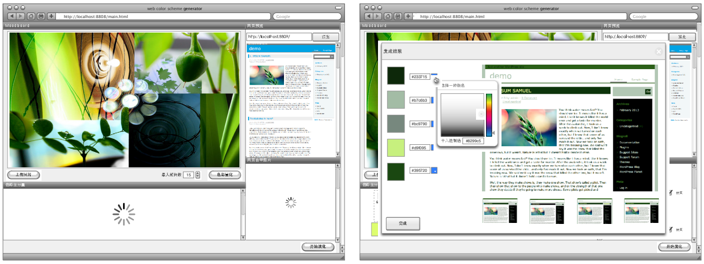

Fig. 3. The upper is a new mood board created by a user. The lower is the consequent new webpage color scheme generated by WCS.

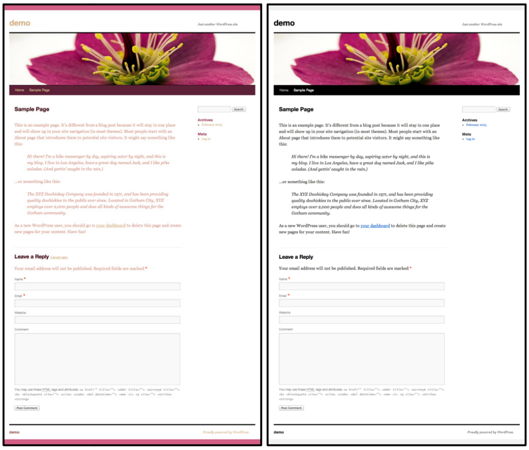

Fig. 4. The left is original webpage. The right is a new color scheme generated by WCS, using the flower picture on the page as a mood board.

5 Conclusion

This WCS we are developing demonstrates a general framework of a computational approach to web color scheme design. The framework generally performs well. The application is developed for both professional designers and amateurs. It can be used right after the wireframe design stage, or to redesign an existing webpage's color scheme. It is especially helpful when parts of the webpage are composed with pictures that have distinct color tones: the system is capable of harmonizing the colors of the webpage. The algorithms and models in the framework, however, still need more convincing validations and refinements. Some alternative algorithms and models may be compared in future experiments. K means clustering is rough for color theme extraction. We shall devise some new clustering algorithms, which are more faithfully reflecting people's color perception. Some unsupervised feature learning and knowledge-discovering techniques may be added into the computational models for assessing the color contrast and harmony of webpages. The effectiveness of the models needs to be cross-validated. This research is funded by ministry of education of China (11YJCZH044) and SJTU art-science joint research fund.

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