Visualising the Munsell Colour Space

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ABSTRACT

Historically important and still in widespread practical use, the Munsell Colour System is usually presented in the form of two-dimensional pages in a book or leaves within a three-dimensional tree. The physical Munsell Tree presents part of the overall colour space but is unable to faithfully reproduce the intended appearance due to shadows, reflection and non-uniform illumination. This paper describes the implementation of an on-screen 3D representation of the Munsell Colour System which seeks to address some of these limitations for the purpose of colour education.

1. INTRODUCTION

The Munsell Colour System was developed by the artist and teacher Albert Munsell as a logical means of representing colour with the express goal of applying it to colour education. Pre-dating CIE colorimetry, his notation system[1] is the oldest to be continuously available in physical form. Even after a hundred years, it is still widely used by artists and designers for colour selection and colour communication tasks. Not only has Munsell's system been the subject of considerably more research publications than any other colour system, it is also of historical importance because his was the first systematic and consistent illustration of a three-dimensional colour space[2]. Initially, this was realised as a sphere however Munsell had conceived the notion of a "colour tree" comprised of vertical constant-hue leaves as early as 1902.

The Munsell Tree is undoubtedly a very useful means of visualising the colour space formed by the system's Hue, Value and Chroma attributes. In common with other physical specifiers, however, it suffers from a number of practical shortcomings. These include fragility (colours fade, become dirty or damaged through everyday use) and the inevitable compromise between the limited number of available colour patches versus the necessary expense of reproducing them to within a close tolerance[3]. The Tree also has limited portability and is comprised of even fewer colour patches than the Munsell Book of Color. Furthermore, its 3D nature introduces a number of undesirable visual artefacts that detract from the intended appearance, namely: size difference due to perspective, simultaneous colour contrast caused by overlapping colours, and non-uniform illumination which creates shadows and typically makes colours at the top appear lighter than they should. In this paper, a solution to these problems is proposed through the implementation of an interactive computer-based Munsell Tree.

2. METHOD

There have been a number of software implementations of the Munsell system, using both two[3,4] and three[5,6] dimensions, however the latter have concentrated on reproducing the Munsell solid. This solid, which is illustrated in Figure 4, depicts the most chromatic colours that are reproducible on a given medium. Unfortunately, this is of limited use in understanding the Munsell colour space because it is not possible to see the less chromatic colours that lie beneath the surface. The physical tree addresses this limitation by displaying vertical leaves taken from the ten principal hues (5R, 5YR, 5Y, 5GY, 5G, 5BG, 5B, 5PB, 5P and 5RP). Each leaf is comprised of coloured chips taken from a plane of constant hue and mounted on a transparent backing. This arrangement works well in practice and allows the user to see through the space. Due to physical constrains, however, the tree only covers 10 different Munsell Values and critically lacks a central neutral axis.

A key goal of this work was to maximise accessibility. To aid portability and performance, the programming environment used the OpenGL library[7] for graphic rendering. This is a crossplatform, efficient application programming interface used for developing interactive 2D and 3D software. OpenGL provides elaborate control over illumination (both ambient and multiple point sources) and material properties which include texture, shininess and the control of specular and diffuse reflection. While these features can lead to highly photo-realistic images, they were deliberately turned off to eliminate the effects of shadows and non-uniform illumination mentioned previously. Instead, each colour patch was made to "emit" light of the desired Munsell colour.

In 1943, the Munsell Renotation System colorimetrically defined the aim points[8]. This data is currently available for download from the MCSL web site[9]. The data was supplemented with neutral colours which were calculated via the Judd polynomial[3]. Based on this combined data, each of the displayed colours is pre-computed as follows:-

1. For each Hue, Value and Chroma aim point, find the corresponding CIE xyY value.
2. From xyY determine XYZ.
3. Transform XYZ from C/2° to D65/2° using a chromatic adaptation transform.
4. Calculate sRGB coordinates paying attention to any out of gamut colours.

The sRGB colour space[10] was used because many display manufacturers have now adopted this as the default configuration for their devices. (Where this is not the case, further recalibration or a more advanced characterisation model can easily be applied.) Step 3 is necessary because the white points of the Munsell System and sRGB differ. In this implementation, the Bradford chromatic adaptation transform[11] was chosen. Chromatic adaptation operated on the assumption that patches are colour-constant; this cannot necessarily be assumed for physical embodiments of the system. In the final step, any colours falling out of sRGB gamut are discarded. In total, 45% of the aim points could not be displayed (as illustrated in Figure 1); however this is partly due to the fact that the database includes data obtained by extrapolation beyond the original renotation scaling experiment colours. It should also be noted that the physical atlas is similarly constrained. A conscious decision was taken not to perform gamut compression on the data in order to preserve as closely as possible the overall appearance of the Munsell System.

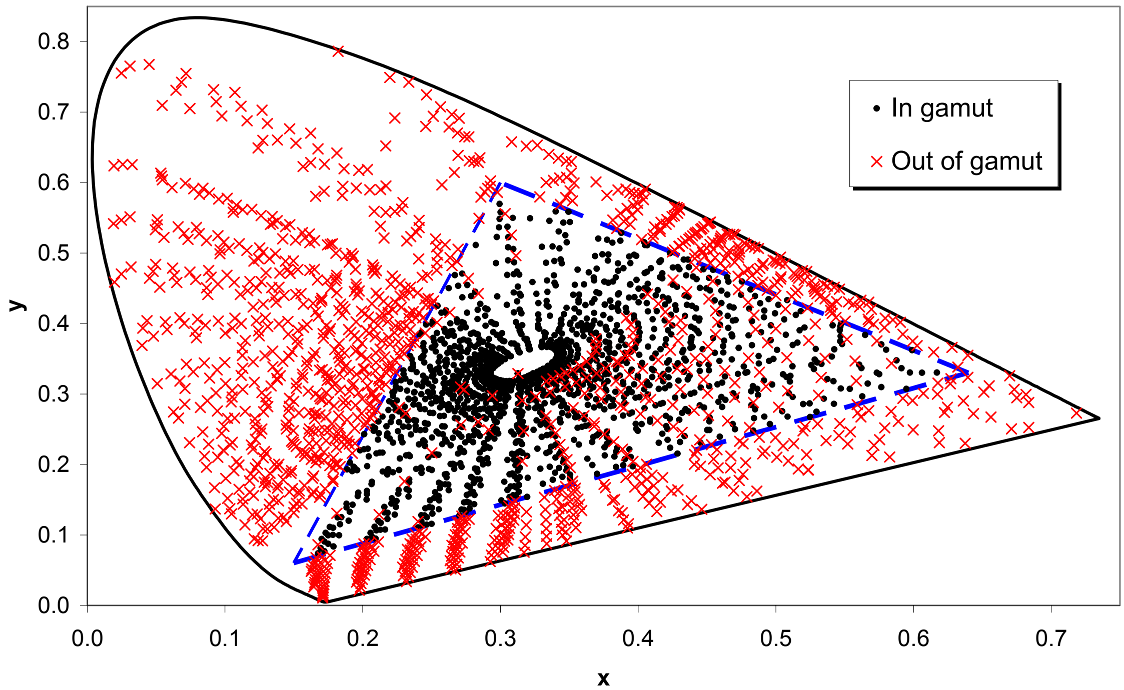

Figure 1: Renotation system colours plotted on a CIE 1931 chromaticity diagram (dashed triangle delimits the sRGB gamut)

3. RESULTS

A simple geometric model of the tree was implemented using OpenGL primitives. These mimicked the layout of the colour patches that constitute the physical tree without the need for a transparent backing supporting each hue leaf. Experimentation revealed that the number of hue leaves could be doubled to include 20 angles (i.e. 5R, 10R, 5YR, 10YR, etc) without significantly cluttering the display; however it was decided to also provide an alternate 10-hue view for backwards compatibility. A central neutral axis was constructed from vertically stacked cylinders at eleven equal-Value steps. The physical tree does not have a neutral axis nor as many Value steps. Through mouse control, this computer model can either be interactively turned in real time about its centre or set to continually spin. Moving the mouse horizontally controls yaw whilst vertical motion affects pitch. An example of the virtual tree can be seen in Figure 2 next to the "real" tree for comparison in Figure 3.

Two further views were subsequently added to this software to extend the visualisation: the Munsell colour solid (Figure 4) and a colour gamut view (Figure 4). These are both limited to depicting only those colours situated on the edge of sRGB gamut. The solid is comprised of cylindrical wedges which, to improve clarity, have black outlines drawn (this can be turned off). The gamut view is made up of a triangular mesh. Since the surface of each triangle is smoothly interpolated between each vertex (an OpenGL feature), this has a more regular appearance than the solid. By overlaying a black wireframe mesh representing the limits of the renotation data, this presents a much clearer illustration of sRGB gamut than the projection previously given in Figure 1. As before, both these views can be manipulated using the mouse.

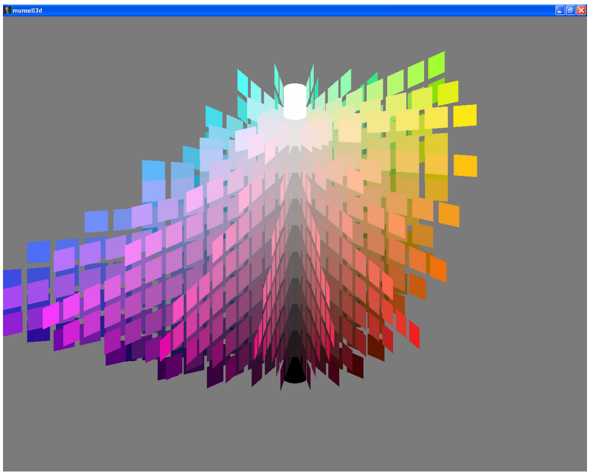

Figure 2: A virtual Munsell Tree

Figure 3: The physical Munsell Tree

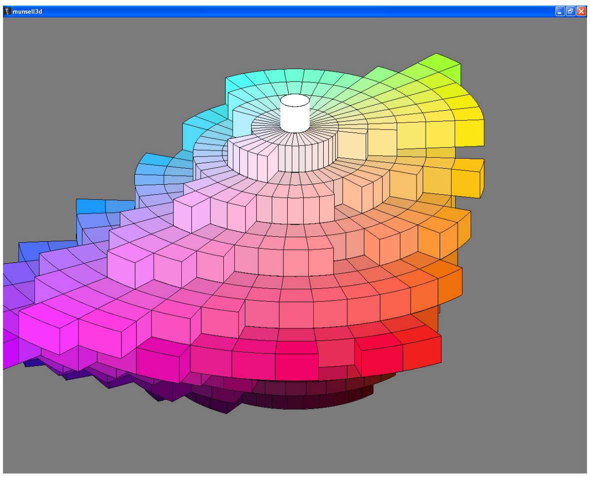

Figure 4: The Munsell colour solid

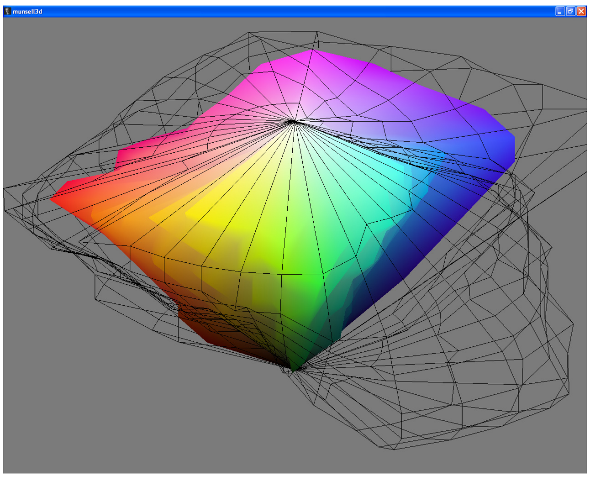

Figure 5: sRGB gamut in Munsell space

Very recent work by Wu and Takatsuka[6] has also endeavoured to represent the Munsell colour space in three dimensions for the purpose of colour selection. Their aim point data was obtained from GretagMacbeth. Unfortunately, the calculation of corresponding RGB values was not described. In particular, neither the white point nor the particular RGB space used were defined. Furthermore, they chose to display out of gamut colours using an approximation which could easily give rise to misleading results. In their implementation, a 2D colour selection palette was formed from cross-sections through the 3D Munsell solid. Unlike the 2D Munsell atlas, this section need not be made vertically through the Value axis. While Munsell scales are individually approximately perceptually uniform, their combined colour space is not globally uniform. This means that an arbitrary cross-section will have inconsistent uniformity. A further complication is that colours are presented adjacently without gaps. This is quite different from the conventional Munsell atlas which has a white background (important for adaptation) and gaps between patches (to avoid edge contrast effects). While this leads to a rather novel visualisation, it can be argued that for the task of colour selection it is more important to preserve the original system's appearance if colour notation is to be compared or communicated.

4. CONCLUSIONS

This paper has described the implementation of a software-based system for visualising the Munsell colour space. The system strives to overcome the limitations of the physical colour tree. Provided that the display calibration is maintained, this version is exempt from the problem of sample fragility. Furthermore, for laptop computers at least, it is physically portable. Although gamut constraints do limit the range of colours that can be depicted, this is also true of the real tree. At this stage, the issues of colour contrast and perspective have not been addressed. It can be argued that these are less important for visualising the space but are critical to the somewhat different task of choosing colours. This software is being used by the author for colour education and is currently being further extended to combine the tasks of visualisation and selection.

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