Is information always informative? Perhaps to you, but is it to the Colour-vision deficient?

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Abstract: - Every day we are surrounded by information which is supplied in many forms and we might be expected to make important decisions from that information. However, it may not be possible for all recipients of the information to make such necessary and informed decisions. In this paper we focus on the difficulties encountered by those who suffer from colour-vision deficiencies. We provide one mechanism of a potential solution to information derived from the frequently used pie-chart which are commonly used by businesses to visually represent (raw) data as information. We use the pie-chart creation tutorial provided by MSDN to highlight how the colour-vision deficient might have difficulties in interpreting information. Our potential solution is an image processing software tool called the HCBEenhanced. HCBEenhanced identifies the actual pie-chart within an image, which we call the Region of Concern (ROC) and any legend provided within the image. HCBEenhanced then inserts a halo around each segment of the pie-chart, which we call the halo-effect of segments. This new pie-chart is then provided as an output file to the user. We demonstrate that those suffering from colour-vision deficiencies, by use of HCBEenhanced, can have significant improvements in the ability to interpret the information that was intended from the original pie-chart.

Key-Words: - **Colour-vision deficient, colourblind, information, data, image, image processing, pie-chart, Microsoft Developer Network (MSDN)**

1 Introduction

Today we are bombarded with information, where information is the meaning that has been applied to data. Data are gathered facts and/or statistics which are collated for analysis and/or for reference. For example, pie-charts and other images are commonly used to show information from gathered (raw) data in a meaningful and graphical manner. But do pie-charts, as images, actually achieve what their creators intended? This is an interesting question and it poses many dilemmas. As authors of this paper we deliberately use the term dilemma as the informative information that pie-charts, as images, are intended to provide may result in a position where difficult choices have to be made and those choices may be desirable or even undesirable.

We consider that it is the pie-charts creators' responsibility to convey the information in a meaningful manner such that those difficult choices that may be made are correct and true [1]. However, if you were colour-vision deficient do you consider that the dilemmas we have highlighted would be exacerbated? Do you think if you were colour-vision deficient you would be in a position to make accurate and true decisions from the intended information provided by a typical pie-chart? Would you be able to process the pie-chart image in the way that the creator intended? Just think, if you did not appreciate that the information you were deriving was not what was intended, you could make severe undesirable choices.

Approximately 1 in 12 males are colourblind and very few females (approximately 1 in 250) are also colourblind. What difficulties do you think they might encounter when interpreting information from pie-charts? Consider, a small business is considered to consist of less than 100 employees and a medium size business is considered to consist of between 100 and 999 employees. Potentially, that means a small business could employ up to approximately 8 male colourblind males, and a medium size business could employ up to 80 colourblind male employees and up to 4 female colourblind employees.

In the remainder of this paper we intend to demonstrate some of the problems that information from typical business pie-charts may cause the

colour-vision deficient in the production of informative decisions. We also propose to demonstrate an image processing software tool which we are developing that may aid the colour-vision deficient to make informative decisions from such business pie-charts. We call our image processing software tool The Hertfordshire colourblind Emulator enhanced (HCBEenhanced), which is an enhanced version of the previously published Hertfordshire colourblind Emulator (HCBE) [2, 3]. We also call our method "the halo-effect of segments". The reason behind our name will be discussed later.

2 Colour-vision deficiency

Although in this paper we are using the terms colour-vision deficient and colourblind interchangeably, the term colour-vision deficient is more accurate. Colourblindness is the total inability to see any colour and colour-vision deficiency is the difficulty or more accurately the inability to distinguish between certain colours [3, 4, 5, 6 and 7].

Colour-vision deficiencies can be manifested in a number of ways including:

- finding it difficult to detect the differences between the colours including reds, oranges, yellows, browns and greens;
- finding it difficult to detect the differences between the colours including blues, greens, and yellows;
- have a difficulty in observing different shades of colours, in particular purple;
- observing colours in a manner which is much duller than they really are;
- mixing reds with blacks or blacks with reds.

There is a number of different types of colour-vision deficiencies and only one of those types can truly be considered as colourblind. In this study we investigate the difficulty encountered by the following colour-vision deficient types: Protanopia, Deuteranopia, Tritanopia and Monochromacy. In our previously work we have investigated the impact of colourblindness in online education of Higher Education [2]. For clarity of this work we provide a short summary of these types of colour-vision deficiencies.

2.1 Protanopia

Protanopia is classified as a two colour phase deficiency (a dichromic defect) and is manifested as red-green colour-vision deficiency, which is caused by a complete lack of retinal photoreceptor cells.

2.2 Deuteranopia

Deuteranopia is similar to protoanopia, in that reds and greens are almost indistinguishable. However, the cause of the condition is different, in that it is the green receptors in the eye that are missing. In the majority of cases the effect very similar to protanopia. Although the contrast between blue and purple seems to be affected to a greater degree by deuteranopia.

2.3 Tritanopia

Tritanopia is manifested with a blue-yellow variation due to the lack of blue photoreceptors. It is not present as frequently as protanopia and deuteranopia.

2.4 Monochromacy

Monochromacy is the complete loss of colour, where colours are visible as shades of grey and is therefore in the accurate sense colourblind. Monochromacy is caused by either defected cones or absence of cones.

3 Microsoft® Pie-Chart Tutorial

To demonstrate the problems the colour-vision deficient may encounter on a daily basis we have chosen to use one of the Microsoft Developer Network (MSDN) Tutorials [8]. The tutorial is provided to teach users how to create informative pie-charts in the Microsoft® Office Suite. The tutorial does not consider the problems that the colour-vision deficient encounter. Hence those who use this tutorial to learn from may quite easily fall into the trap of creating subsequent pie-charts that can be difficult to gain the correct intended meaning from. The tutorial shows users how to create a number of pie-charts of varying complexity, most of which are shown in figs. 1, 2, 3, 4, 5, 6, and 7.

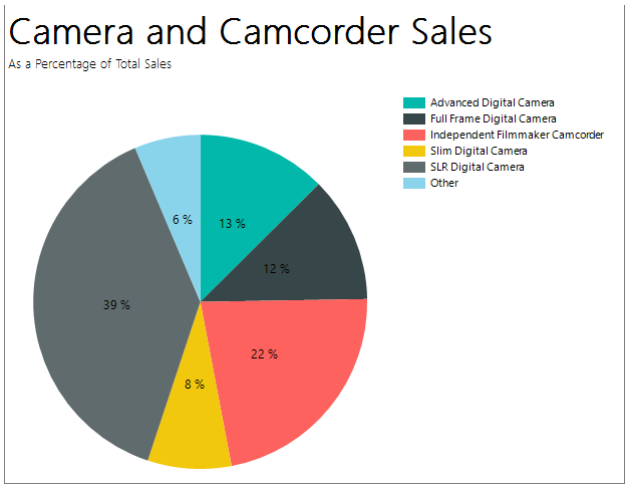

Fig. 1, MSDN pie-chart example 1

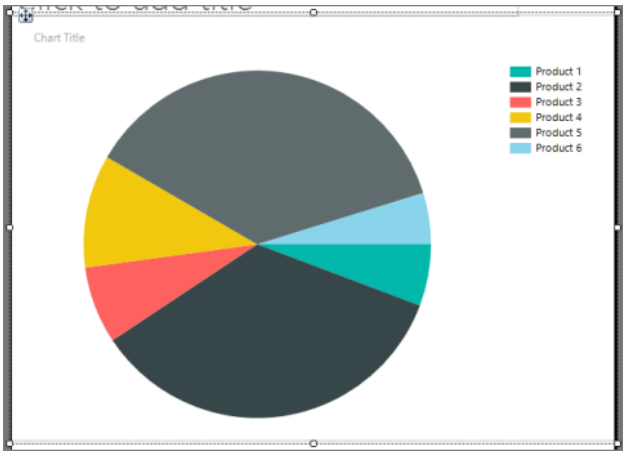

Fig. 2, MSDN pie-chart example 2

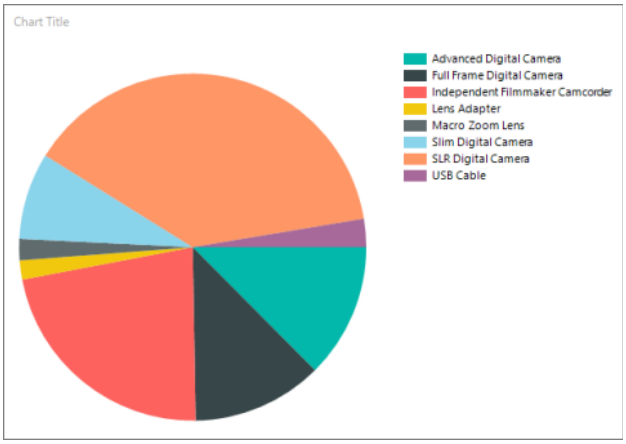

Fig. 3, MSDN pie-chart example 3

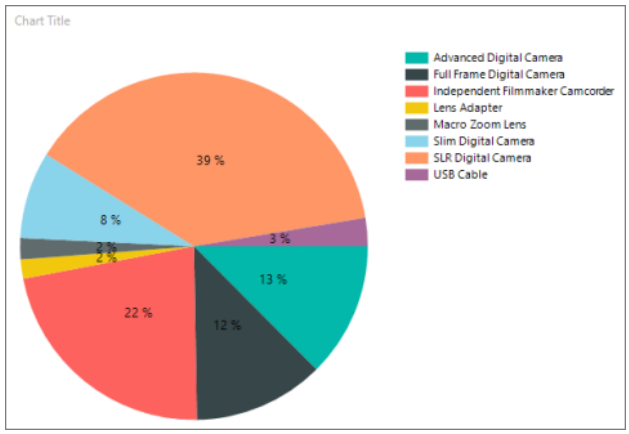

Fig. 4, MSDN pie-chart example 4

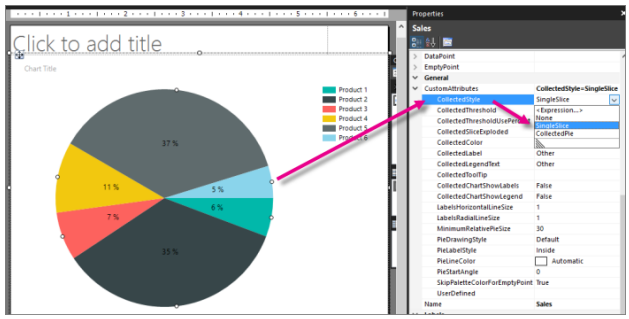

Fig. 5, MSDN pie-chart example 5

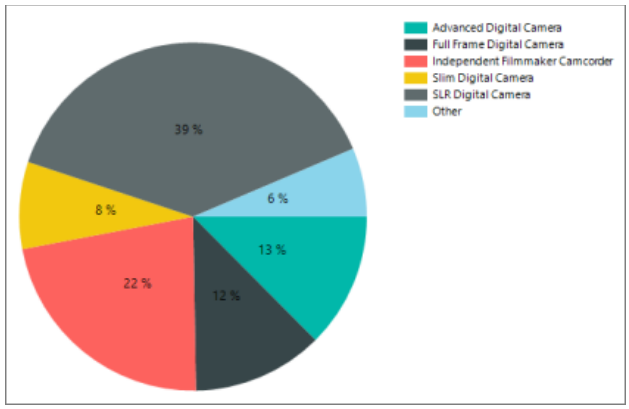

Fig. 6, MSDN pie-chart example 6

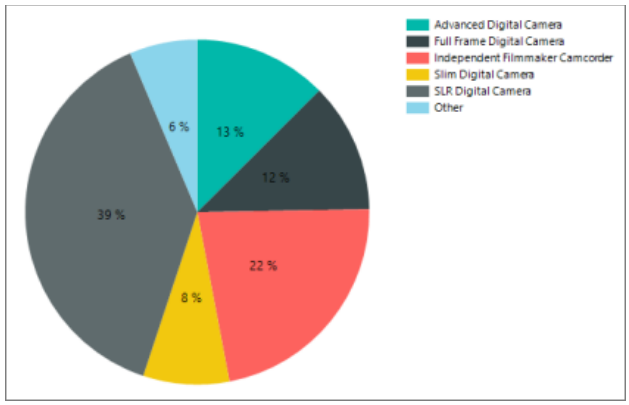

Fig. 7, MSDN pie-chart example 7

3 The Hertfordshire Colourblind Emulator (HCBE)

The Hertfordshire Colourblind Emulator (HCBE) [2 and 3] generates images as they would be seen by the colour-vision deficient. Currently, HCBE relies on the images creators' to make the decision whether the original image conveys the information to the colour-vision deficient as intended or not. In the case that the information is not conveyed as intended then it is the creators' responsibility to make necessary changes to the image such that the information is conveyed as intended [ref equality act]. This could be, for example, by simply changing colour schemes.

HCBE is a software tool that, as input, takes in an image in a number of formats and one of four types of colourblindness selected (protanopia, deuteranopia, tritanopia or monochromacy). That image is then processed pixel by pixel such that if the type of colourblindness is detected then the colour of the pixel undergoing processing is altered to that seen by the selected colour-vision deficiency. Once the input image has completely been processed a new processed image is then output to the user as a Joint Photographic Experts Group (jpeg) file [9].

In subsequent sections of this paper we show enhancements we have been making to HCBE (currently called HCBEenhanced) output .jpeg images that potentially may convey to the colour-vision deficient the meaning that the images' creators originally intended.

3.1 HCBE and the Microsoft® Pie-Chart Tutorial

We have input each of the MSDN pie-chart tutorial's images into HCBE for each of the four types of colourblindness, resulting in 28 altered .jpegs highlighting how the colour-vision deficient would view the pie-charts. In this paper, we only present the output images associated with Deuteranopia (figs. 8, 9, 10, 11, 12, 13, and 14) but we will discuss all of our 28 output files.

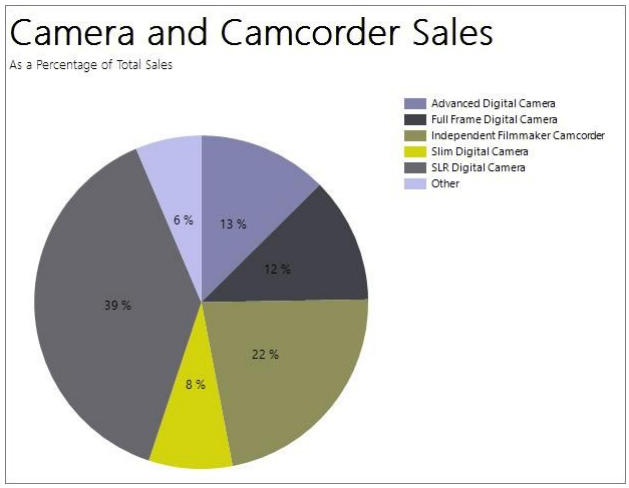

Fig. 8, Deuteranomaly MSDN pie-chart example 1

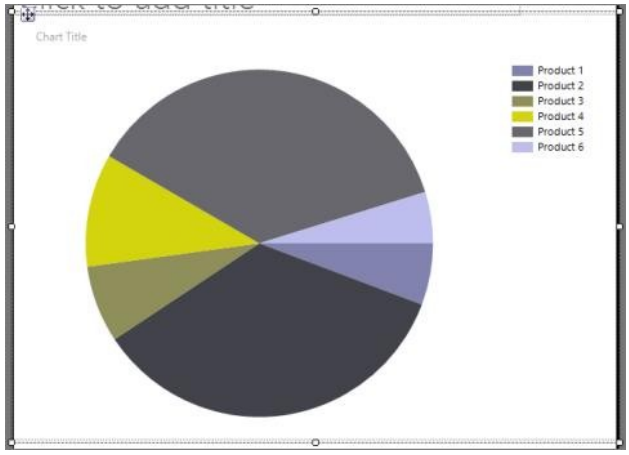

Fig. 9, Deuteranomaly MSDN pie-chart example 2

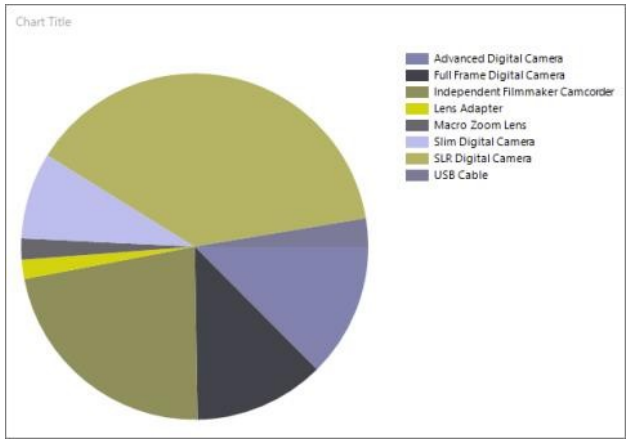

Fig. 10, Deuteranomaly MSDN pie-chart example 3

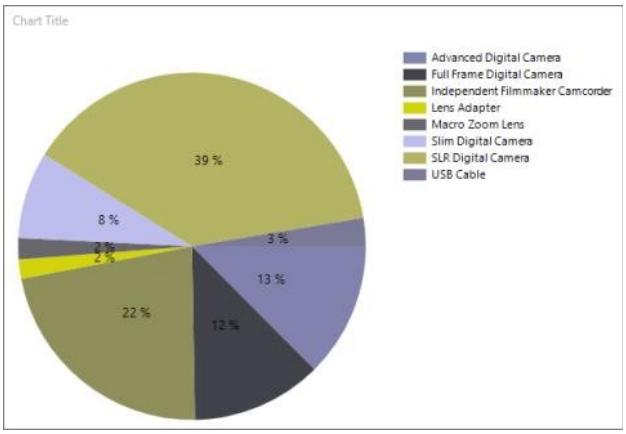

Fig. 11, Deuteranomaly MSDN pie-chart example 4

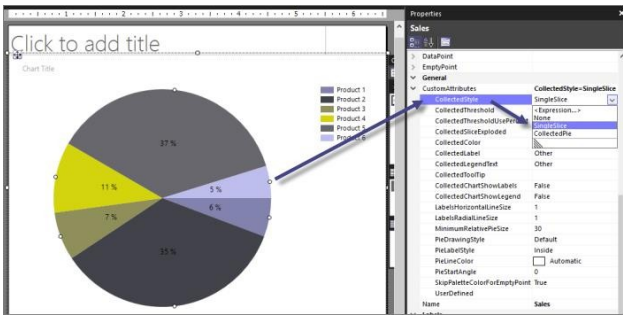

Fig. 12, Deuteranomaly MSDN pie-chart example 5

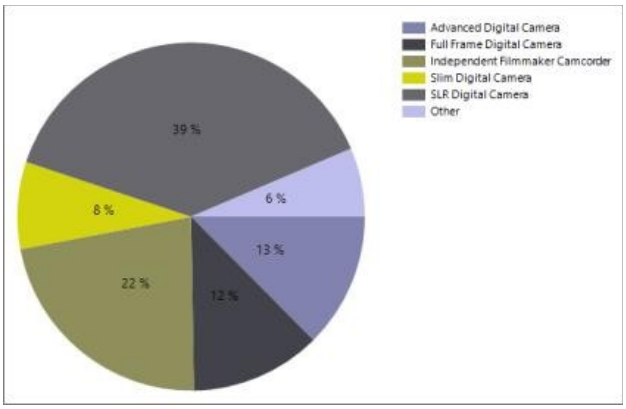

Fig. 13, Deuteranomaly MSDN pie-chart example 6

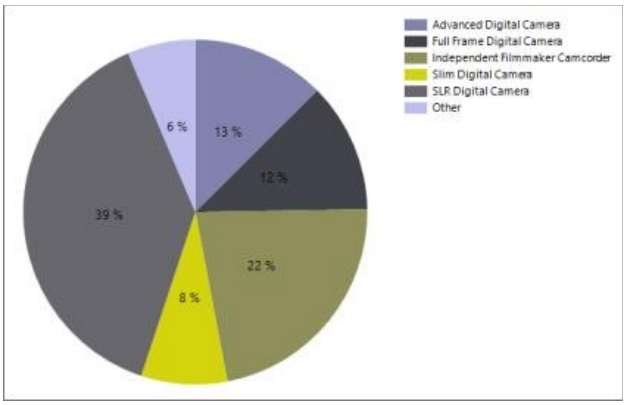

Fig. 14, Deuteranomaly MSDN pie-chart example 7

Comparing fig 1 with fig 8, fig 2 with fig 9, fig 3 with fig 10 and so on to fig 7 with fig 14 demonstrates the problem that those suffering from Deuteranopia suffer. Even though the segments of each pie-chart are visible they are not clearly visible rendering it potentially difficult to comprehend the MSDN tutorial. Our findings were mirrored with the other types of colourblindness that we investigated: Protanopia, Tritanopia and Monochromacy. Even though we do not show the images, the same problems are exhibited in all of the four types of colour-vision deficiencies, in particular (and as expected) those with total colour deficiency (Monochromacy).

4 The Hertfordshire Colourblind Emulator enhanced

Similarly to HCBE the enhanced version is an image processing software tool that, as input, takes in an image in the same number of formats as HCBE and one of the same number of types of colourblindness can be selected for processing.

However, this time the inputted image is first processed to identify the Region Of Concern (ROC). Where we define the ROC to be the areas within an image that will cause those suffering from colour deficiencies would have difficulties in interpreting the information as intended. In these examples the circle within the pie-chart. Once the ROC is identified, HCBEenhanced then processes the image within the ROC and a halo is placed around each segment within the pie-chart. We call this method the halo-effect. We also identify any region where a legend may be provided so that HCBEenhanced also renders the legend in a manner by which the colour-vision deficient can interpret the information as intended.

The halos clearly define the boundaries between the segments of the pie-chart which should render the pie-chart in such a way that those suffering from colour deficiencies can interpret the information as was originally intended. This is shown to the user by an output image post processing.

4.1 HCBEehanced and the Microsoft® Pie-Chart Tutorial

For consistency of comparison figs 15 to 21 show the addition of halo-effect around the segments of the MSDN pie-chart tutorial. As before we show the results of the colour-vision deficient who suffer from Deuteranopia, even though we investigated all types of colourblindness.

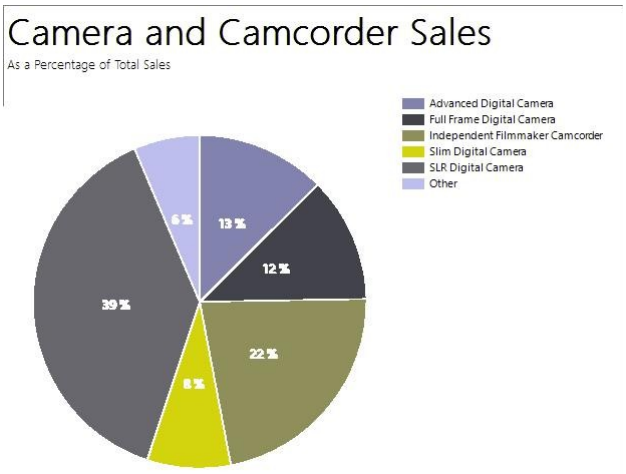

Fig. 15, Deuteranomaly with the halo-effect MSDN pie-chart example 1

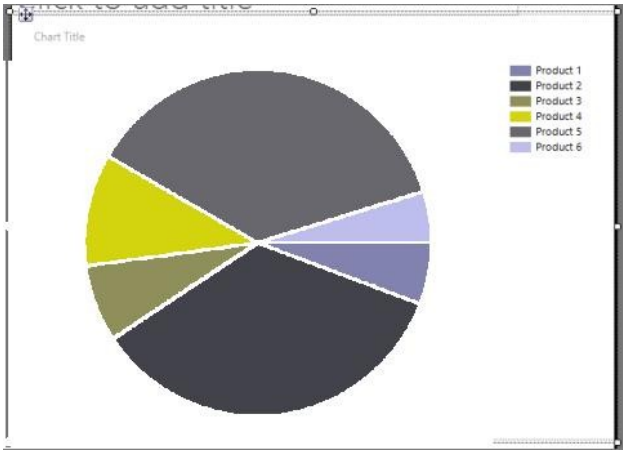

Fig. 16, Deuteranomaly with the halo-effect MSDN pie-chart example 2

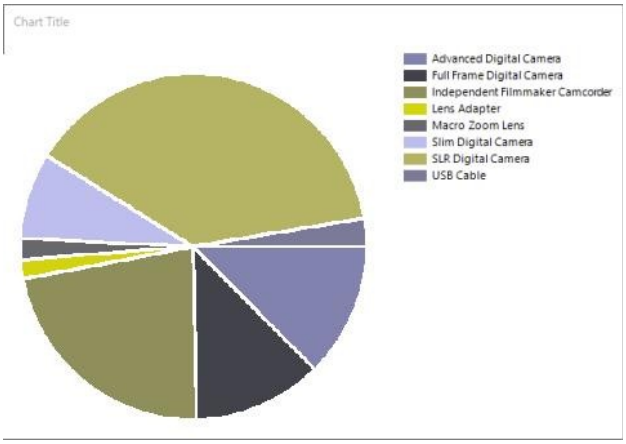

Fig. 17, Deuteranomaly with the halo-effect MSDN pie-chart example 3

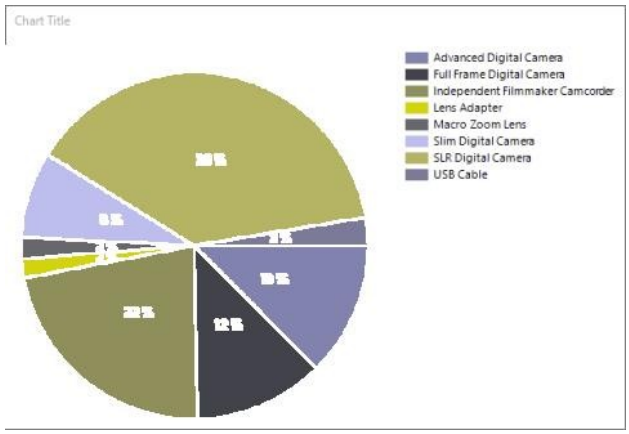

Fig. 18, Deuteranomaly with the halo-effect MSDN pie-chart example 4

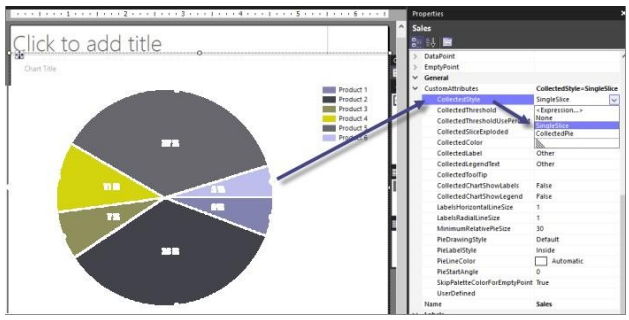

Fig. 19, Deuteranomaly with the halo-effect MSDN pie-chart example 5

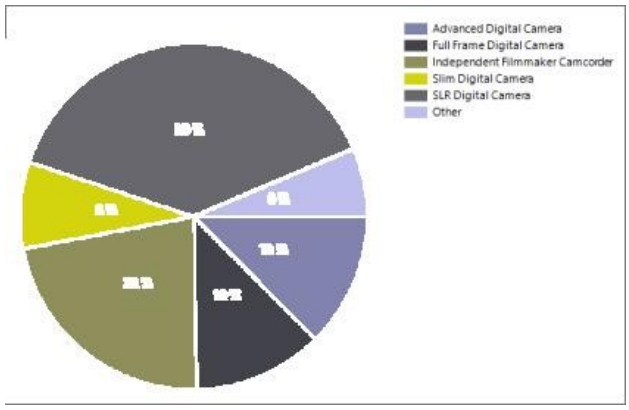

Fig. 20, Deuteranomaly with the halo-effect MSDN pie-chart example 6

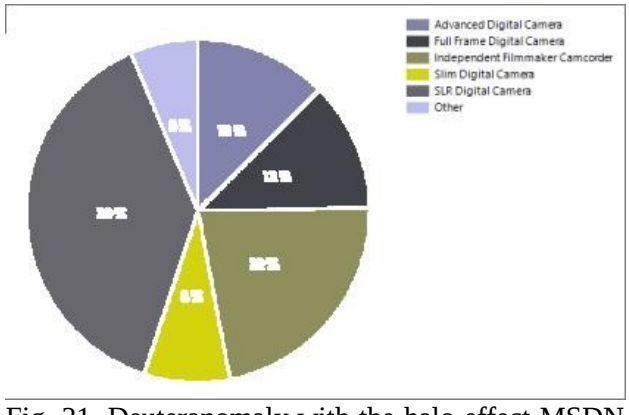

Fig. 21, Deuteranomaly with the halo-effect MSDN

pie-chart example 7

By doing a similar comparisons as before, comparing fig 1 with fig 8 and fig 15, fig 2 with fig 9 and fig 16, fig 3 with fig 10 and fig 17and so on to fig 7 with fig 14 and 21 demonstrates the problem that those suffering from Deuteranopia suffer. However, with the halo-effect we now show that the colour-vision deficient can interpret the original information as intended.

As before, our findings were mirrored with the other types of colourblindness that we investigated: Protanopia, Tritanopia and Monochromacy.

Note that the percentage values shown in some segments of the images are altered to white. This is because we have also surrounded these percentage values with the halo-effect. This means that any problems the colour-vision deficient would have reading the percentage values in the original image are now made visible to the user. Unfortunately, due to size of the images in this paper the percentage values are not clearly shown. However, in the actual output images the percentage values can clearly be identified by the user.

5 Conclusion

In this study we sought to demonstrate how information, as intended, is not always informative in particular for those who suffer from colour-vision deficiency. To highlight this hypothesis we chose to use pie-charts as they are a commonly used visual mechanism to show descriptive or qualitative information. We also chose the MSDN pie-chart tutorial as a publicly available means to show how to provide information in a meaningful and visual manner. However, we also showed that this may not always be as easy at it may seem in particular to those who suffer from colour-vision deficiencies.

We have also shown that by altering the original image then the information as intended can be provided to those suffering colour-vision deficiencies. In this paper, we only show a subset of our results for those suffering from Deuteranopia. Our full set of results mirror what we have shown for Deuteranopia with the three other major types of colourblindness: Protanopia, Tritanopia and Monochromacy.

Our conclusion, therefore, is that by making minor changes to the way information is presented then informative information can be obtained as intended to include those who suffer from the colour-vision deficiencies.

We have introduced the HCBEenhanced as an image processing software tool to achieve this. We consider that it would be better for tutorials such as the MSDN tutorial to consider those who suffer from colour-vision deficiencies, which would mean image processing software tools such as HCBEenhanced would be rendered redundant. Research into this area is also important not only to highlight such problems, but to encourage pie-chart creators to be aware of all different types of users who may view their visual representations. However, until this happens image processing software tools such as HCBEenhanced will be required.

HCBEenhanced is in its infancy in the way to provide potential solutions to the problems of showing how information should be conveyed in pie-charts. Currently, the user would have to have a copy of HCBEenhanced on one of their (non-mobile) desk-top computer systems. The user would then have to obtain an e-copy of the pie-chart in question and input it into HCBEenhanced before viewing the output image. We are already developing a version of HCBEenhanced for use on mobile computer systems such as smart-phones and tablet PCs.

Our research is on-going and we have recently undertaken a survey on colour-vision problems that both the colour-vision deficient suffer and the non-colour-vision deficient suffer. It is too early to release the finding of this study but it will enable us to develop software to enhance the opportunity to interpret information provided in other colour information formats such as the popular ‘traffic light system’ [10]. We propose to continue our work with international collaboration with Saudi Arabia and with individual subjects in the UK.

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