Interaction Design and Architecture(s) Journal - IxD&A, N. 5-6, 2009, pp. 41-48

Increasing Web accessibility through an assisted color specification interface for colorblind people

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ABSTRACT

Nowadays web accessibility refers mainly to users with severe disabilities, neglecting colorblind people, i.e., people lacking a chromatic dimension at receptor level. As a consequence, a wrong usage of colors in a web site, in terms of red or green, together with blue or yellow, may result in a loss of information. Color models and color selection strategies proposed so far fail to accurately address such issues. This article describes a module of the VisAwis (VISual Accessibility for Web Interfaces) project that, following a compromise between usability and accessibility, allow color blind people to select distinguishable colors taking into account their specific missing receptor.

Categories and Subject Descriptors

D.2.2 [**Design Tools and Techniques**]: *User interfaces.*

General Terms

Human Factors.

Keywords

Colorblindness, transcoding, assistive technologies, color specification, usability, accessibility.

1. INTRODUCTION

The accessibility of Web content is gaining an increasing interest and several research activities deal with standards and methodologies for enforcing Web sites accessibility (see, e.g., the Web Content Accessibility Guidelines (WCAG) 2.0 [1,2]). In spite of all these efforts most of the actual Web sites are still not accessible at all. The reason of that is twofold: from on side, most of Web site developers are unaware of the actual standards and methodologies for accessibility; on the other side, such standards are still too broad to address in an effective way all the accessibility issues.

The Vis-A-Wis (VISual Accessibility for Web Interfaces) [3] project attacks the Web accessibility problem following two different strategies:

1. In order to be effective it focuses on a subset of the accessibility issues, dealing with problems associated with *hypo-sight* and *colorblindness*. In fact, it is the authors' belief that, in order to address affectively accessibility issues, it is mandatory to focus on a specific class of users at a time, addressing only the problems that are relevant for that class. As an example, while dealing with colorblind people it is crucial to ensure color separation between plain text and hyperlink text; such an activity is totally useless for people impaired by hypo-sight.
2. It defines a set of strategies and metrics to *automatically* adapt (i.e., transcode) any Web page, according to a specific disability, improving in a measurable way the page accessibility.

This paper presents a new module of the system, i.e., an assisted color specification environment for colorblind persons. The environment is necessary to increase the degree of usability, allowing colorblind users to configure the system according to their needs, following a compromise between accessibility and usability.

Nielsen, in [17], states that technical accessibility is a pre-condition for usability: if users can not access the content of web pages, they can not use the site. So accessibility is necessary but not sufficient for ensuring usability. Even if a site is theoretically accessible, because the web developers follow accessibility standards, it can still be very difficult to use for people with disabilities. It is no surprising that technical accessibility is insufficient to ensure ease of use and ease of learning and high performance user.

Moreover, as a matter of fact, nowadays web accessibility refers mainly to users with severe disabilities, neglecting colorblind people, i.e., people lacking a chromatic dimension at receptor level. As a consequence, a wrong usage of colors in a web site, in terms of red or green, together with blue o yellow, may result in a loss of information; the Vis-A-Wis system allows for presenting colorblind users with distinguishable colors and the assisted color specification environment allows for easily customizing the system. On the other hand, usual color selection strategies rely on color models that are not adequate for colorblind people and, as a consequence, usability becomes a key issue.

Summarizing, the contribute of the paper is the following:

1. It relies on a transcoding environment (VisAwis) that address in a specific way the colorblind accessibility issue;
2. It provides an assisted novel color specification environment that allows dichromats to easily select distinguishable colors using a color model tailored for their specific receptor disorder;
3. It simulates their choices for trichromats, allowing web designers to evaluate how their web pages are perceived by dichromats.

The remainder of this paper is organized as follows: Section 2 presents related work; Section3 recall the human perception of colors focusing on dichromatic vision and presents the metrics implemented for evaluating our transcoding strategies; Section 4 presents the assisted color specification environment for dichromats; Section 5 presents some conclusions and future work.

2. RELATED WORK

Normal color vision is trichromatic, i.e., it is based on the stimuli coming from three different receptor types, responding to different light wavelengths. Dichromatic people are affected by some disorder involving one or more receptors and cannot accurately distinguish some colors. Approximately 7% of males and less than 1% of females are dichromatic and are unable to discriminate some color stimuli that normal color vision can distinguish. Those people are sometimes referred to as colorblinds. The most common form of dichromacy (afflicting about 2% of males) is red-green color blindness, or red-green dichromacy, which itself split into two different types: whereas people affected by protanopia are less sensitive to red light, deuteranopia or deuteranomaly are less sensitive to green light.

The research activity that inspired our work is the simulation for trichromats of dichromatic color perception began with the German writer and scientist Goethe (1810). The first rigorous analysis is provided by excerpts from the report On Colorblindness [6], presented by the engineer William Pole to the prestigious English Royal Society of London, on 19th June 1856. Although the text is quite dated, it contains a clear and precise description altered vision, typical of individuals suffering from a certain kind of blindness to colors. According to Pole's report, blue and yellow are perfectly distinguishable, and are seen by dichromats as normal color vision people do. In more recent times, Boynton (1979) in a excellent text, Human Color Vision, which includes a section titled, “What do Red-Green Defective Observers Really See?” asserts that “the issue of what dichromats really see probably can never be fully resolved” [7]. The past experiments suggest that both protanopes and deuteranopes see the same blue at 470 nm and the same yellow at 575 nm as trichromats (Judd, 1948) [8]. A more recent paper, “What do color blind people see?” (Viénot et al. 1995; see also Brettel et al. 1997) [9], contains color illustrations purporting to show to normal subjects what a picture of flowers would look like to dichromats. Similar illustrations can be found on many websites [10]. Brettel [9] proposes an algorithm able to simulate colorblindness to person with normal color vision. The Brettel algorithm represents color stimuli as vectors in a three-dimensional LMS space, and the simulation algorithm is expressed in terms of transformations of this space. The LMS space represents the wavelengths perceived by the three classes of cones in the retina that give life to the colors (the short (S), middle (M), and long (L) wave sensitive cones, each of which contains a different photo pigment. Protanopes lack the L-photo pigment, while deuteranopes lack the M-photo pigment. Tritanopes, the rare third kind of dichromats, lack the S-photo pigment.

To ensure accessibility Web designers (should) follow the WCAG 2.0 formulae and guidelines. Such formulae have been tested by the research center of the University of Toronto [16] and the way of calculating the contrast has yielded positive results over a wide sample of people with deficient vision. The formulae may yield results slightly different depending on the type of screen (LCD or CRT) and display settings. In the following we recall the WCAG 2.0 standard formulae.

Color brightness (WCAG 2.0: Technique 2.2.1 [priority 3]), is determined by the following formula:

$$((\mathrm{Red} * 299) + (\mathrm{Green} * 587) + (\mathrm{Blue} * 114)) / 1000 \quad (1)$$

where <Red, Green, Blue> refer to the intensity of the three primary components in a usual RGB monitor and the three coefficients are based on the V(λ) [23] function representing the relative sensitivity of the human eyes to light of different wavelengths. This calculation produces a value in the range from 0 - 255. For ease of reading, it is essential that text have a reasonable difference from its background and the guidelines states that it must be greater than 125.

The difference of color (hue) is determined by the following formula:

$$\begin{gathered}(\max(\mathrm{Red}\ 1, \mathrm{Red}\ 2) - \min(\mathrm{Red}\ 1, \mathrm{Red}\ 2)) + \\ (\mathrm{maximum}(\mathrm{Green}\ 1, \mathrm{Green}\ 2) - \\ \min(\mathrm{Green}\ 1, \mathrm{Green}\ 2)) + (\max(\mathrm{Blue}\ 1, \mathrm{Blue}\ 2) - \\ \min(\mathrm{Blue}\ 1, \mathrm{Blue}\ 2))\end{gathered} \quad (2)$$

where <Red1, Green1, Blu1> and <Red2, Green2, Blu2> are the three primary components of the two colors.

According to the guidelines, the difference of color between the text and the background must be greater than 500. Then a large difference in brightness (> 125) and a large difference in hues (> 500) indicate a high degree of legibility.

It is worth noting that, even if the Toronto tests gave positive results, these formulae are not explicitly thought for dichromats.

There are a number of approaches [23] to allow users to select colors but, to the best of our knowledge, no one refers specifically to colorblind users. The most used strategies allows for choosing colors by using three sliders, specifying a point in a tridimensional (e.g., RGB) color space or selecting the colors from a palette of predefined samples, following different color layouts (e.g., circle, triangle, square, hexagon), each of them embodying the idea of a chromatic plane and Foley et al. in [4] provides algorithms for a number of different color geometries.

One other widely used color interface in computer graphics is based on the hue saturation and value (HSV) color space. Hue is the element that distinguishes one color of the rainbow from another one, saturation, the "pureness" of the color, i.e., its distance from the white, and the third element, brightness, is sometimes called "lightness" or "value." (The highest value is white; the lowest value is black.)

However, the problem of the best color selection interface is by no means resolved and experimental studies have failed to show that one way of controlling color is substantially better than another one (Schwarz et al-, 1987) [5].

The situation is even worse for colorblind users: for most of them red and green hues are not distinguishable and they experiment difficulties in moving the R and G sliders, or selecting a color from a palette that presents non distinguishable colors. Concerning the HSV space, saturated colors are harder for the colorblind to distinguish and the same happens for colors with similar brightness: the more similar two colors are in brightness or in saturation, the harder they will be to distinguish [23, 15].

Following the line of thought of such studies and a comprehensive study of color deficient vision, a color specification interface in a reduced LMS color space has been designed for dichromats, allowing to alter the color of text, hyperlinks, and visited hyperlinks, in order to guarantee a clear color separation.

Summarizing, the color selection interface presented in this paper differs from the above proposals for three main aspects:

1. It uses a reduced LMS color space (vs. the usual RGB) for color specification;
2. It uses the Brettel algorithm to simulate their choices for trichromatics, allowing Web designers and other trichromats to evaluate how the Web pages are perceived by dichromats after transcoding.
3. It introduces novel metrics for evaluating the accessibility of pages transcoded for colorblinds.

3. COLOR SPECIFICATION STRATEGIES

This section presents a description of the LMS color space and of the Brettel algorithm, together with the strategies adopted to design color specification environment for colorblind users.

The perception of the color of an object depends on the properties of our visual system and the source of light that interacts with the object itself. The visible light is a narrow part of the electromagnetic spectrum from approximately 380 to 780 nanometers. Visible light, entering into the eyes, stimulates photoreceptors sensitive to a certain interval wavelength [18]. There are three types of photoreceptors that differ in their sensitivity according to spectral wavelengths received. The three classes of cones have their peak sensitivity at about 420 nm (short wavelength S cones), 530 nm (medium-wavelength M cones) and 560 nm (long wavelength, L cones), as depicted in Figure 1. The brain processes the three different signals and gives us the sensation of color. Various colors are recognized, when the different types of cones are stimulated to different extensions [11].

A common cause of the loss of color vision is the lack of a particular type of cone vision. For example, if there is no pigment on the cone S (Tritanopia), the subject would not be able to distinguish between colors in the yellow-blue spectrum, while an individual who lacks the cone L or M would not be able to distinguish the tones in the green-red spectrum. Achromatopsia corresponds to the lack of two or three cones: colors are not perceived and, because vision relies only on rods that are extremely sensitive (they are active in very low light) achromatopes are very sensitive to brightness.

In order to simulate dichromatic vision Brettel et al. [9] propose a replacement method based on the LMS color space and on the assumption that neutrals for trichromats are perceived as neutrals for dichromats.

As a first step they identify a neutral axis which is a straight line connecting the origin in the LMS space and the brightest possible metamer of an equal energy stimulus perceived on a RGB monitor. The metamer is ranging from black to white. Secondly, they represent the surface of the reduced stimuli of protanopes and deuteranopes by the two half planes anchored by neutral axis and 475-nm and 575-nm locations in the LMS space, and for tritanopes, they anchor the reduced stimuli surface by neutral axis, 485-nm and 660-nm. Finally, they compute a replacement stimulus for a stimulus in trichromatic vision by projecting it onto the half planes aforementioned by the direction parallel to the missing fundamental axis.

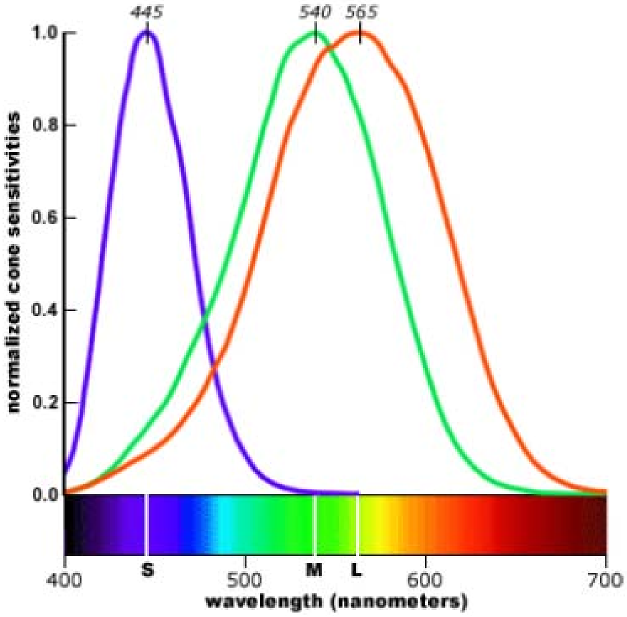


Figure 1. Spectral sensitivity curves, measured inside the eye, based on the Stockman & Sharpe (2000) 10° quantal cone fundamentals.

Roughly speaking, the algorithm converts an image from RGB color space to LMS space, applies the correction for colorblindness removing stimuli for the missing cone, and converts the image back to the RGB color space.

In the following we present the different color specification strategies we designed for different colorblind users.

3.1 ACHROMATOPSIA

Gray tones, from white to black, are the only colors visible to persons with achromatopsia. The only needed control is a slider to adjust the brightness, creating color gradations in the scale that ranges from black to gray and white. It is worth noting that the purpose of the slider is not only to specify colors on the gray scale, but above all, to acquaint the users with a thorough overview of brightness levels, since studies show that these subjects are highly sensitive to light.

3.2 PROTANOPIA, DEUTERANOPIA, AND TRINATOPIA

From the consideration about the LMS color space it is easy to realize that the gamut of visible colors is different for each type of colorblindness, but, despite this, there is a common reason to all these disabilities: the lack of one receptor. According to this issue, we designed a color specification interface that allows a dichromate to select a color in the LMS space, by varying only the two perceived components and leaving at a constant value the missing one. This results in a quite effective interaction: because they are not allowed to change the contribution of their missing component (e.g., component L for those with protanopia) it is impossible to generate colors that differ only in the wavelengths of the missing component, and then indistinguishable. This solution need a mapping between LMS and RGB colors, based on the values obtained by Stockman [13]. Moreover, to present normal users with the simulation of what is effectively perceived by dichromats we apply the Brettel algorithm on the chosen colors.

3.3 METRICS

The color contrast is generally considered to be one of the most important quality parameters. It is commonly defined in terms of tone reproduction curves for color reproduction applications. Unfortunately, the quality of color contrast is usually evaluated on a universal model that do not consider haw the contrast is perceived by colorblinds. The most common model uses a simple definition of Lightness-Contrast, Chroma-Contrast and Sharpness-Contrast [22] in the CIE L*a*b* color space. In the following we present a model that is appropriate for colorblind users.

3.3.1 Text contrast

To increase readability we have to insure high contrast between text and background. According to Ware [23] luminance ratio is the key parameter to use when measuring contrast and we use the W3C formula for computing the CR (Contrast Ratio) based on the luminance of text and background L_1,and L_2, where $L_1 > L_2$.

$$CR=(L_1+0.05)/(L_2+0.05) \qquad (3)$$

where L is computed weighting the RGB color components with the CIE (Commission Internationale de L’Eclairage) V(λ) function representing the relative sensitivity of the human eye to light of different wavelengths (for the sake of clarity we omit some details about the calculation of R, G, and B values; a full discussion about the matter is in [2, 23]).

$$L = 0.2126 * R + 0.7152 * G + 0.0722 * B \qquad (4)$$

Using equation (3) we can compute the RCP (Readable Contrast Proportion) as follows:

$$RCP=\text{Number of characters having } CR\geq 5 / \text{Total number of characters.} \qquad (5)$$

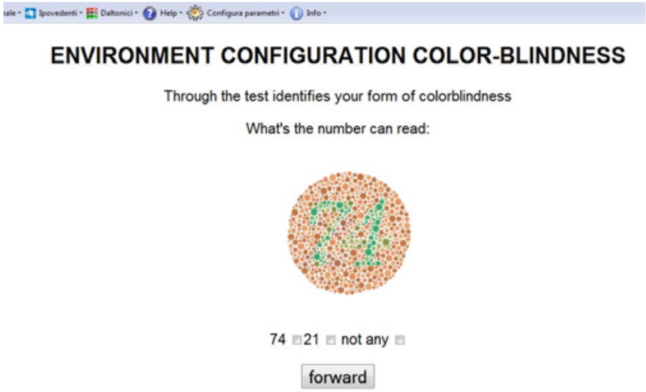
that ranges in [0..1] (1 is the best value) and the threshold 5 is the minimum contrast ratio required by WCAG 2.0 [3].

Obviously, the L calculation differs for colorblind people and in such a case we use a different formula based on the result appearing in [9]. So the contrast is seen in terms of how dichromats perceive colors and luminance.

4. THE COLOR SPECIFICATION PROTOTYPE

In this section we describe the prototype of the specification interface, enumerating the main user interaction steps.

1. Identify the type of colorblindness. Most dichromatics discover late in their life that they are blind to some color differences. In fact, and partially surprisingly, color vision is irrelevant to much of normal vision and becomes essential only when colors are coding relevant information (e.g., the green and red colors used in traffic lights). As a consequence, most of the colorblind people are unaware of the precise kind type of colorblindness they are affected. For that reason, the initial user interaction is devoted to discover, using the classical Ishihara [14] test, the type colorblindness and to direct users to the appropriate pages. A step of the test is shown in Figure 2.
2. Specify the essential colors in a Web environment: background, text, links, and visited links. The logic of design allows a choice of colors that are distinguishable and presents high contrast for all the types of considered disabilities. An example for protanopia is shown in Figure 4.
3. Simulates the page appearance for trichromatics, using the Brettel algorithm [9]. This simulation has been implemented for two reasons:
   a. to have a further confirmation that the specified colors are clearly visible and distinguishable even for trichromats;
   b. to make the Web designers and other trichromats aware of the appearance of the page for dichromats.



ENVIRONMENT CONFIGURATION COLOR-BLINDNESS

Through the test identifies your form of colorblindness

What's the number can read:

74 ☐ 21 ☐ not any ☐

Figure 2. The first screen of the color specification environment directs the user in dichromatic (21), achromatic (not any) or normal vision (74). Further, similar tests, will determine the specific dichromatic deficiency.

As an example, starting from Figure 2 and clicking on “not any” the user is directed to the page for the achromatopsia (see Figure 3). In this screen the variation of brightness plays a key role.

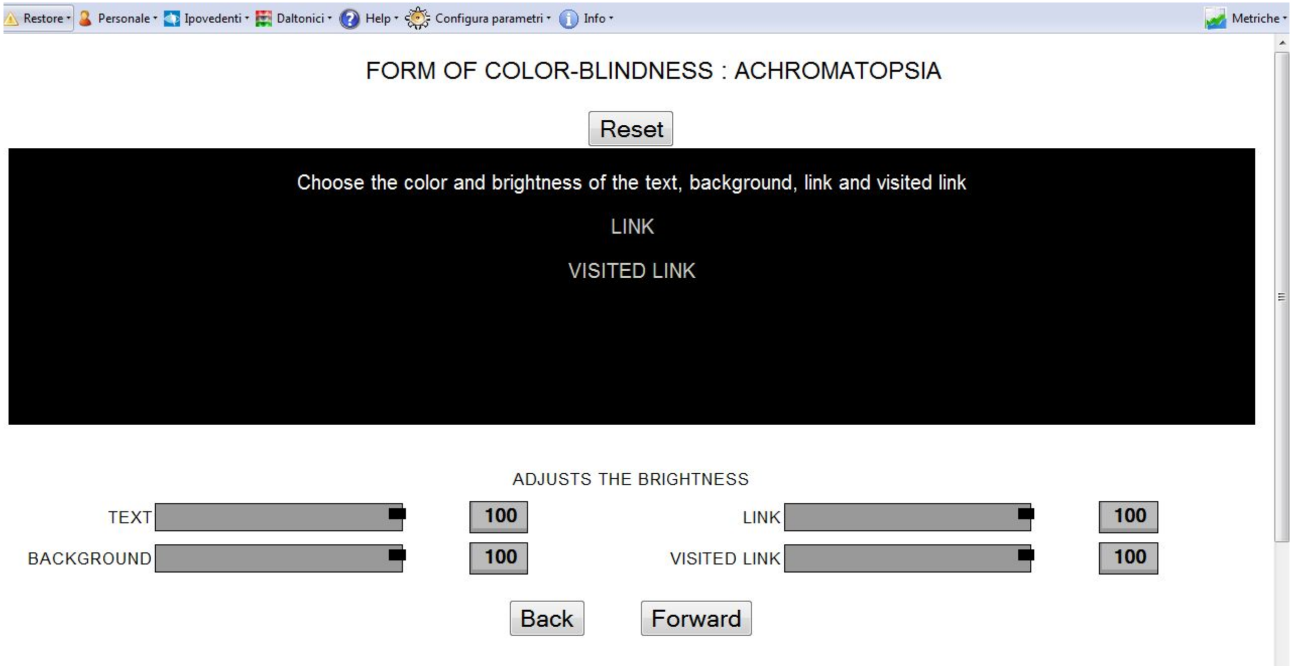
In the screen shown in Figure2 clicking on “21” the user is directed to the page for the dichromatic vision. According to the Ishahara test, the user is then presented with other three tables that allows for discovering if s/he is affected by protanopia, deuteranopia, or tritanopia.

Assuming that the user is affected by protanopia (the other two cases follows a quite similar approach) and therefore is redirected to the page in Figure4. The sliders A and B allow the user to manipulate the values of the perceived component in the LMS space.

For colorblindness users affected by protanopia, the parameters A corresponds to cone M and parameters B corresponds to cone S, into LMS space. The value of cone L is assigned a constant value. Through the white and black buttons, the user can immediately select these two colors, speeding up the interaction.

The table in Figure 5 allows for inspecting technical details about the selected colors, like color differences and color contrast using the formulae described in Section3.

The final, transcoded page is shown in Figure 6.



FORM OF COLOR-BLINDNESS : ACHROMATOPSIA

Choose the color and brightness of the text, background, link and visited link

LINK

VISITED LINK

ADJUSTS THE BRIGHTNESS

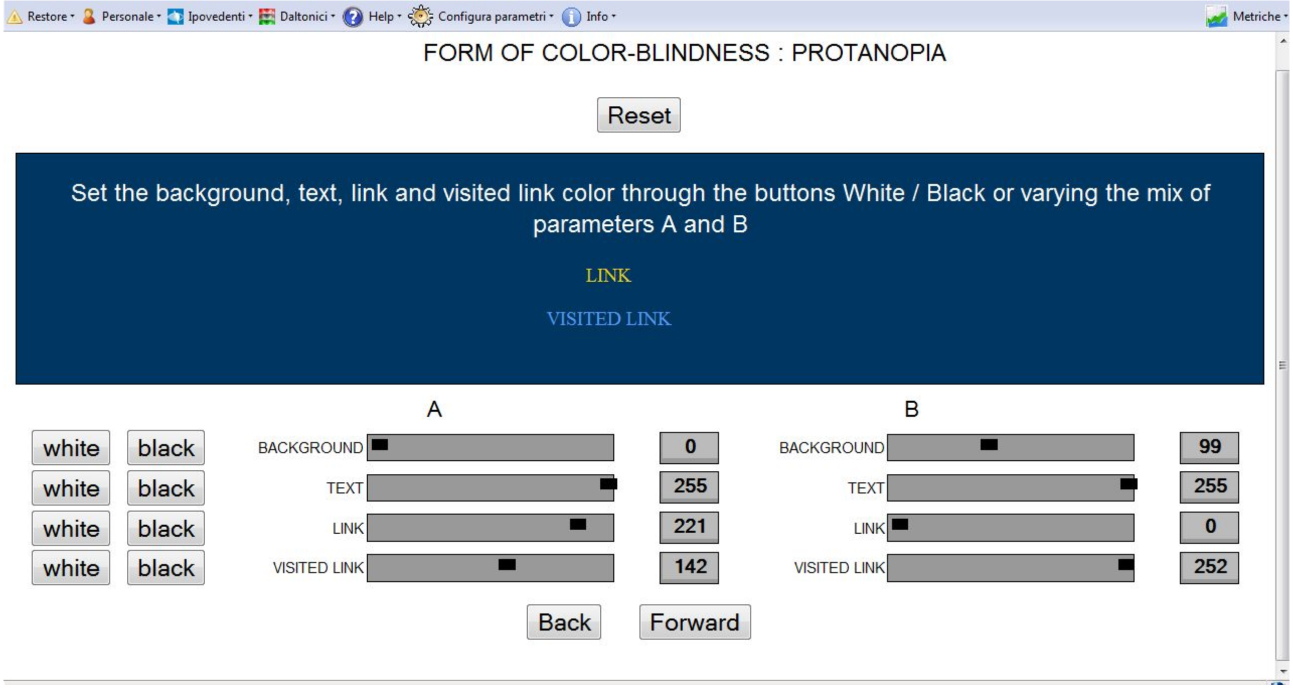
TEXT 100

BACKGROUND 100

LINK 100

VISITED LINK 100

Figure3. Achromatopsia. The user can adjust the brightness through the use of the sliders getting distinguishable and high contrast grayscale tones.



FORM OF COLOR-BLINDNESS : PROTANOPIA

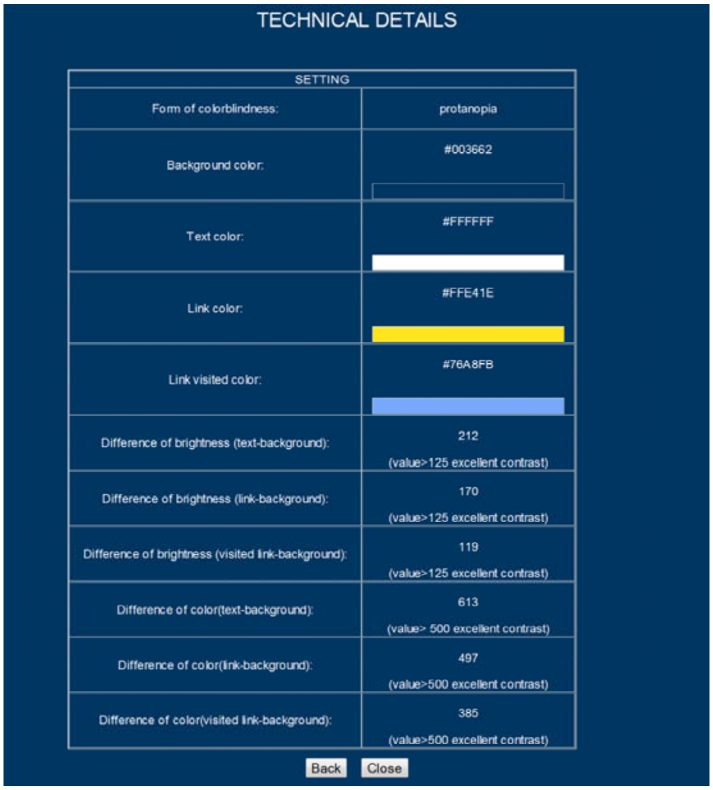
Set the background, text, link and visited link color through the buttons White / Black or varying the mix of parameters A and B

LINK

VISITED LINK

		A		B	
white	black	BACKGROUND	0	BACKGROUND	99
white	black	TEXT	255	TEXT	255
white	black	LINK	221	LINK	0
white	black	VISITED LINK	142	VISITED LINK	252

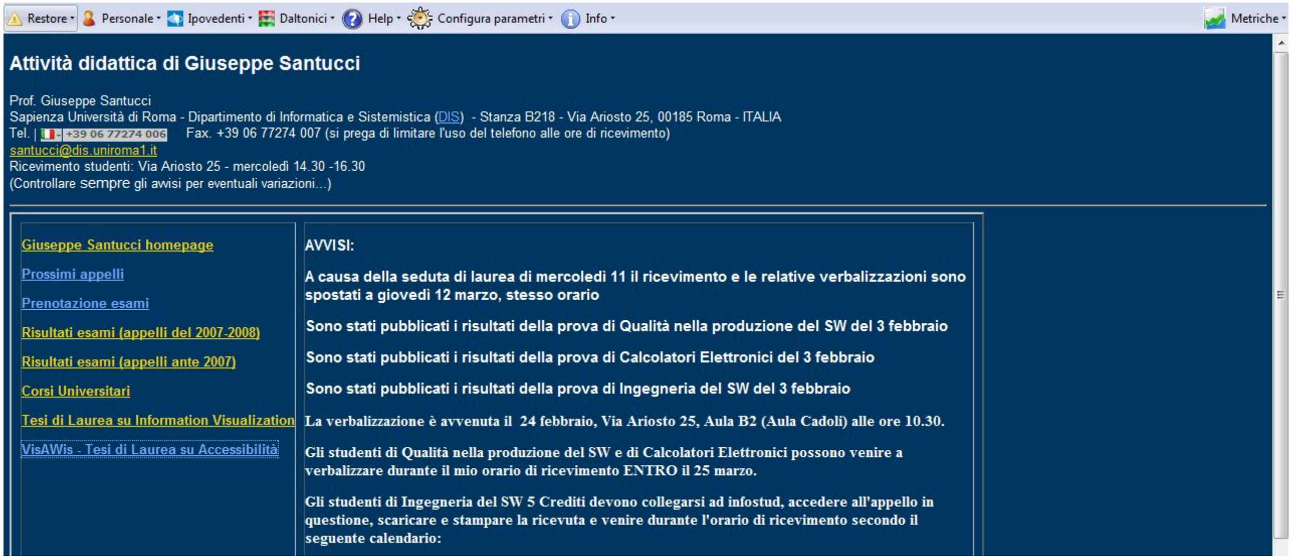
Figure4. Protanopia. The user can specify the colors through the use of two slider (corresponding to the M and S cones) getting distinguishable and high contrast colors



TECHNICAL DETAILS

SETTING	
Form of colorblindness:	protanopia
Background color:	#003662
Text color:	#FFFFFF
Link color:	#FFE41E
Link visited color:	#76A8FB
Difference of brightness (text-background):	212 (value>125 excellent contrast)
Difference of brightness (link-background):	170 (value>125 excellent contrast)
Difference of brightness (visited link-background):	119 (value>125 excellent contrast)
Difference of color(text-background):	613 (value> 500 excellent contrast)
Difference of color(link-background):	497 (value>500 excellent contrast)
Difference of color(visited link-background):	385 (value>500 excellent contrast)

Figure5. Details and quality metrics



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Tesi di Laurea su Information Visualization
VisAWis - Tesi di Laurea su Accessibilità

AVVISI:

A causa della seduta di laurea di mercoledì 11 il ricevimento e le relative verbalizzazioni sono spostati a giovedì 12 marzo, stesso orario

Sono stati pubblicati i risultati della prova di Qualità nella produzione del SW del 3 febbraio

Sono stati pubblicati i risultati della prova di Calcolatori Elettronici del 3 febbraio

Sono stati pubblicati i risultati della prova di Ingegneria del SW del 3 febbraio

La verbalizzazione è avvenuta il 24 febbraio, Via Ariosto 25, Aula B2 (Aula Cadoli) alle ore 10.30.

Gli studenti di Qualità nella produzione del SW e di Calcolatori Elettronici possono venire a verbalizzare durante il mio orario di ricevimento ENTRO il 25 marzo.

Gli studenti di Ingegneria del SW 5 Crediti devono collegarsi ad infostud, accedere all'appello in questione, scaricare e stampare la ricevuta e venire durante l'orario di ricevimento secondo il seguente calendario:

Figure 6. Example of transcoding for protanopes

5. CONCLUSION AND FUTURE WORK

This paper presents a novel approach to Web accessibility for colorblind persons. The main idea is to adapt (i.e., transcode) in automatic way the content of existing Web pages in order to address these kinds of disability. Transcoding is driven by a suitable set of metrics and mainly consist in altering text font, size, spacing, and color preserving, as much as possible, the original page structure and maximizing the information presented on the screen. The focus of this paper is on the assisted environment that allows dichromats to configure their environment. A prototype, available at [19], has been implemented to test the adaptation strategies.

The prototype has been demonstrated at Handymatica 2008 [20], the most important Italian event about technologies and handicaps, receiving positive consensus.

At time of writing, serious user studies have not been performed and we plan to validate our quality measurement through subjective experiments and analyze the correlation between the metric predictions and the observer ratings.

We are currently working on:

- Tuning some default values (e.g., the default color values for colorblind users);
- Extending and improving the set of accessibility metrics;
- Improving the adaptation algorithm for handling images;
- Setting up a user study for evaluating our approach;
- Deepening the challenging idea of adapting Web pages for blind people, analyzing and adapting the content of a Web page, extending the ideas presented in [21].

6. ACKNOWLEDGMENTS

Our thanks to all the students that implemented the plug-in and to Ing. Emiliano Di Reto for his invaluable help and suggestions.

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