Efficient Edge-Services for Colorblind Users

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Categories and Subject Descriptors: K.4 [Computers and Society]: Social issues — Assistive technologies for persons with disabilities.

General Terms: Algorithms, Human Factors.

Keywords: Web Accessibility, Colorblindness, Vision, Edge Services.

1. ACCESSIBILITY BY EDGE-SERVICES

Web Content Accessibility guidelines by W3C (`http://www.w3.org/TR/WCAG10/`) provide several suggestions for Web designers on how to author Web pages in order to make them accessible to everyone. In this context, we are proposing to use edge services as an efficient and general solution to the problem of colorblind users: we, first, describe an efficient algorithm that modifies any color in Web pages, by increasing contrast and lightness, in order to make them accessible for users with such a disability; then, the algorithm is implemented as an edge service called the *ColorBlind Filter Service* on top of a programmable intermediary framework called SISI [3].

1.1 Colorblindness

The human eye perceives an electromagnetic radiation only in a particular segment of the enormous range of its frequencies called "visible light spectrum", that ranges approximately from 380 to 780 nm (1 nm = 10^{-9}m). Each individual wavelength within the spectrum of visible light wavelengths is representative of a particular color.

Moreover, the human eye contains three types of color sensitive receptors, called cones, which are responsible for the vision of a different portion of the spectrum, that is, *Long* (reddish), *Middle* (greenish), or *Short* wavelengths (bluish) [5] A color deficiency is present when one or more of the three cones light sensitive pigments have a spectral sensitivity similar to the sensitivity of another cone type or when are entirely missing.

The most common forms of color deficient vision, called protanopic and deuteranopic, are characterized by difficulties in distinguish between green and red tones. This type of deficiency, also know as color blindness, is mostly a genetic condition, and it is much more common in men than in women (roughly 8% of the male population against only 2% of female population).

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WWW 2006, May 22–26, 2006, Edinburgh, Scotland.
ACM 1-59593-332-9/06/0005.

It must be emphasized that red and green colors are absolutely unknown for color blind users. Therefore, all the analyzed approaches, both in computer graphics and mathematics, for preserving the reproduction of colors, have mainly addressed the problem of how to avoid, as much as possible, any "loss of information" due to a genetic condition.

Research in this field have been mainly done in the field of computer graphics and mathematics (see, as an example [1]). As a consequence, results are typically not suitable to be used in on-the-fly filtering, as in the case of WWW navigation by a colorblind user [10]. Anyway, among the results, interesting is the work by Dougherty and Wade [4] that also proposed a mechanism (on a web site) for digital images correction. More recent work [6] proposed algorithms that transform color to gray scale by preserving image details. In [9] an extension of this algorithm is shown to allow a re-coloring of images for color-deficient viewers. While an interesting extension, their technique is "far from having real-time performance" [8], that is, instead, the main motivation that has guided our work in this field.

1.2 Colorblind Filter Service

Our main goal in this field is how to provide an *efficient* instrument to promote accessibility of Web pages navigated by users with visual disabilities. We set-up an edge-service ColorBlind Filter Service (CBFS) that translates on-the-fly any HTTP query in order to obtain a page that is more accessible to users with colorblindness.

Using edge services to solve accessibility problems is a known technique [2, 7], but research effort was mainly focused on the HTML tags and the structure (i.e. composition) of the page.

Our approach, here, is to tackle the accessibility for dichromatic users by modifying both HTML and the images embedded, on-the-fly. In fact, the main goal of the CBFS is to modify background and foreground colors in HTML pages and to re-color embedded images (also animated GIF images), in order to make more recognizable the red/green contrast for dichromatic users. The service parses on-the-fly each Web page and, for each HTML tag, analyzes the corresponding attributes to modify background and/or foreground text and images, if some correction is required, by also taking into account inline Internal and External Cascading Style Sheets. The following attributes of HTML pages will be taken into account: color, bgcolor, background, img, text, link, alink, vlink and style attributes that specify images/backgrounds/colors (by following the rules suggested by "Techniques For Accessibility Evaluation And Repair Tools" of W3C (`http://www.w3.org/TR/AERT`)).

The CBFS uses the HSL representation of colors, by specifying them in terms of Hue (H), Lightness (L) and Saturation (S). The Hue value describes the individual colors (the portion of the spectrum that contains the color), the Saturation value represents the intensity of a specific color, and the Lightness value determines the perceived intensity (light or dark color). We choose the HSL color representation model instead of the RGB one since its ability to manipulate lightness that, on the other hand, represents the most important discrimination element for dichromatic people.

Our algorithm's goal is to reduce all stimuli along the so-called "confusion lines" that are the lines of intersection between the plane of not visibility for dichromat people and the 3D color space of normal users [1]. In fact, by changing proportionally hue, saturation and lightness values, it is possible that all stimuli fall in two different half-planes (of the 2D representation) by making them distinguishable both for normal and dichromatic users.

Our algorithm, shown below, has complexity of $\Theta(n*m)$ where $n*m$ is the size of the image expressed in pixel.

Algorithm 1 ColorBlind Filter Service

```
RedPixel ← 0
GreenPixels ← 0
for all pixel do
   if (R > G + 45 and R > B + 45) then
      RedPixel++
   else if (G > R + 45 and G > B + 45) then
      GreenPixel++
   end if
end for
if (GreenPixel > RedPixel) then
   Color ← Green
else
   Color ← Red
end if
for all pixels with RED/GREEN components do
   ColorPixel = Convert { RGB to HSL }
   if ColorPixel is close to Color then
      Hue ← Hue − 30%
      Saturation ← Saturation − 10%
      Ligthness ← Lightness + 25%
   else
      Saturation ← Saturation + 10%
      Ligthness ← Lightness − 10%
   end if
   ColorPixel = Convert { HSL to RGB }
end for
```

An important characteristic of our algorithm is that it is customizable, that is, each user can choose the proportion by which hue, saturation and lightness are changed[1]. The personalization of edge-services offered by SISI allows such an easy personal tuning to meet different deficiencies.

We show, now, an example of application of the algorithm to a picture of Paul Gauguin[2] showed in Fig.1, on left as perceived by trichromatic and on the right as seen by dichromatic. As you can see, in the the image on the right the details of the road in the meadow are lost, but by properly modifying colors, as showed in our algorithm, colorblind viewers are able to distinguish the edge between the road and the meadow, even not being able to perceive exactly the right colors used by Gauguin. In Fig.2, we show the image as modified by our algorithm, as perceived by a trichromatic user (left), and as perceived by a dichromatic user (right[3]). As you can see, the details now are evident also in the image on the right-hand side.

[1]The values used in the algorithm have been tested with several users and with the Vischeck simulator in [4].

[2]Landscape, 1890. Oil on canvas. The National Gallery of Art, Washington DC, USA.

Figure 1: Original image (left) and as perceived[3] (right) by a dichromatic user.

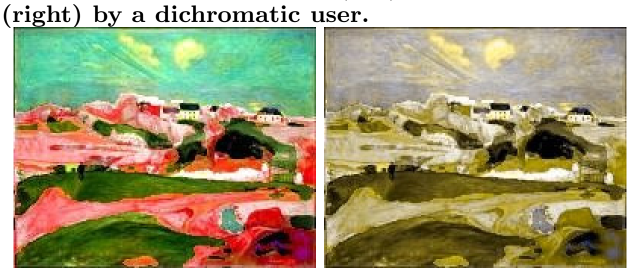

Figure 2: Modified image (left) and as perceived[3] (right) by a dichromatic user.

The results of the CBFS are currently being tested on Web pages with light colors hardly perceived by color blind users.

Finally, it should be emphasized that the results obtained seem to have almost no impact on the responsiveness of user navigation, being the overhead introduced by CBFS amortized by the latency usually experienced by users.

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[3]Images on the right-hand side of Figs. 1 and 2 are obtained with the Vischeck simulator described in [4].