Computerised Simulation of Colour-blind and Colour Enhancement assisted Colour-blind

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Abstract: This paper presents the computerised simulation of colour-blindness and proposes a colour enhancement technique to aid colour-blinded people to use Visual Display Units (VDU). With the red-green colour perception difficulties, the ISH model has been used to develop the algorithms. The simulator and colour enhancement have been tested by colour-blind people and compared to existing simulators for colour-blindness.

1. Introduction

This paper proposes a computerised simulation of how sufferers from colour-blindness perceive colours on a VDU. Approximately 5% to 8% of the population have some sort of colour-blindness [1]. The world looks differently to these people because they often find it difficult to separate red and green apart or unable to see the same colours as people who do not suffer from colour blindness. It is sometimes difficult for colour-blinded people to see graphics, images and read web pages because the person who designed them may not realise the problem. With the algorithm described in this paper, you will know what the world looks like if you were colour-blinded. With this knowledge, this paper also intends to present a colour enhancement technique to assist colour-blinded people to use a computer.

2. Method

Normally, RGB (Red-green-Blue) colour cube is used to represent the image colours. However, in this paper, the ISH (Intensity-Saturation-Hue) model has been used instead to understand colour appearance due to saturation and hue, where both are closely related to the way we describe colour perception. For the colour-blind simulation method, firstly, the RGB colour model has been transform into ISH model [2]. The ISH model is represented by a triangular colour plane as in Figure 1, where each of the primary colours (R, G and B) are connected to form a triangle. The hue (H) of a colour at any point is the angle of the vector shown with respect to the red axis. Therefore, the colour will be red when H= 0, yellow when H = 60, and so on.

In order to simulate colour blindness, the saturation value is multiplied to the function curve (R(H)) which runs from 0 to 1 and can be calculated with equation 1. The R(H) curve is shown in Figure 2(A), the horizontal axis of the curve is the original hue (h) value ranging from 0° to 359°. The vertical value is the ratio function which is necessary for the multiplication with the original saturation (S) to form a new set of saturation values (S').

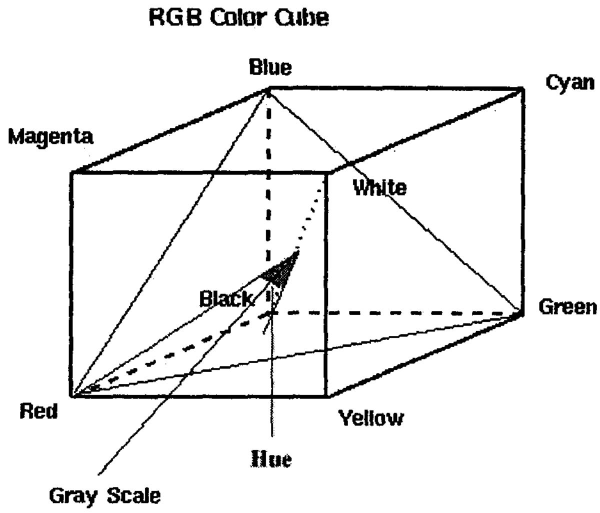

Figure 1: The relationship between RGB model and Hue parameter.

$$R(h) = 1 - Ae^{-\left(\frac{h-x_1}{\sigma}\right)^2} - Be^{-\left(\frac{h-x_2}{\sigma}\right)^2} - Be^{-\left(\frac{360+(h-x_2)}{\sigma}\right)^2} \quad (1)$$

With the assumption that the cyan and red-magenta colours are unsaturated like the grey colour, the following parameters can be set: A = 1.0, B = 0.8, $x_1 = 180$, $x_2 = 330$ and $\sigma^2 = 800$ respectively.

The hue parameter is shifted and reallocated to the new range because this parameter represents the red appearance. In order to shift and reallocate the new range of the hue value, the transformation curve shown in figure 2(B) is used. The defect function curve comes from the assumption that all pixels have the hue value in the range 45 to 240 (yellow to blue). With this assumption, the defect function curve proposed in this paper can be calculated by using the function described by equation 2 and has been shown in figure 2(B).

Equation (2):

$$h = x_1 + (x_2 - x_1)e^{-\left(\frac{h-x_2}{\sigma}\right)^2} + (x_2 - x_1)e^{-\left(\frac{h-x_3}{\sigma}\right)^2}$$

Where $x_1 = 45$, $x_2 = 180$, $x_3 = 325$ and $\sigma^2 = 20$.

The equation above applies when the hue value is less than 180 or greater or equal than 330, otherwise the hue value will be:

$$h = x_0 + \sqrt{(R^2 - (h - y_0)^2)}$$

Where the parameters were calculated by fitting the three points ((180, 180), (240, 240), (360,180)) as part of a circle which has a radius R and centre at the co-ordinate (x_0, y_0) respectively.

Finally, the new range of hue and saturation are applied and combined with the original intensity, then converted back to RGB for display. With the technique described above, the red and green colour will be difficult to separate simulating how a colour-blinded person would see.

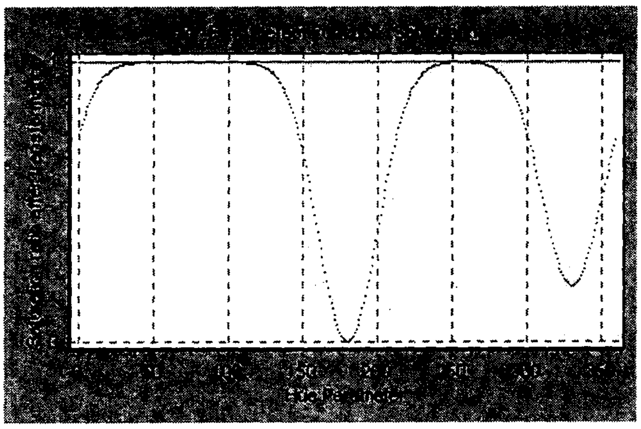

Figure 2(A): Saturation ratio for Colour-blind simulation

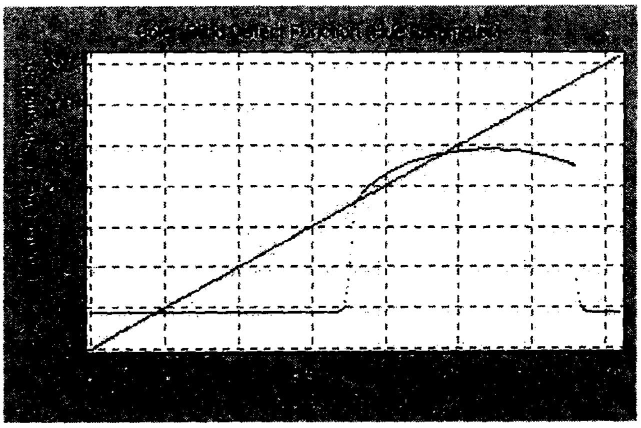

Figure 2(B): Hue transformation function.

Figure 2: Simulation function of Colour-blind on Saturation and Hue parameters

With the assistance of colour enhancement, colour-blinded people can use the same technique but applied to a different curve as shown in Figure 3. Saturation has been increased as the curve in figure 3(A). The horizontal axis of the curve is the original saturation value ranging from 0 to 255. The vertical axis is the saturation value after the transformation with the saturation function curve (green curve). By fitting the three points ((0, 0), (M_x, M_y), (255,255)) as part of circle, the saturation function can be calculated similar to equation 2(B). With this technique, saturation is enhanced to give a higher colour. For the hue parameter, the range of hue is expanded by the transformation curve shown in figure 3(B). The horizontal axis of the curve is the original hue value ranging from 0° to 359°. The vertical axis is the hue value after the transformation with the enhanced function curve (blue curve). The curve proposed in this paper can be calculated by using the third degree polynomial function, described by equation 3, fitting on the four co-ordinates ((0, -100), (180, 180), (300, 300), (360, 400)) as shown in figure 3(B)[3]. For hue values higher than 360 and less than 0, they are rounded to zero and rounded up to 360 respectively.

$$y = a_0x^3 + a_1x^2 + a_2x + a_3 \tag{3}$$

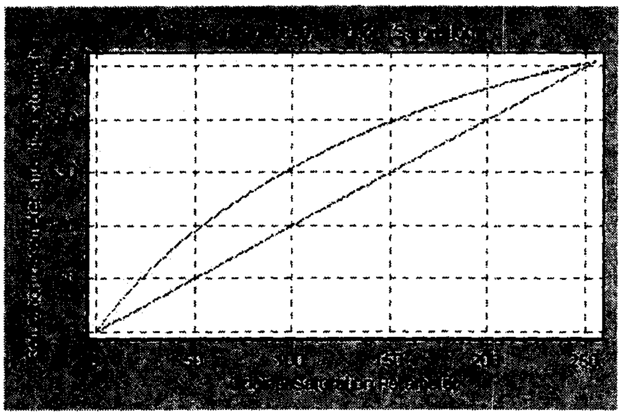

Figure 3(A): Saturation Transformation function.

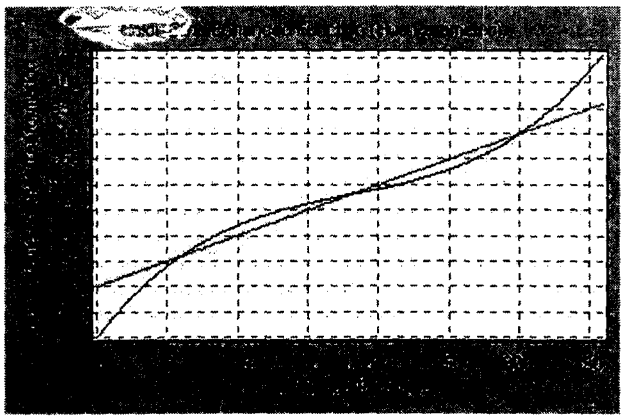

Figure 3(B): Hue transformation function.

Figure 3: Contrast functions assisted Colour-blind on Saturation and Hue parameters

The result from the algorithm has been tested by a normal person, colour-blinded person and compared to the

Vischeck colour blindness simulator (http://www.vischeck.com)[4].

3. Result

The colour-blind simulation was compared against the Ishihara test for colour blindness. The simulation has shown that the numbers on the test patterns disappear in accordance to the colour blinded person. The results are shown in Figure 4. Figure 5 shows the result of the colour enhancement assistance effect on a colour-blinded person. The result was confirmed by a colour-blinded person who did not pass the Ishihara colour-blind test. With the colour enhancement technique, he succeeded in reading the number on each image.

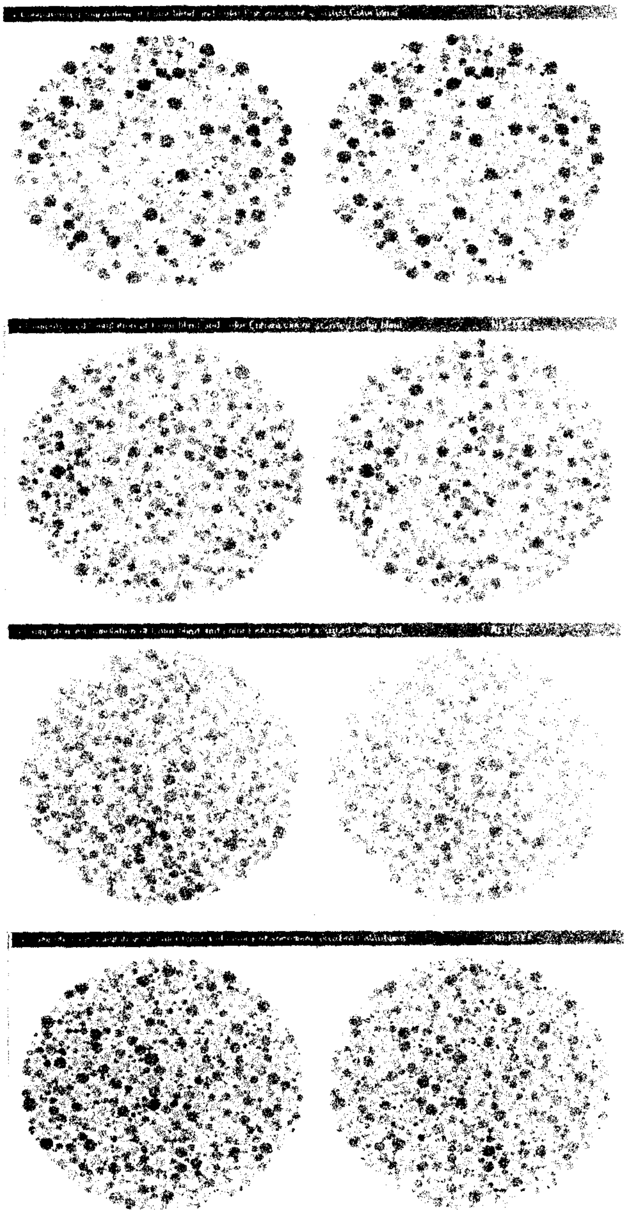

Fig 4: The colour-blind simulation results from the Ishihara test for a colour-blinded person. The left images of each couple are the test pattern (there is a number on each circle), the right images (of each couple) are the simulation images of colour-blinded people (the number on each circle does not seem to be present).

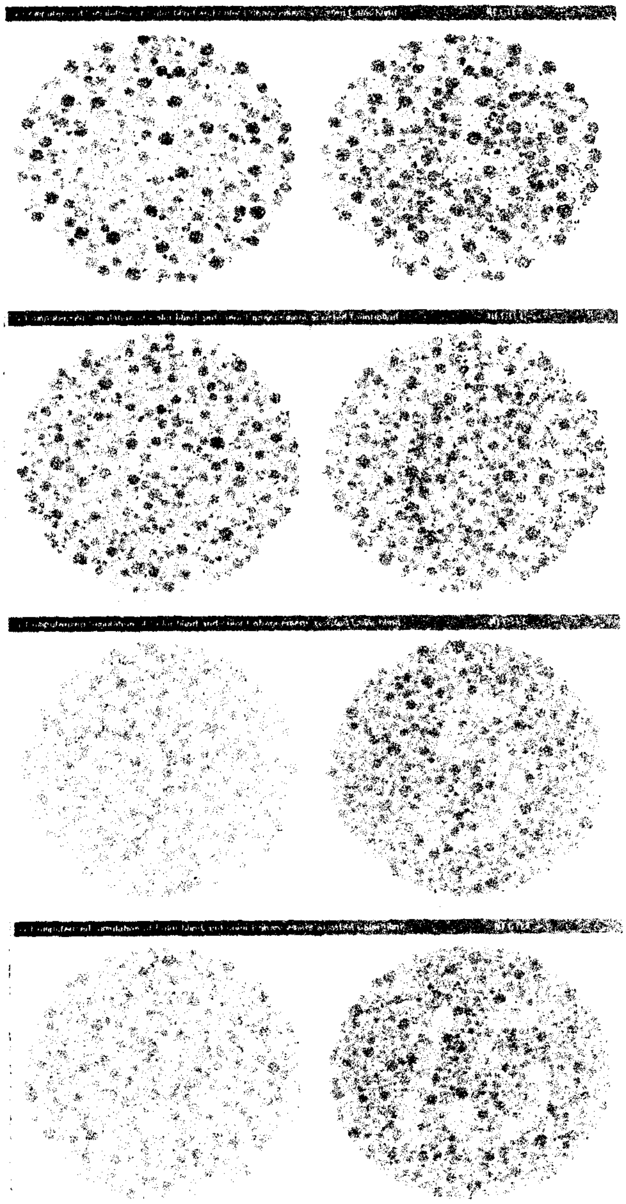

Fig 5: Results from the Ishihara test with the colour enhancement assistance on a colour-blinded person. The left images of each couple are the test patterns (there is a number on each circle but the colour-blinded person can not identify them), the right images (of each couple) are the enhanced images (this time the colour-blind person can identify the number from the background).

In comparison to the Vischeck colour blindness simulator, the Vischeck program can only simulate colour blindness but does not try to solve or assist the vision of a colour-blinded person. The image after enhancement was applied to the Vischeck simulator and the simulation algorithm in this paper, both simulators have been shown that the number can still be recognised.

4. Conclusion

With the techniques described above, the colour-blind simulation and contrast enhancement algorithms were incorporated into a software called E-LENS. E-LENS is an application which can zoom in on the computer monitor for colour-blind simulation and adjust the colour for better enhancement as shown in Figure 6.

References

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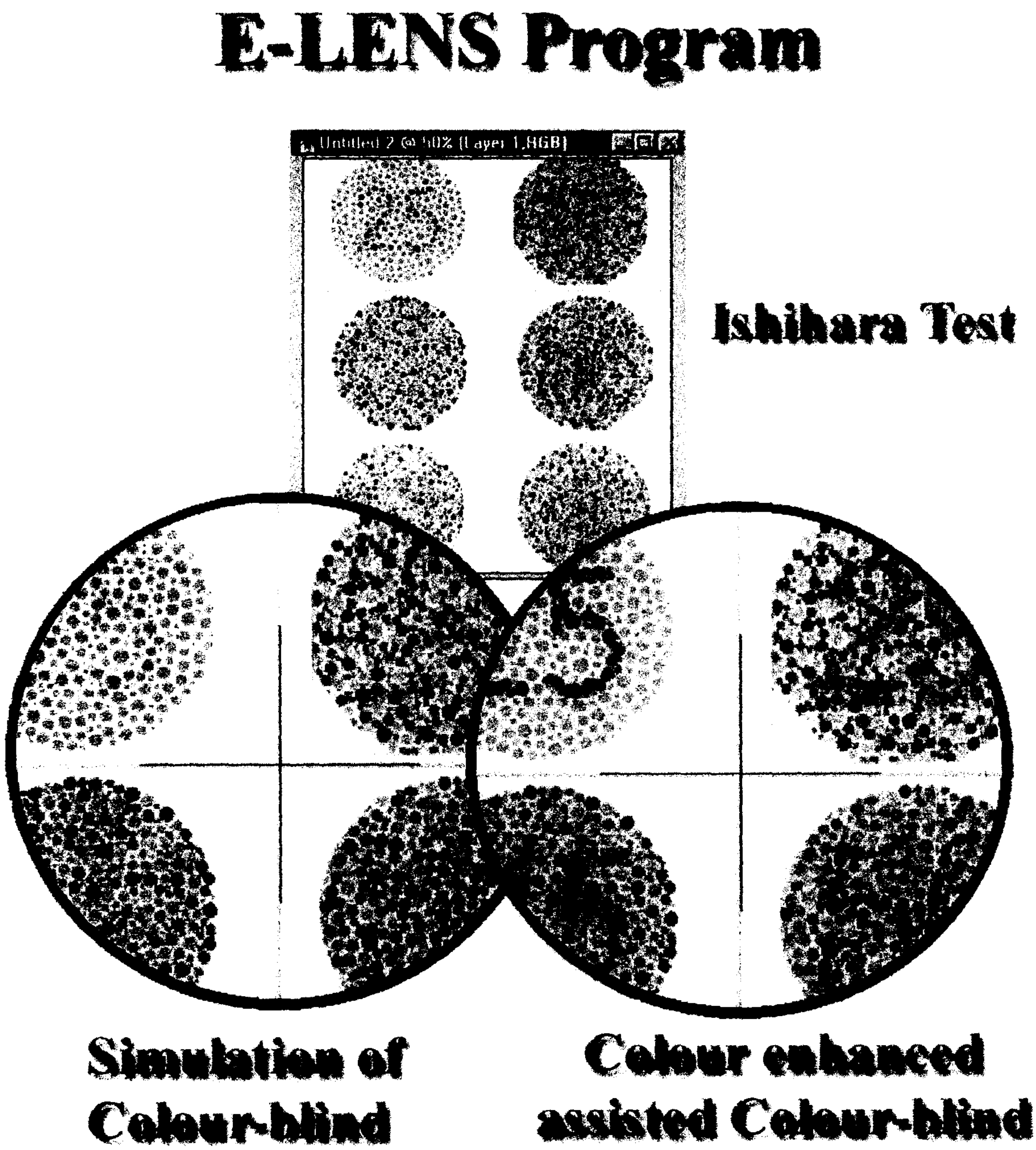

Figure 6: E-LENS Program: - A software application that zooms in on the computer monitor for colour-blind simulation and also adjusts the colour for better enhancement