Individualization of 2D Color Maps for People With Color Vision Deficiencies

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Figure 1: *On the left is a color map that has been deformed through the methodology. Lines are selected from the color map, and the user has to sort them. An example of this is shown in the center. On the right are two different colorings of semi-random data. The left one uses the deformed color map shown on the left, the one on the right uses the non-deformed color map.*

Abstract

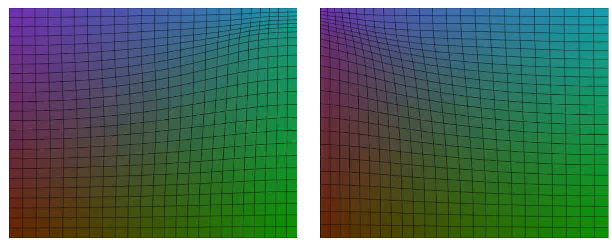
2D color maps are often used to visually encode complex data characteristics such as heat or height. The comprehension of color maps in visualization is affected by the display (e.g., a monitor) and the perceptual abilities of the viewer. People with color vision deficiencies, such as red-green blindness, face difficulties when using conventional color maps. We propose a novel method for adapting a color map to an individual person, by having the user sort lines extracted from a given color map.

Keywords: color vision, color vision deficiency, color map

Concepts: •**Human-centered computing** → *Empirical studies in accessibility; Accessibility design and evaluation methods;* Visualization design and evaluation methods;

1 Introduction

Color maps must be adapted for users with color deficiencies. There are methods for calibrating monitors to people with color deficits in order to recolor images, such as [Flatla and Gutwin 2011] and [Flatla and Gutwin 2012]. However, the trend of personalizing visualization and color maps is gaining momentum. One approach uses human perception of faces to generate isoluminant color maps [Kindlmann et al. 2002]. Another approach is to personalize the color map. [Gresh 2010] shows a method whereby a one dimensional color bar can be adapted to an individuals color perception by searching for small changes in the color bar. However, if we expand it to 2 dimensions, we estimate it will take approximately 75 minutes. There is the added problem of needing to always respond with 5 seconds. In our method, the user can solve it at his own pace and can be done in as little as 30 to 40 minutes. We achieve this by having the user sort lines extracted from the color map.



(a) (b)

Figure 2: *Color Map adapted to two individuals with red-green color vision deficiencies. As can be seen in the top right and top left corner, the users had difficulty sorting lines in different areas.*

2 Methodology

The color map is divided up into a grid of rectangles. An equal number of lines are randomly extracted from each rectangle. Points along the line are extracted and shown to the user as squares he must sort. The change between squares along the line is not necessarily the same for each step along the line. This is due to line aliasing. Essentially, we rasterize the line in RGB space. However, the difference between two squares needs to be equivalent to two steps, e.g., [1, 0, 0] + [0, 1, 0]. Changing only one value leads to a loss of direction, as it will change the direction by 90 degrees. An error occurs when two squares are incorrectly ordered. The RGB values of the errors of one line are summed up into one vector and projected orthogonally onto the color map in order to take the difference in direction between the line and the color map into account. To establish the magnitude of error in a given direction, we use PCA on the projected line errors to get a major and minor axis. By taking the dot product between a direction and the PCA axes, the error in a direction can be calculated.

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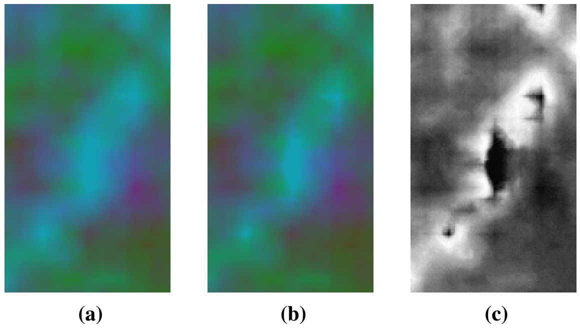

Figure 3: *The images show a map where each pixel has 2 data values. 3a is colored by the default color map, 3b according to 2a. 3c shows the normalized difference in value. In terms of distance in normalized RGB space, the maximum difference is 0.123 and the mean 0.04.*

The color map is divided up into a, regular, square grid for the purposes of deformation. We use squares instead of rectangles, because this allows us to compare edges directly. We then use a mass-spring system in order to contract and expand areas in the following manner: The errors are calculated for each spring. Then they are normalized and flipped by subtracting them from 1 (i.e., a = 1-a), so larger errors result in contractions. The distance between vertices is set equal to the mean, with the resting distance of diagonal springs being multiplied with $\sqrt{2}$. Afterwards the mass-spring simulation is run.

3 Results

The subjects with normal color vision took 56 minutes on average to complete the study. The minimum time was 28 and the maximum 90 minutes with a standard deviation of 21.7 minutes. The subjects with red-green weakness took 55, 51 and 39 minutes respectively. There was no correlation between time taken and number of errors. The three subjects with red-green color weakness all had substantially different results. The results of two of them can be seen in Figure. 2. This illustrates a need for personalized color maps for individuals with color deficiencies.

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