Visual Color Design

Mountaz Hascoët
LIRMM - CNRS, Univ. Montpellier II
UMR 5506 - CC 477
161, rue Ada
34095 Montpellier Cedex 5 France
{mountaz@lirmm.fr}

Abstract

Many efforts from both artists and scientists on color design have resulted in a variety of models and rules devoted to coloring graphics. Based on these results, a lot of interactive tools are now available to help with color design based on various sorts of color themes, templates, palettes, swatches, brushes, etc. However, despite the numbers of tools and results available, in many situations, color design is still tedious and time consuming for both amateurs and professionals. In this paper, we introduce visual color design as a new approach to handling coloring problems interactively. The coloring of web documents is used to illustrate our approach with a real case study. The case study takes as input (1) a given color image and (2) an HTML/CSS document to be colored.

Keywords--- **Visual Color Design, Coding, Color Matching**.

1. Introduction

Handling harmony and contrast is often considered as one of the most important aspects of color design. It is widely accepted that contrasts and harmony significantly impact the usability and attractiveness of colored graphics and contributes to the overall message of the graphics. Even though a lot of progresses have been made to provide new color design tools and techniques [14,15,16,17,18,19], adjusting harmony and contrast is still tedious and time consuming in many situations. Most recent work has focused on studying the color design space and has resulted in tools useful to explore, use and adjust color spaces. For example, web sites such as Kuler [14] exhibit very sophisticated color templates to create color themes. Kuler and other similar initiatives provide tools to create reduced and organized color spaces. However, the challenging aspects of color design is to find appropriate matches between color spaces and information to be colored. Reducing color spaces independently of the coloring problems is relevant only for limited coloring situations. We define visual color design as the process that integrates the analysis of the coloring problem and the exploration and mapping to relevant color spaces. Visual color design is based on wish templates and color schemes. Wish templates express the coloring problem in terms of contrasts and harmony that sets of elements are expected to meet. Color schemes are meant to characterize color design space. A color scheme is an organized set of colors. Color schemes can be created from example by analyzing input color images or they can be imported from other tools used to create color palettes or theme.

In this paper, we start by a review of recent work related to coloring and a clarification of the underlying concepts. We discuss color contrast and color harmony that are central to color design. We further introduce wish templates and color schemes and show how they can be used to automate simple color design. We finally introduce Visual Color Design to handle more challenging coloring problems.

Background and related work

Colorization, re-coloring, adjusting and harmonizing have recently been the focus of graphic research papers leading to the useful clarification and refinement of otherwise overused and confusing concepts.

Colorization [22] [25] is the computer-assisted process of adding colors to a monochrome image or movie. In this domain, Levin et al. [22] have recently proposed a colorization model based on user input and a heuristic. This approach contrasts with previous approaches based on complex image segmentation and region tracking used to produce a colored image. Similarly to Levin et al., Irony et al. propose a method to colorize one or more grayscale images based on user-provided reference.

Re-coloring [27] [26] is usually the reverse process of generating grayscale images while preserving contrast and luminance consistency with an input color-image. The aim of re-coloring is to preserve saliency of the input image or other information conveyed through chrominance and saturation differences in the color image.

Harmonizing is defined in [28] as the computer-assisted process that, given an arbitrary image, possibly a photograph, modifies the colors of the image to enhance the relationships among them and to increase their. harmony. Harmonizing differs from re-coloring and colorization by an important detail: the relationships between colors are given from the input user image in the cases of re-coloring and coloring. In harmonizing, on the contrary, the creation and control over color relationships and color groups constitute the main challenge. In [28] , harmonizing is based on harmonic schemes developed by Matsuda and presented in [29].

Wang et al. [30] goes one step further in the automation of the coloring processes. The aim is similar to harmonizing but the path is different. In [31], the authors learn the rules of color adjustments from graphic and designers examples. While harmonizing aims at modifying colors of a given image based on a fixed set of rules, the computer-aided process proposed in [31], aims at learning rules for color adjustments from examples before applying them.

While all these approaches are typical of image-processing field, another set of approaches to coloring problems has emerged from the field of information visualization with different perspectives. Brewer [10] has proposed sets of harmonized colors to represent data depending on the type of data: qualitative, quantitative, ordinal. Healey [12] has investigated the numbers of different colors that can be perceived pre-attentively. Rogowitz and Treinish [13] have proposed to incorporate perceptual rules in the design process of visualization software and have proposed colormaps and rules for selecting colormaps depending on the task and data.

Our approach to coloring builds from the previous work merging image-processing colorization approaches and visualization color coding approaches. Taking an image as input to capture harmonious colors is similar to approaches found in image-processing research. However, both the color scheme extraction processes and the coloring problem addressed in this paper are different from these approaches. In particular, the coloring problem is to build a mapping between a color space and an information space so that a set of colors can convey a given message. In that sense, our approach is closer to the information visualization approach aiming at building color schemes that best fit the characteristics of some data.

The main contribution of this paper is in the definition of color wishes and the introduction of visual color design as a new approach to mapping color wishes to colors schemes to solve coloring problems. This contribution results in the design of a coloring tool that stands with a foot in the problem space and a foot in the design space. A direct benefit from visual color design is a better coupling between the exploration of the coloring problem space and the exploration of the coloring design space.

Color harmony

As noted by Donovan et al. [31] , it is generally believed that certain color combinations are harmonious and pleasing, while others are not. According to Itten [3] though, the distinction between color harmony and pleasing colors is worth making clear. Subjective approaches that compare user preferences often lead to contradictory confusing results. In that area, recent attempts have brought some clarifications [5] but the field cannot be left without considering the subjective aspects of color perception.

A consistent definition of color harmony is hard to capture as various definitions found in the literature can be both useful and contradictory. Therefore, our approach is to integrate various harmony definitions, considering the harmony as a set of coordinated or balanced colors.

Following widespread coloring rules [4] [11], we define a color harmony of type 1 as a set of colors built from one base color and a set of colors made of the same hue + black (shade), the same hue + gray (tone), the same hue + white (tint).

Following previous work definition of harmony [9] [16] we define harmony of type 2 as the result of a color combination of n colors such that all colors share the same values for two of the three color characteristics (hue, saturation, brightness) and vary for one of them.

Following Lyons and Moretti [22] Itten and Munsell previous work on color strength and color harmony, we can define harmony of type 3 as the result of a combination of n compatible colors c_1, c_2, … c_n, such that

$$\forall i,j \in [1,n]\ CS(c_i) * surface(c_i) = CS(c_j) * surface(c_j)$$

where

$$CS(c_i) = saturation(c_i) * lightness(c_i)$$

with $saturation(c_i)$, $lightness(c_i)$ $surface(c_i)$ representing normalized functions that respectively characterize the saturation, brightness and surface corresponding to a given color c_i. Thus a small area of color c_i with high color strength will balance a large area of color c_j with low color strength. The colors are considered compatible if the cumulating of their hues covers the color spectrum. The objective interpretation of harmony, is focused on characterizing color combinations that together physiologically satisfy the eyes of the viewer. In this paper, in order to limit the scope of this work, we focus on these three types of harmonies but the aim of our approach is to be general enough to account for other types of harmonies.

Color Contrasts

While harmonies can be considered as sets of balanced colors, contrasts can be considered as the particular case of harmonies where only pairs of colors are involved. In his seminal work on colors[3] , Johannes Itten has exhibited seven different types of contrasts that have inspired many subsequent work involving color schemes [25] [29] . These contrasts include contrast of light and dark, contrast of hue, contrast of temperature, contrast of saturation, simultaneous contrast, contrast of sizes and contrast of complementary. In this paper, we focus on a subset of contrast types. In the next sections contrasts of type 1, type 2, and type 3 will respectively refer to contrast of luminance, contrast of hue, and contrast of temperature.

Contrast of light and dark defined by Itten is similar to the widespread luminance contrast even though many physiological aspects of human perception are not accounted for in such contrasts.

Contrast of hue is the highest when three primary colors - blue, yellow and red in Itten's view - are used in combination. The strength of the contrast diminishes as the colors move away from the primary colors. Attempts to provide quantitative definition of hue contrast are based on color differences. Color differences computation have been the focus of an evolving process involving different approaches. Even though CIE has published uniform models such as CIE l*a*b, CIE l*u*v*, and more recently CIEde2000, computing accurate and uniform color differences is still an open issue [33]. Eager to define standards for accessibility, W3C has proposed WCAG1.0 [6].

In this work we have used two different widespread color difference computations: the CIE l*u*v, for its relative accuracy and uniformity useful for extracting color schemes from images and the W3C color for its simplicity useful in expressing color contrast wishes.

One of the W3C color contrast requirements, is that two colors C1 and C2 defined in RGB color model respectively by (r1,v1,b1) and (r2,v2,b2) have a difference value d above 500, following the tentative difference definition:

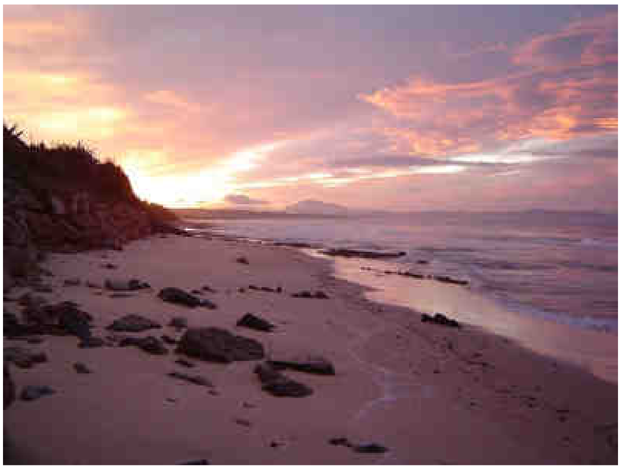
$$d = |r1-r2| + |v1-v2| + |b1-b2| \quad [6]$$

Contrast of temperatures comes from a generally agreed tendency to consider that some colors convey cool sensations while others convey warm sensations. On Itten's color wheel, colors ranging from yellow to red-purple are considered as warm colors whereas colors on the other side of the wheel ranging from green-yellow to purple are considered as cool colors. Due to the impact of other aspects of colors such as saturation and luminosity on the perceived temperature, there is no widely agreed objective function that can measure a contrast of temperature between several colors.

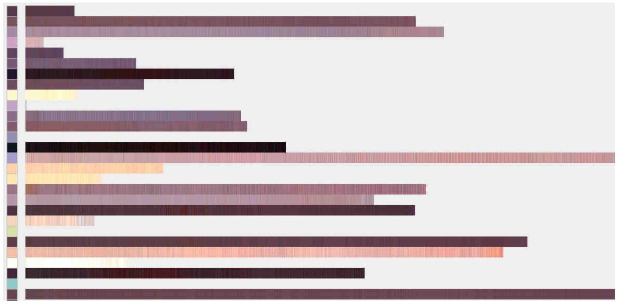
Color Schemes

Color schemes are built from user input image. In that respect our approach is similar to the approach of [34]. However, we proceed differently: the automatic extraction of target colors from the input color image consists of a selection of a small subset of k colors - colors useful to cover a wish template, amongst a potentially large set of colors - color originating from an input color image, possibly a photo. Our approach to this selection problem is to process a k-mean based on the CIE l*u*v* representations of the color pixels of the input image. A k-mean process is one of the mostly used clustering processes [35]. It applies to any set of points of a Euclidean space to build and optimize a partition of these points into k subsets.

As mentioned previously, the CIE l*u*v* color model represents colors as points in a Euclidean space.



(a) Input Image



(b) KMean result

(c) Colored Web Page

Figure 1: Automating Color Design

The main purpose of using a k-mean on a l*u*v* representation of image pixels is that the extracted set of colors reflects the image colors as a whole and if the image is harmonious, this harmony is likely to be preserved in the resulting set of extracted colors.

Wish template

Wish templates are used to express requirements of contrast and harmonies between information elements. Colorists are defined as coordinators between information elements. Colorists are created to embody the various types of contrast and harmonies discussed in previous section. A wish template can further be represented as a graph made of nodes that can be either elements or colorists. Figure 4 shows a typical wish template where several contrast and harmony wishes have been expressed.

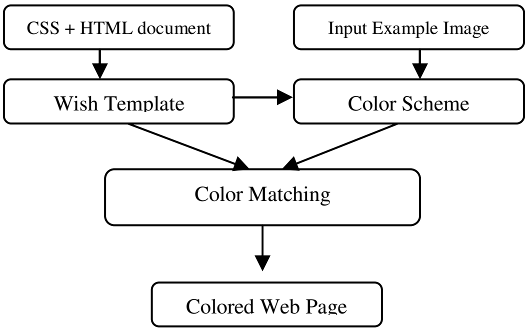


Figure 2: Simple Matching for Automatic Coloring

Wish templates are best described through a scenario related to our illustrative case study: a designer wants to fully color a web page. He wishes a harmony of type 2 between the backgrounds of his various areas represented by div elements named s0, s1, s2, s3. He further wants text elements to contrast with their backgrounds respectively s0, s1, s2, s3. The contrasts he wants in this case is a contrast of type 1. Now he wants to harmonize the color of hyperlink elements. He chooses a harmony of type 1 for this. Finally, he wants to harmonize the title elements of each div element and at the same time he wants to ensure that all elements corresponding to "headings 1" in any of the various div have the same color.

These color wishes can be expressed interactively by creating new wish template. A wish template is further represented by a graph. The graph corresponding to the wish template of the scenario is displayed in the top window of figure 3. The graph is made of two types of nodes.

The first set of nodes corresponds to html elements which, in this scenario, are html elements. These elements to be colored are denoted by their corresponding css selectors in figure 3.

The second type of nodes is depicted by circles in figure 3 and corresponds to colorists denoted by code C_i for colorist handling contrasts of type i and H_i for colorists handling harmonies of type i. The top window corresponds to the initial step in visual color design: expressing the needs in terms of contrast and harmony wishes.

Color Matching

Color matching is the process that computes coloring from the input wish template and color scheme. In the case study, the particularities of CSS and HTML elements enable a simple heuristic to provide a simple color matching - e.g. a matching in which only one type of contrast is taken into account without minimizing the number of color used.

A straightforward automatic matching is used to match each color in the color scheme to each element in the wish template after having sorted them. Figure 3 depicts the important steps of such a matching.

From the input image (a), a k-mean is computed to provide n average colors from the image. The colors are sorted by luminance and applied to the CSS elements sorted from background elements to the foreground elements. Such a matching ensures that the luminance contrast between text and background is satisfying considering the range of luminance values available in the color scheme. Another direct benefit of such a matching is to be computationally light. However, such a simple matching only satisfies simple coloring wishes.

Processing more complex wish templates in the general case is a open problem of a different complexity that can is related to a graph coloring problem given a set of wishes. Another concern with more complex wish template matching is that very often interactive approaches accounting for human choices in result in better choices at lower cost than automatically processed matching. These two aspects of the general case are two key motivations for introducing Visual Color Design.

Visual Color Design

We introduce Visual Color Design as a process that (1) visually displays wish templates, color schemes and intermediary results of underlying color matching and (2) interactively accounts for human choices when solving a color design problem.

As illustrated in Figure 2, Visual Color Design takes as input elements a color wish template from a given information space and a set of color schemes from a given color space.

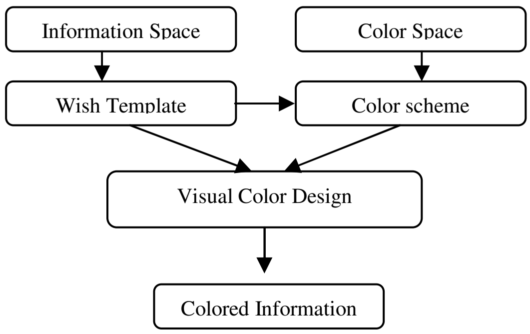


Figure 3: Visual Color Design

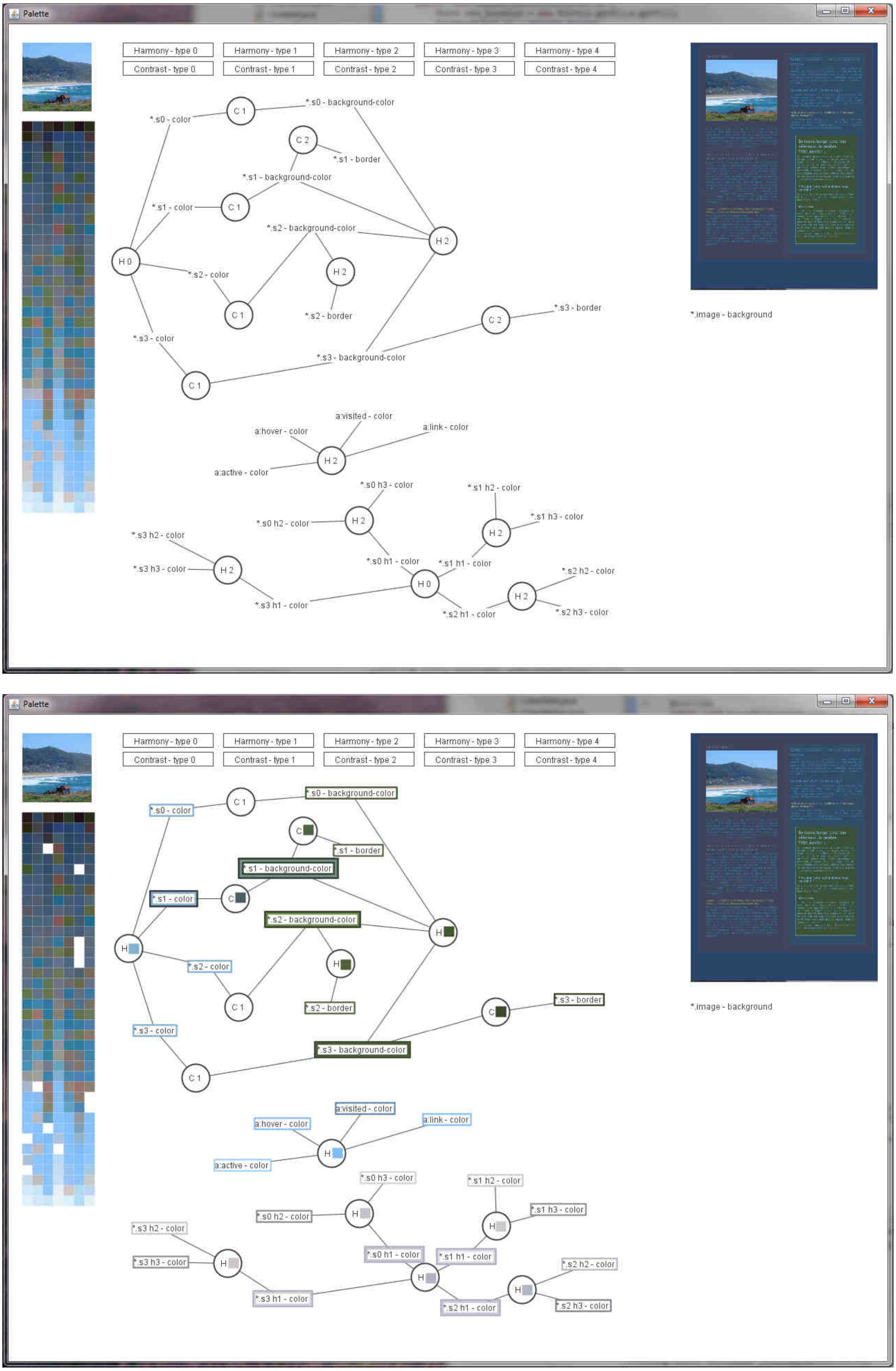


Figure 3: Visual Color Design – Creating Color Wishes (top) – Visual Coloring (bottom)

The bottom window of figure 4 shows visual color design in action. The designer brings colors from the color schemes to colorists, depicted by circles in the display, by dragging and dropping colors from color schemes to colorists.

When a color is dropped on a colorist, the colorist performs coloring on the elements associated with it and colored elements are surrounded by a rectangle of the appropriate color. In this work, we favor an approach where colorists color elements independently one from another.

The result is that elements involved in concurrent wishes are surrounded by more than one colored rectangle corresponding to the various colors computed from the various colorists.

Elements surrounded by multiple rectangles are visually salient. Once spotted by designers, designers can apply various strategies directly on the elements or on the colorists to adjust the final color of the related elements. Strategies available include choosing one color amongst the different colors associated with the element, choosing another color in the color schemes or applying operators to compute color blending from the associated colors.

Coordinating colorists through automated processes would be an alternative approach to handling concurrent wishes. However, handling concurrent wishes automatically possibly lead to complex open problems. Furthermore, handling concurrent wishes are the interesting part where a human can make relevant choices at relatively low cost, our future work is to improve the interaction techniques related to visual color design to facilitate designers choices and exploration. With appropriate interaction techniques, solutions to coloring problems can be derived from a better exploration and analysis of both design and problem spaces.

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References

[1] CIE. Recommendations on uniform colour spaces, colour difference equations and psychometric color terms, Graphics Press. 1990.

[2] Rogowitz, Bernice and Lloyd Treinish, “How NOT to Lie with Visualization”, Computers in Physics, 1996.

[3] Itten J. L'art de la couleur, édition abrégée.

[4] Stone Maureen, a Field Guide to Digital Color, 2003.

[5] Schloss, K. B. & Palmer, S. E. (2011). Aesthetic response to color combinations: Preference, harmony, and similarity. Attention, Perception and Psychophysics, 73, 551-571.

[6] http://www.w3.org/TR/AERT#color-contrast

[7] http://www.w3.org/TR/WCAG20/#visual-audio-contrast

[8] Mark A. Harrower and Cynthia A. Brewer, 2003, ColorBrewer.org: An Online Tool for Selecting Color Schemes for Maps, The Cartographic Journal 40(1): 27-37.

[9] Ferenc Szabó, Peter Bodrogi, János Schanda, Experimental modeling of colour harmony, Color Research & Application Volume 35, Issue 1, pages 34–49, February 2010

[10] Brewer, C. A. 1999. Color Use Guidelines for Data Representation, Proceedings of the Section on Statistical, Graphics, American Statistical Association, Alexandria VA. pp. 55-60.

[11] Stone M., Choosing Colors for Data Visualization, http://www.perceptualedge.com/articles/b-eye/choosing_colors.pdf, 2006.

[12] Christopher G. Healey. 1996. Choosing effective colours for data visualization. In Proceedings of the 7th conference on Visualization '96.

[13] B. Rogowitz and L. Treinish, How Not to Lie with Visualization, Computers in Physics n.3, pp. 268-274, May/June 1996

[14] http://kuler.adobe.com

[15] http://www.tigercolor.com/

[16] http://www.abitom.com/

[17] http://www.colourlovers.com/

[18] http://www.color-wheel-pro.com/

[19] http://www.w3.org/TR/AERT#color-contrast

[20] http://www.w3.org/TR/2010/NOTE-WCAG20-TECHS-20101014/G18

[21] http://www.w3.org/Graphics/Color/sRGB.html

[22] Giovanni S. Moretti. A Calculation of Colours. Doctoral dissertation, Massey University, New Zealand, 2010.

[23] A. Levin, D. Lischinski, and Y.Weiss. 2004. Colorization using optimization. ACM Trans. Graph. 23, 3 689-694.

[24] Daniel Cohen-Or, Olga Sorkine, Ran Gal, Tommer Leyvand, and Ying-Qing Xu. 2006. Color harmonization. In ACM SIGGRAPH 2006, 624-630.

[25] Ironi, R., Cohen-Or, D., and Lischinski, D. 2005. Colorization by example. In Eurographics Symposium on Rendering, 201--210.

[26] Rasche, K.; Geist, R. & Westall, J. Re-coloring Images for Gamuts of Lower Dimension. Comput. Graph. Forum, 2005, 24, 423-432.

[27] Amy A. Gooch, Sven C. Olsen, Jack Tumblin, and Bruce Gooch. 2005. Color2Gray: salience-preserving color removal. ACM Trans. Graph. 24, 3 (July 2005), 634-639.

[28] Daniel Cohen-Or, Olga Sorkine, Ran Gal, Tommer Leyvand, and Ying-Qing Xu. 2006. Color harmonization. In ACM SIGGRAPH 2006 Papers (SIGGRAPH '06). ACM, New York, NY, USA, 624-630.

[29] Tokumaru, M., Muranaka, N., and Imanishi, S. 2002. Color design support system considering color harmony. Int. Conference on Fuzzy Systems, IEEE Press, 378--383.

[30] Baoyuan Wang, Yizhou Yu, and Ying-Qing Xu. 2011. Example-based image color and tone style enhancement. ACM Trans. Graph. 30, 4, Article 64 (August 2011), 12 pages.

[31] Peter O'Donovan, Aseem Agarwala, and Aaron Hertzmann. 2011. Color compatibility from large datasets. In ACM SIGGRAPH 201.

[32] Lyons, P., G. Moretti, and M. Wilson. Colour Group Selection for Computer Interfaces. SPIE - The International Society for Optical Engineering, 302--313.

[33] Pant, Dibakar Raj, Farup, Ivar, Geodesic calculation of color difference formulas and comparison with the munsell color order system, Color Research & Application, Wiley.

[34] B. Morse, D. Thornton, Q. Xia, and J. Uibel. Image-based color schemes. In IEEE International Conference on Image Processing (ICIP), volume III, pages 497–500, September 2007.

[35] A. K. Jain, Data Clustering: 50 Years Beyond K-Mean , Pattern Recognition Letters, Vol. 31, No. 8, pp. 651-666, 2010.