Accessibility for Individuals with Color Vision Deficiency

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Abstract

Individuals with Color Vision Deficiency (CVD) are often unable to distinguish between colors that individuals without CVD can distinguish. Recoloring tools exist that modify the colors in an image so they are more easily distinguishable for those with CVD. These tools use models of color differentiation that rely on many assumptions about the environment and user. However, these assumptions rarely hold in real-world use cases, leading to incorrect color modification by recoloring tools. In this doctoral consortium, I will present Situation-Specific Models (SSMs) as a solution to this problem. SSMs are color differentiation models created in-situ via a calibration procedure. This calibration procedure captures the exact color differentiation abilities of the user, allowing a color differentiation model to be created that fits the user and his/her environmental situation. An SSM-based recoloring tool will be able to provide recolored images that most accurately reflect the color differentiation abilities of a particular individual in a particular environment.

Problem and Motivation

Color vision deficiency (CVD – commonly called color blindness), is a condition in which the affected individual cannot differentiate between colors as well as individuals without CVD. CVD can result from congenital, acquired, or situationally-induced causes. Up to 8% of the male population experiences genetically-caused CVD [Birch 2001] and it has been speculated that 10% of the general population may have some degree of CVD [Stone 2003]. Considering that human color differentiation varies substantially with age [Knoblauch 2001], this is not unreasonable.

Color adaptation tools (or recoloring tools) modify the colors used in an image to improve the discriminability of colors for individuals with CVD [Wakita 2005, Rasche 2005, Jefferson 2006, Kuhn 2008]. These tools rely on models of color vision that provide predictions regarding the differentiability of colors (differentiation models). These predictions allow recoloring tools to identify colors that individuals with CVD cannot differentiate, but those without CVD can. Colors that present differentiation problems for individuals with CVD are replaced with more differentiable colors. As a result, the discriminability of colors used in images is improved for individuals with CVD, thereby increasing image accessibility for these individuals.

Currently, the color differentiation models used in recoloring tools are based almost exclusively on early research that simulates the appearance of images for individuals with a particular form of CVD called dichromatism [Meyer 1998, Viénot 1995, Brettel 1997]. This work assumes a carefully-controlled viewing environment (controlled ambient lighting), calibrated graphics system (OS, graphics card, monitor), and that the type of CVD to be simulated is known. However, in real-world situations, lighting is rarely controlled or constant, graphics systems are rarely calibrated, and few individuals with CVD have been accurately diagnosed with the type and severity of CVD they have. Additionally, there are many other factors that influence color perception (e.g., presence of cataracts or depression, Viagra, age) that are not reflected in these simulations. Newer models that simulate a larger range of CVD types have been proposed (e.g., [Machado 2009]), but still rely on the assumptions of earlier models and require even more detailed information about the type and severity of CVD to be accommodated.

Solution

To address the limitations imposed by current differentiation models, I propose a Situation-Specific Model (SSM) of color differentiation. This model represents the color differentiation abilities of an individual in any environment by sampling the individual's color differentiation abilities using an in-situ calibration procedure. By performing a calibration in-situ, every factor that influences color differentiation (congenital, acquired, and situational) is automatically included in the model, thereby overcoming the restrictions of current assumption-based color differentiation models.

This solution began with my Master's thesis research [Flatla 2009], in which the preliminary design, implementation, and evaluation of an in-situ model of color differentiation was presented. My doctoral research will be comprised of the following:

1. Revise the implementation and design of the model presented in [Flatla 2009], with a more extensive evaluation, and apply it specifically to color use in information visualization. Resulting model has a 30 minute calibration procedure.
2. Reduce the calibration time and improve the accuracy of the SSM from 1) by using discrimination ellipsoids [Poirson 1990] within a perceptually-uniform color space (CIE Luv). To evaluate this model, its calibration time and prediction performance will be compared to the version 1) in a user study.
3. Further improve accuracy by refining the model's internal representation of the user's color differentiation abilities. Also reduce the time taken to make a color differentiation prediction. Will also incorporate game elements into the calibration procedure to reduce tedium [Flatla 2011]. To evaluate this model, its prediction accuracy and prediction time will be compared to the version from 2) via a user study. User preference regarding the game-based calibration procedure will also be explored.
4. Construct a full SSM-based recoloring tool for information visualizations. This will be the final evaluation of the SSM as a color differentiation model for recoloring tools for individuals with CVD. Using a comparative performance-based user study, the performance of this recoloring tool will be compared to two existing recoloring tools, in multiple situations that induce CVD, with CVD and non-CVD participants.

Stage of Research

Regarding my program of study, I have fulfilled the course requirements for my PhD, and I have presented a small proposal to my committee, which they approved. I have yet to present my comprehensive examination, after which a formal proposal is required. Once these milestones are completed, I will need to present a department seminar, then prepare and defend my dissertation.

Regarding my PhD research, I have now completed all of the items in the solution list above. Item 1) was presented at CHI 2010 [Flatla 2010], and received an Honorable Mention Award. Item 2) was presented at ASSETS 2011, where it received the Best Paper Award [Flatla 2011]. I combined items 3) and 4) (except for the game elements component) this past summer and the resulting work is currently in submission.

Contributions

The primary contribution of this research is a model that frees recoloring adaptation tools from the restrictions of current assumption-based models of color differentiation. This new model provides rapid and accurate predictions of the differentiability of any two colors for a particular individual in a particular environment.

Secondary contributions include:

1. The general approach of using in-situ calibration to overcome the limitations imposed by current modeling techniques.
2. Proposed extension of SSMs to reduce the frequency of calibration by making all previously-generated models available to every user (presented at the Dynamic Accessibility workshop at CHI 2011 [Flatla 2011]).
3. As SSMs can represent the color differentiation abilities of any individual, CVD arising from acquired or situationally-induced causes can also be modeled. This allows recoloring tools to be used by any individual that experiences difficulties differentiating colors.

My Hopes for the Doctoral Consortium

Attending the ASSETS 2011 Doctoral Consortium will present a number of opportunities for me. First, I will have the opportunity to present my research to faculty and fellow students. I appreciate any chance I have to describe what I do to others. Second, this presentation will likely illicit feedback from those listening. This feedback will contribute to my general growth as a researcher, to my production of quality research in the future and to the overall quality of my PhD dissertation.

Third, the consortium will present networking opportunities with senior researchers in this field as well as my future colleagues. These are the individuals I will be working under and with for the remainder of my career. Fourth, potential career paths and opportunities may arise from these discussions. As an example, I will be looking for a post-doctoral position in the near future, and the senior researchers in this field are potential supervisors for this position.

Finally, the consortium will allow me the opportunity to provide feedback to fellow students regarding their research and presentation styles. I enjoy these opportunities to understand other researchers' work, and to provide insights that I have gained from my own research.

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About the Author:

David R. Flatla is a third-year PhD student at the University of Saskatchewan, Canada under the supervision of Dr. Carl Gutwin. His work on extending recoloring tools to consider all of the factors that influence human color perception has been awarded an Honorable Mention Award at CHI 2010 and a Best Paper Award at ASSETS 2011. His PhD is funded through NSERC – the Natural Sciences and Engineering Research Council of Canada.