A Contrast Colour Selection Scheme for WCAG2.0-compliant Web Designs based on HSV-half-planes

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***Abstract*—Sufficient colour contrast between text and background is necessary for the text to be readable. WCAG2.0 defines contrast guidelines that ensure web pages can be read by people with a visual acuity of as low as 20/80. However, the WCAG2.0 specification is hard to understand for web-designers and they often perform colour checks after the design is finished using colour contrast calculators. It is then often too late to make significant changes to the design. This paper proposes a new colour selection scheme that integrates contrast constraints into the main design phase by only allowing designers to select colour pairs that contains sufficient contrast. The mechanism is compatible with the colour harmony systems commonly used by designers. The tool gives designers an easily perceivable overview of the design space of available colours. The paper briefly describes a prototype of a colour picker tool that implements the proposed scheme.**

Keywords- colour, HSV, RGB, contrast, WCAG2.0

I. Introduction

The perception of visual stimuli requires difference. For text to be readable by observers it needs to be sufficiently different from the background. This is often referred to as contrast. There is a vast body of research into contrast and its effect on reading. The pioneering studies investigated printed text [1, 2], later studies addressed text on various forms of displays [3-9], the web [10, 11] and more recently the legibility of text on electronic paper [12].

Recommendations for what constitute sufficient contrast on the web are specified in the W3C Web Accessibility Guidelines WCAG2.0 [13]. WCAG2.0 divides contrast into three levels according criterion a, aa and aaa. The basic a-level criterion ensures that web pages are readable by individuals with colour blindness; the stricter level aa-criterion ensures that there is sufficient contrast to accommodate for individuals with 20/40 vision and the most strict aaa-level criterion caters for individual with 20/80 vision. Clearly, there is a relationship between humans' visual acuity, the text sizes and the levels of contrast. By supporting visual acuity levels of 20/80 the majority of the population is included [14]. Attention to contrast level and readability is extremely important as visual acuity deteriorate with age [15].

Although WCAG2.0 provides precise advice, its mathematical formulation makes the advice hard to understand and use in practice for most designers. Instead, designers often use colour pickers such as the ones shown in Figs. 1 and 2 and rely on contrast calculators to determine the contrast level between foreground and background colours. Such contrast calculators are widely available on the web. However, a problem with this approach is that designers tend to check their design after the designs are finished. Often this is too late.

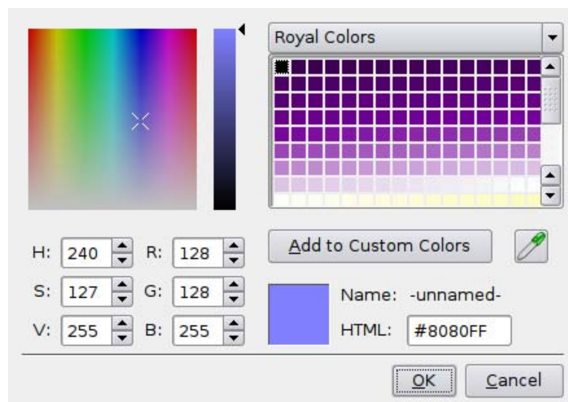

Figure 1. "Qt color chooser" by Trolltech - Qt. Licensed under GPL via Wikimedia Commons

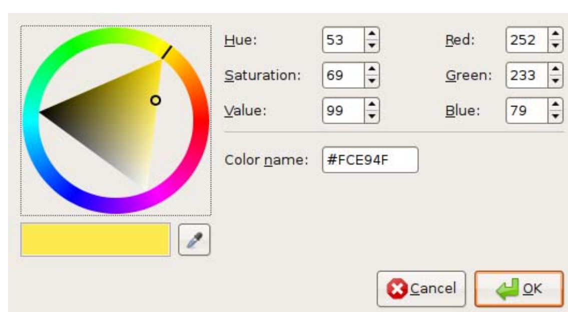

Figure 2. "GTK color chooser" by GNOME Foundation - GTK+. Licensed under LGPL via Wikimedia Commons

There is surprisingly little research into how designers select colours and how colour picking interfaces should be designed. Of the few studies available van den Broek et al. [16] explored a colour picking interface for information retrieval applications. Douglas and Kirkpatrick [17] addressed the visual presentation of colour picker interfaces.

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Gonzales and Latulipe [18] studied two hand interactions to explore colours and Troiano et al [19] optimized palettes to account for colour blindness.

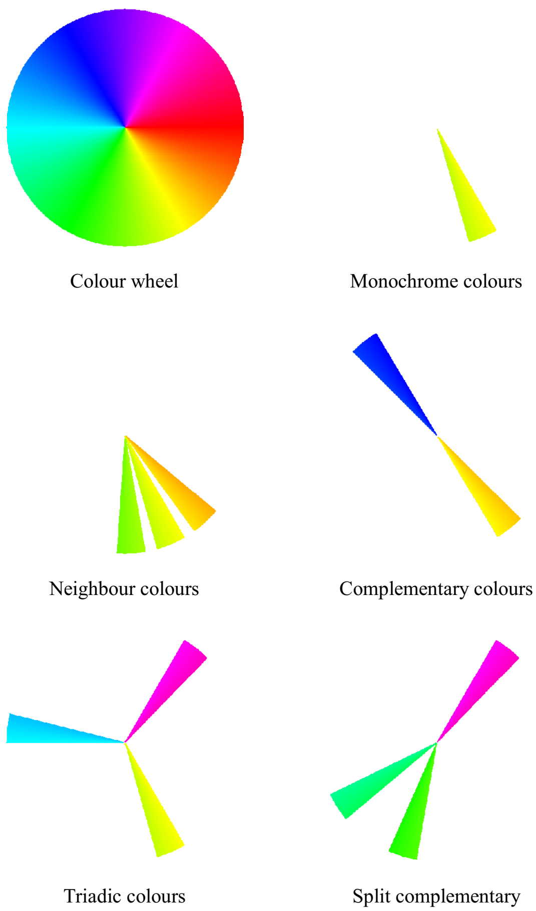

Figure 3. Common colour harmonies

Sandnes [20] explored the colour space in light of the WCAG2.0 contrast constraints and proposed the idea of limiting the available colours in the colour picking interface. In a later study Sandnes and Zhao demonstrated such a tool [21]. However, their tool operated in the RGB colour space by laying out incremental slices of the RGB colour cube. This layout scheme made colour selection difficult, because the valid colours were dispersed throughout the colour selection area. This study thus builds on Sandnes and Zhao's work where the objective is to allow knowledge about contrast levels to be integrated into the design process. The novel contribution herein is to limit the displayed colours to HSV half-planes defined by hues of a chosen colour scheme. This allows the colour selection area to be used more effectively and intuitively.

II. Colour Harmonies

The colour space is huge and web pages often can be coded with as much as 256 x 256 x 256 = 16 777 216 different colours. For the novice this abundance of colours is overwhelming. Web designers however, often constrain themselves to smaller sets of colours known as colour harmonies. These colour harmonies are known to work well together. The colour wheel is commonly used as a tool to define colour harmonies. The colour wheel contains all the available hues organized in a circle from red (0°), yellow (60°), green (120°), cyan (180°), blue (240°), magenta (300°), and the hues in between.

The colour wheel can be viewed as a projection of the RGB colour cube on to a plane defined by the normal line going from black (0,0,0) to white (255, 255, 255) as shown in Fig. 3. The most common colour harmonies include

Monochromatic colours: Monochromatic colours all have the same hue, but vary in brightness and saturation. Monochromatic colours give the impression of order.

Neighbour colours: Neighbour colours are characterised by lying next to each other on the colour wheel, for instance yellow, green-yellow and green. Neighbour colours are often found in nature.

Complimentary colours: Complimentary colours are located 180° in relation to each other on the colour wheel, for instance red (0°) and cyan (180°) or yellow (60°) and blue (240°). Complimentary colours are vibrant.

Triadic colours: Triadic colours are separated by 120° on the colour wheel dividing the wheel into three parts, for example red (0°), green (120°) and blue (240°), or yellow (60°), cyan (180°) and magenta (300°). Triadic colours are also vibrant and express excitement.

Split Complimentary colours: Split Complimentary colours comprise a basic hue and the two neighbours of the complimentary colour on the colour wheel.

The colour harmonies greatly limit the available set of colours while ensuring that the design achieves the expressive effect associated with the respective colour harmony.

III. Colour Models – RGB and HSV Transformation

Designers often prefer to use other models than RGB such as the HSV model, because they allow designers to reason about colours more closely to how they speak about colours. Often we refer to the basic hue with adjectives defining the characteristics of that hue. For instance, we can easily comprehend descriptions such as dark red, a saturated green, etc. Contrastively, it is hard for humans to reason around and describe colours using the hardware-centric RGB-model.

This study uses the HSV-model based on hue, saturation and value. The hue is the colour on the colour wheel described previously. Saturation is the pureness of a colour, while an unsaturated colour contains white. Value represents the strength of the colour. A low value is close to black while a high value is bright.

We therefore need to be able to transform HSV values to RGB. The following is a commonly cited formulations where a colour is specified using hue H in [0..360], saturation S in [0, 1] and value V in [0,1] and the corresponding RGB values are computed using

$$(R',G',B') = \begin{cases} (0,0,0) & if\ H'undefined \\ (C,X,0) & if\ 0 \le H' \le 1 \\ (X,C,0) & if\ 1 \le H' \le 2 \\ (0,C,X) & if\ 2 \le H' \le 3 \\ (0,X,C) & if\ 3 \le H' \le 4 \\ (X,0,C) & if\ 4 \le H' \le 5 \\ (C,0,X) & if\ 5 \le H' \le 6 \end{cases} \quad (1)$$

where the chroma C is defined as

$$C = SV \quad (2)$$

and

$$H' = \frac{H}{60} \quad (3)$$

and

$$X = C(1 - |H' \bmod 2 - 1|) \quad (4)$$

The values are then scaled using

$$(R,G,B) = (R'+m, G'+m, B'+m) \quad (5)$$

Where m is given by

$$m = V - C \quad (6)$$

In our implementation the colour space conversion functions provided by the java graphics framework were used.

IV. Colour Contrast Distance Function

The colour presentation approach employed herein is based on only displaying valid colours given a certain colour choice defined by C_1. In order to determine if a colour C_2 is valid it needs to be sufficiently different from the chosen colour. We therefore need a colour distance function $d(C_1,C_2)$ defined in terms of contrast.

$$d(C_1,C_2) = contrast(C_1,C_2) \quad (7)$$

The World Wide Web Consortium (W3C) Web Contents Accessibility Guidelines (WCAG2.0) [2] refers to luminance contrast that combines hue, value and saturation. The WCAG2.0 guideline for level a-criterion (criterion 1.4.3) recommends that text should not rely on hue contrast. The level aa criterion recommend a luminance contrast ratio of at least 4.5:1 for text and 3:1 for headings. The level aaa criterion specifies a contrast ratio between text and its background of 7:1 and similarly 5:1 for headings. WCAG2.0 defines luminance contrast as

$$contrast = \frac{L1 + 0.05}{L2 + 0.05} \quad (8)$$

where $L1$ is the luminance of the brightest colour and $L2$ is the luminance of the darkest colour. Luminance is defined as

$$L = 0.2126r + 0.7152g + 0.0722b \quad (9)$$

The factors r, g and b represent linear red, green and blue colour components. The conversion between linear c and non-linear components k is

$$c = \frac{k}{12.95} \quad (10)$$

If $k \leqslant 0.03928$, or

$$c = \left(\frac{k + 0.055}{1.055}\right)^{2.4} \quad (11)$$

If $k > 0.03928$. The value k is given by

$$k = \frac{C}{255} \quad (12)$$

where C represents one of the three RGB-vector values defined by an 8-bit value in the interval 0 to 255. This mathematical contrast definition is non-trivial and it is understandably not easy for designers to build a mental model of how colour choices affect contrast.

V. Colour Presentation Model

The colour presentation model is based on the designer first choosing a given colour scheme. Having selected a colour scheme the tool displays the colour half-planes of the HSV cylinders for each of the hues selected for the colour scheme. Each such half-plane lists all the combinations of saturation and values for the respective hue. This process is illustrated in Fig. 3.

Once the user selects the first colour the contrast distance function is applied and only the colours with sufficient contrast distance from the selected colour are displayed. This process is illustrated in Figs. 5, 6 and 7.

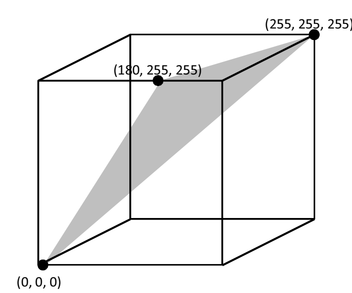

Figure 4. Colour plane for a given hue in the RGB colour space.

VI. An RBG Formulation

The proposed scheme can also be expressed completely in the RGB colour space. The respective colour space is then represented by the polygon defined by the two end points black (0, 0, 0) and white (255, 255, 255) and a point on the edge of the colour cube according to the desired hue (see Fig.

4). The colour wheel is thus represented by traversing the outer edges as follows.

1. Red (255, 0, 0) -> yellow (255, 255, 0)
2. Yellow (255, 255, 0) -> green (0 , 255, 0)
3. Green (0, 255, 0) -> cyan (0 , 255, 255)
4. Cyan (0, 255, 255) -> blue (0 , 0, 255)
5. Blue (0, 0, 255) -> magenta (255 , 0, 255)
6. Magenta (255, 0, 255) -> red (255 , 0, 0)

The relationship between the hue H and these six edges are as follows:

$$Edge = \left\lfloor \frac{H}{60} \right\rfloor \quad (13)$$

And the portion p in [0, 1] of the respective edge is approximately

$$p \approx \frac{H \bmod 60}{60} \quad (14)$$

The respective polygon can then be directly mapped into a colour picking tool.

VII. THE COLOUR PICKER TOOL

We developed a prototype of a colour picker tool in Java. The tool is depicted in Figs. 8 and 9. The user selects the desired colour harmony, the basic hue in degrees, sets the desired contrast level and the corresponding colour planes are displayed. By altering any of the parameters the colours are adjusted, allowing the designer to experiment with the various settings. The tool also includes a preview with foreground text on a background and their inverse.

VIII. CONCLUSIONS

A novel colour picking scheme is proposed. Colours are represented according to a given colour scheme and the colour planes for saturation and value for each respective hue are displayed. A contrast distance function based on the WCAG2.0 guidelines are used to only display colours on each respective colour plane that has sufficient contrast compared to a selected first colour. The proposed scheme allows knowledge about contrast to be seamlessly integrated into the design process relieving the designers from the mathematical details of contrast computations. Moreover, the set of available colours are intuitively laid out hiding all irrelevant colour combinations for a given design. The approach is simple and relatively easy to implement and it should be possible to easily retrofit existing design tools with the improved colour picker model. Future work includes implementing a javascript version for making the tool easily accessible using web browsers.

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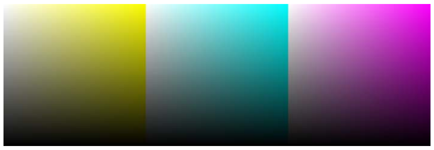


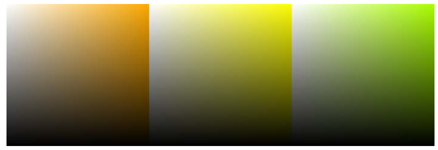
Colour planes for a triadic colour scheme (yellow, cyan, magenta)

Valid colours after selecting a dark(0) half saturated (0.5) cyan.

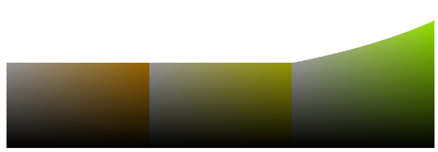
Valid colours after selecting a medium dark (0.5) half saturated (0.5) cyan.

Valid colours after selecting a bright (1) half saturated (0.5) cyan

Figure 5. HSV half-planes for a triadig colour harmony



Neighouring colour sheme with orange, yellow and green.

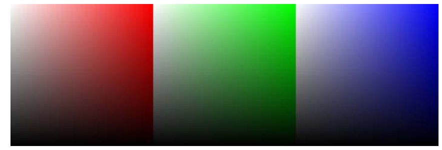


Valid colours after selecting a bright (1) half saturated (0.5) yellow

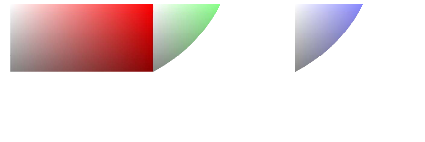
Valid colours after selecting a medium dark (0.5) half saturated (0.5) yellow

Valid colours after selecting a dark (0) half saturated (0.5) yellow

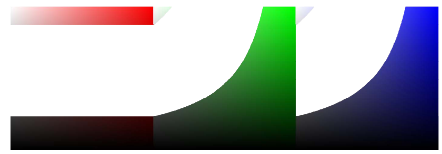
Figure 6. HSV half-planes for a neighour colour harmony



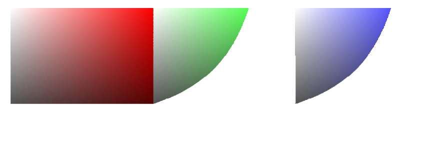
Colour planes for a triadic colour scheme (red, green and blue)



Valid colours after selecting a medium dark (0.5) half saturated (0.5) green



Valid colours after selecting a medium bright (1) half saturated (0.5) green



Valid colours after selecting a medium dark (0) half saturated (0.5) green

Figure 7. HSV half-planes for a triadic colour harmony

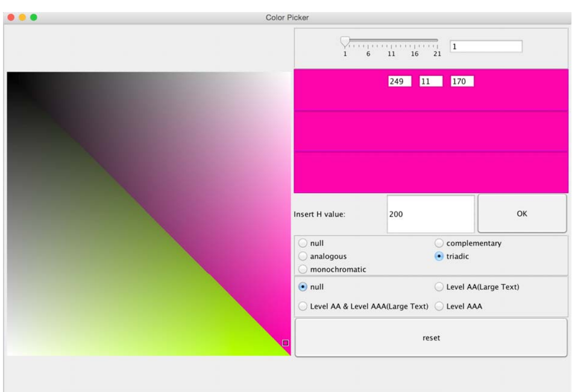


Figure 8. The colour picker tool

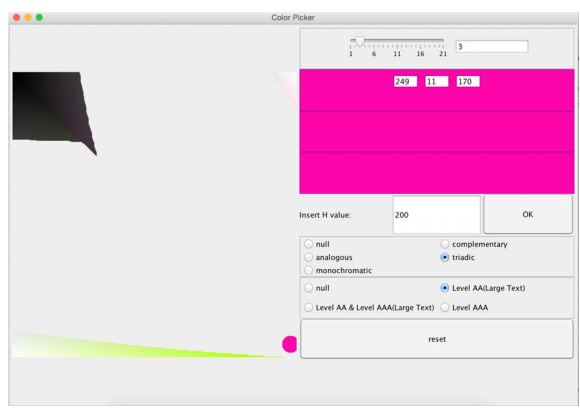


Figure 9. The colour picker tool with one chosen colour and colour space constraints.