FIELD TRIALS OF THE CIECAM02 COLOR APPEARANCE MODEL

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ABSTRACT

This is a report on field trials conducted using the CIECAM02 color appearance model. This model was developed by CIE TC 8-01 and consists of a number of refinements and simplifications of the CIECAM97s color appearance model. The model has been developed specifically for color management applications. The model is tested using the OSA Uniform Color Scales and the Natural Color System. In addition the model is evaluated using prints made using CIECAM02 as a device and viewing-condition independent color space.

Keywords: Color appearance model, CIELAB, CIECAM02, gamut mapping

1. INTRODUCTION

The CIE Technical Committee 8-01, color appearance models for color management applications, has recently proposed[1] a single set of revisions to the CIECAM97s[2,3] color appearance model. A linear chromatic adaptation transform was selected and a new formula was derived for the D factor or incomplete adaptation factor. The post-adaptation non-linear response compression has been slightly revised but is still a hyperbolic function. Many of the perceptual attribute correlates have also been revised, such as changes to the lightness scale so that a zero luminance input corresponds to a zero lightness value regardless of the viewing condition. Additional changes include modifying the chroma scale for near neutrals and a more compact equation for saturation.[4,5]

Color management, or software and hardware for the automated processing and exchange of color information between digital imaging systems and devices, has made use of the CIE color spaces for more than a decade.[6,7] CIELAB is one aspect of the profile connection space or PCS used by the ICC or International Color Consortium.[8] One of the original intentions for CIECAM97s was that it would be used for color management applications.[9]

CIELAB and CIELUV both attempt to provide a more perceptually uniform color space based on CIE colorimetry.[10] Both include a chromatic adaptation transform and a limited number of perceptual attribute correlates. However, the performance of the chromatic adaptation transform for both is sub optimal, with the subtractive transform of CIELUV being particularly problematic.[11] Furthermore, CIELAB has a significant lack of hue constancy for the blues, although this problem is possibly not an inherent limitation of the CIELAB equations.[12]

CIECAM97s and CIECAM02 also provide a large number of features and functionality that simply does not exist for CIELAB and CIELUV, such as a more comprehensive description of the viewing conditions and additional attribute correlates. For example, CIECAM02 models surround and background effects and provides perceptual correlates for brightness, colorfulness, and saturation. CIECAM02 also can predict certain luminance-dependent effects and incomplete adaptation.

2. INDEPENDENT DATA SETS

Although CIECAM02 was not derived specifically with the objective of color uniformity in mind it is informative to consider the overall uniformity of the space. One means to do this is to test the model using independently derived data, in this case a radial sampling of the OSA Uniform Color Scales.[13] Figures 1 and 2 show CIELAB versus CIECAM02 for this data set. The CIELAB results, shown in Figure 1, is plotted with a* on the x-axis and with b* on the y-axis. The CIECAM02 results, shown in Figure 2, is plotted with a_c and b_c as the x and y axes, respectively. The lightness axis for both figures is shown going into the page.

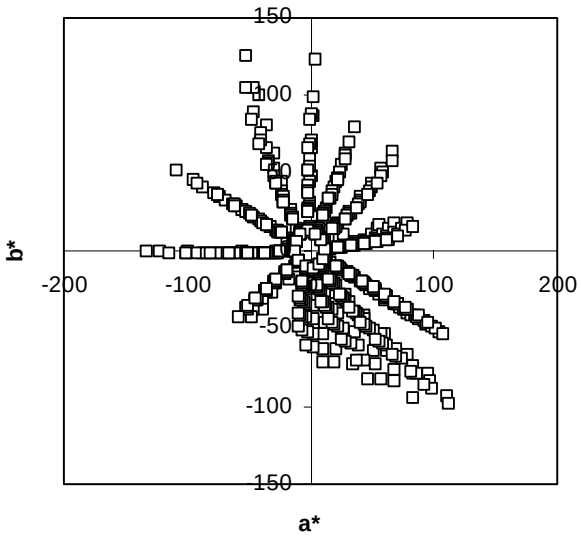

Figure 1. Radial sampling of OSA Uniform Color Scales in CIELAB coordinates.

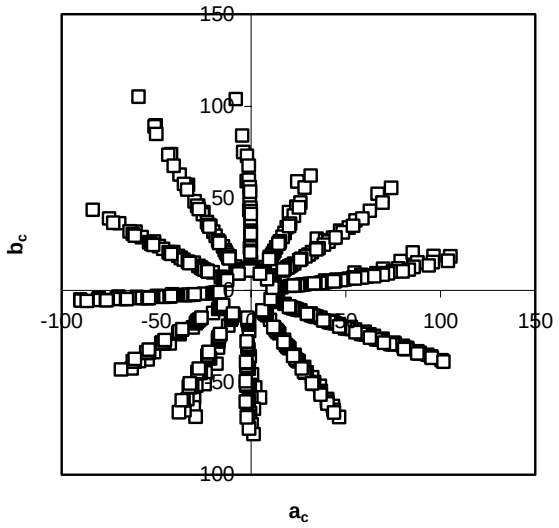

Figure 2. Radial sampling of the OSA Uniform Color Scales for CIECAM02 coordinates.

The results shown in Figure 2 show a considerable improvement in the hue uniformity for CIECAM02, especially for the blue hues. Not shown, is also an improvement in the chroma relative to the results for CIECAM97s. Given that CIECAM02 was not derived using the OSA Uniform Color Scales, the results shown in Figure 2 are encouraging.

In addition to the OSA Uniform Color Scales, the overall uniformity of CIECAM02 can be compared to CIELAB using the Natural Color System. The results of this comparison are consistent with those shown for the OSA Uniform Color Scales, specifically there is less spread in the data for the blue hue angles.

3. IMAGING WITH CIECAM02

The CIECAM02 color appearance model can be used as a device and viewing-condition independent representation of a color image. The model can then be used as a means to transform the color from an input device to an output device.[14-16] This capability was tested for CIECAM02 by comparing its performance relative to CIELAB. The input device was a CRT calibrated to closely approximate the sRGB[17] display standard. The output device was a Hewlett-Packard 970Cxi ink-jet printer. Printing was limited to three colors or CMY printing on a Hammermill JetPrint plain paper media. This resulted in a destination or output gamut with a considerably smaller gamut relative to the input gamut. The prints were displayed in a MacBeth SpectraLight viewing booth closely approximating D65 and viewed with an achromatic background with an L* of about 60. The black point for the prints in the light booth was roughly an L* of 35. A set of 8 example images was selected A Comrey constant-sum scaling[18] was conducted using 11 observers, excluding the authors.

The objective of this visual experiment was to verify that for the purposes of gamut mapping and color interpolations, that CIECAM02 does not have any significant shortcomings relative to CIELAB.[19] A specific consideration was the performance of CIECAM02 for low-key and low chroma colors. Efforts were made to minimize differences in appearance caused by the gamut mapping[20] but this was not completely achieved. The CIELAB chroma compression during gamut mapping was closer to clipping while the CIECAM02 chroma compression had more compression. In addition, it should be noted that because CIECAM02 chroma is a function of lightness additional lightness compression in the shadows was achieved by compressing the chroma of these colors in addition to the overall lightness compression.

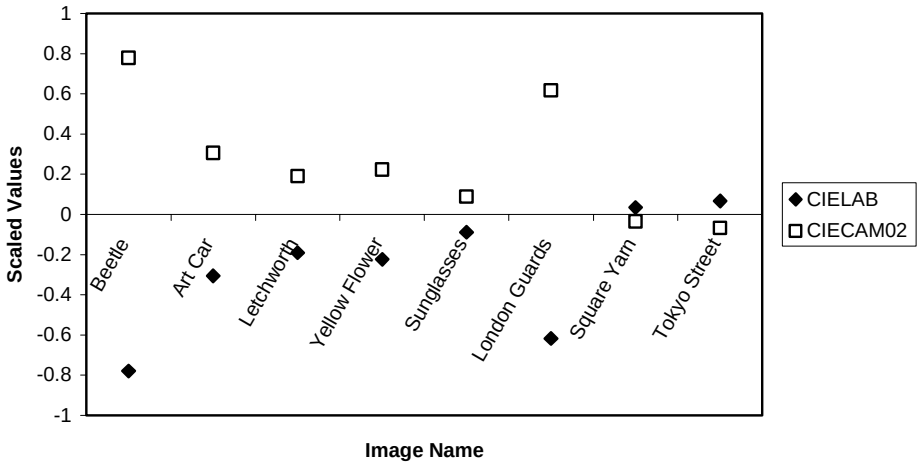

Figure 3. Summary of scaled quality for a set of images processed using CIELAB and CIECAM02.

A summary of the aggregate visual scaling data is shown in Figure 3. The images are shown on the x-axis and the visual scale is shown on the y-axis, a where higher value corresponds to a higher average observer preference. The results show that for 6 out of the 8 images the performance of CIELAB and CIECAM02 is fairly similar. Means testing at a 95% confidence limit results in only images one and six ("Beetle" and "London Guards") having statistically significant differences, The primary difference for image one is patches of navy blue shifted purple for CIELAB and image six in which red fabric lost shadow detail for CIELAB. This loss of detail is likely due to the bias towards chroma clipping for the CIELAB images and not an inherent limitation of the CIELAB color space. Significant tonal or lightness differences were not noted by any of the observers while a majority commented on the blue purple shift.

4. CONCLUSIONS

CIECAM02 provides all the functionality of CIECAM97s while incorporating a several key revisions. Testing with independent data sets show improved hue constancy for CIECAM02 relative to CIELAB. In addition, testing with images demonstrates that CIECAM02 can work as well

as CIELAB for transforming color data from a larger gamut display to a smaller gamut print. Reducing the confounding effect of gamut mapping is difficult but for images with significant amounts of dark blue or navy blue, the CIECAM02 reproductions are preferred by a statistically significant margin.

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