Guideline on Designing Laser Display Primary for Reproducing Real World Object Colors

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Abstract

Laser display is one of the next generation displays with the highly pure reproduction of colors and larger color gamut than any other electronic displays. However, it is inevitable to get some color regions that cannot be reproduced with three primaries. So recently more than three primary controllers[1] are developing. In this study, a set of new RGB primary covering all object colors exist in real world is proposed as the guideline on designing laser display. The color region of real world objects was firstly described by measuring some objects: 367 artificial objects and 86 natural objects. For the artificial objects, garments and electronic devices were chosen, and flowers and leaves were chosen as the natural objects. Most of the measurement data from the artificial objects are located within the Munsell color region, while an amount of measurement data from natural objects are not. As a result, the color region of real world objects was approximated with 1294 Munsell standard colors and some natural colors located outside of the Munsell region. The boundary covering the color region of real world objects was optimized as a triangle so as to include both of NTSC gamut and sRGB gamut as well as measurement data. As a result, the optimum wavelengths of RGB primaries were defined as 630nm, 537nm, and 468nm, respectively.

Introduction

Laser display has been increasingly developed in the last few years and it is known as one of the next generation displays. It basically produces colors by mixing a number of primary colors but only three-primary case is concerned in this research.

The color reproducibility of the laser display shows much better performance than any other displays, because laser can emit the highest pure primaries that reach the spectral locus of the CIE x,y chromaticity diagram. The high purity of laser also possibly leads to creating tremendously large color gamut. A color gamut is defined as a range of colors achievable on a display under a given set of viewing conditions[2] and described as a three dimensional volume in color space. In display manufacturing industry, it is commonly described and communicated as the size of a triangle, which is comprised of three primary color points, on the CIE x,y chromaticity diagram.

In laser display gamut, the size of the triangle is not the only issue but also the position of the primary points is critical. For instance, higher saturated colors can be reproduced as the size increases, while the kind of reproducible colors must be determined by the position of the vertices of the triangle. Thus defining optimum position of the vertices becomes hot issue as well as how large it is for developing high quality laser display. This study intends to propose a guideline on designing the wavelength of three primaries in laser displays, which can reproduce the whole real world object colors.

Measurement

Equipment

To define the color region of real world objects on the CIE x,y chromaticity diagram, a limited number of real objects were measured. A portable type spectrometer (Eye-one Photo, SN/0121018, GretagMacbeth) was used to perform all measurement in the field. Figure 1 shows the comparison of reflectance measured by Eye-one and desktop type Spectrophotometer (Minolta, 3600d) for red, green, blue chips of ColorChecker. It can be seen that there is some difference between the two. Figure 2 shows the difference of chromaticity coordinates caused by the difference of reflectance. The differences shown in Figure 2 are negligible for all colors. High accuracy spectrometer is not necessarily needed in this research.

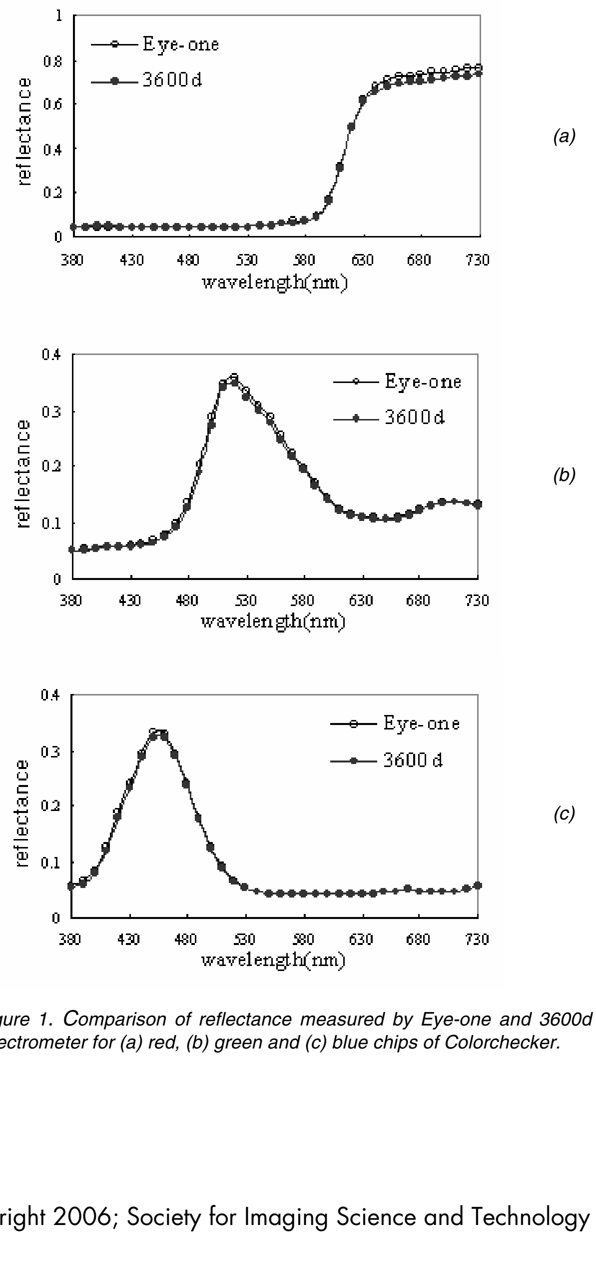


Figure 1. Comparison of reflectance measured by Eye-one and 3600d spectrometer for (a) red, (b) green and (c) blue chips of Colorchecker.

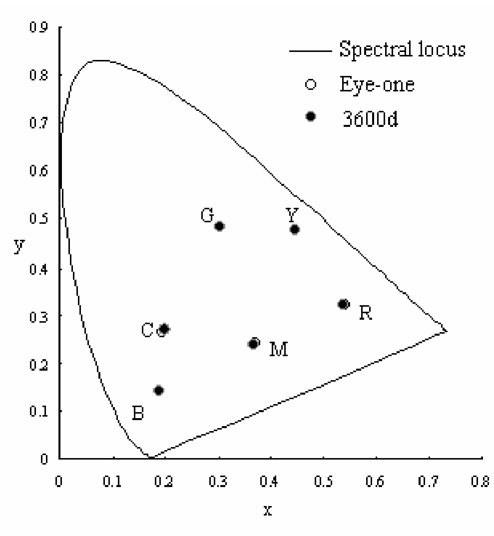


__Figure 2.__ Comparison of chromaticity coordinates resulted by the two spectrometers for red(R), green(G), blue(B), cyan(C), magenta(M) and yellow(Y) chips of ColorChecker.

Sample objects

The kinds of objects are grouped into two: artificial object and natural object. For the artificial objects, 112 casual garments, 156 Tibetan traditional garments and 99 electronic devices were chosen. Casual garments with high chroma were chosen among products displayed in a shop as far as possible. Tibetan traditional garments displayed in 2005 World Museum Culture Expo, which was held in Korea, were measured. Electronic devices like washing machine, refrigerator, hair dryer, etc. were chosen. And for the natural objects, 50 flowers and 36 leaves, which are blown during July and September in Korea, were chosen. As a reference, 1294 standard data of Munsell colors[3] were considered. Since Munsell data are originally defined under the CIE standard illuminant C with 2° viewing angle, they were converted into the viewing condition under standard illuminant D65 using the CAT02 chromatic adaptation transformation[4].

Results and Discussion

Color region of real world objects

Figure 3 shows the measurement data plotted on the x,y chromaticity diagram for casual garments(a) and Tibetan traditional garments(b), electronic devices(c) and flowers and leaves(d). 1294 standard data of Munsell colors are also plotted together in each figure. It can be obviously seen that Munsell colors are partially distributed on the x, y chromaticity diagram. Especially, no colors were around the lobe of the locus at all.

Figure 3(a) shows that casual garments, which are produced by artificial dyes, are distributed evenly in Munsell region. On the other hand, Tibetan traditional garments, which are produced by natural dyes are distributed on the limited region as shown in Figure 3(b). And Figure 3(c) shows that electronic devices are also concentrated in several specific hue locations. However, it can be concluded that any artificial object color is located within Munsell color region, so that Munsell color region can be considered as the representative of the artificial object colors. Meanwhile, figure 3(d) shows that the natural colors are distributed up to beyond Munsell color

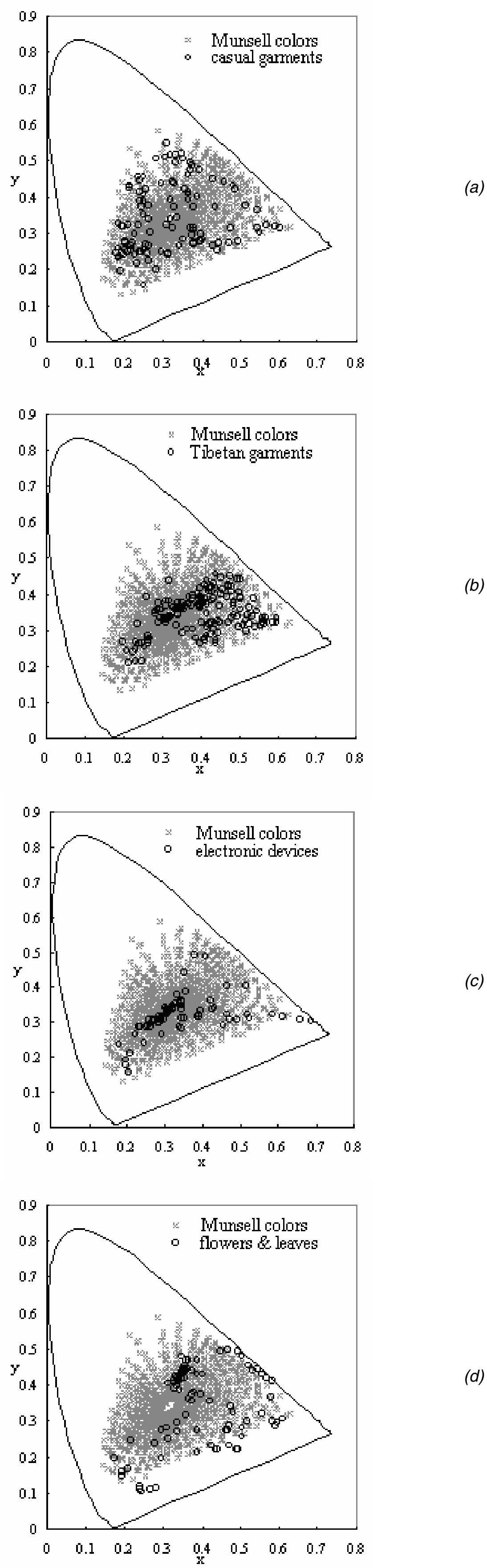


__Figure 3.__ Measurement data for (a) 112 casual garments (b) 156 Tibetan traditional garment, (c) 99 electronic devices, (d) 86 flowers & leaves

region. Some are located to very near to spectral locus between 570m and 600nm, and some are closer to purple line. Other researchers (5~9) reported similar results. As an example, figure 4 shows the comparison of 86 our data and 240 standard data listed in flowers and leaves categories of ISO TR 16066. ISO TR 16066 provides a database of existing object color spectral data more than fifty thousand. This figure shows good agreement in distribution region. As a result, the color region of real world objects was approximated with 1294 Munsell standard colors and some natural colors located outside of Munsell region.

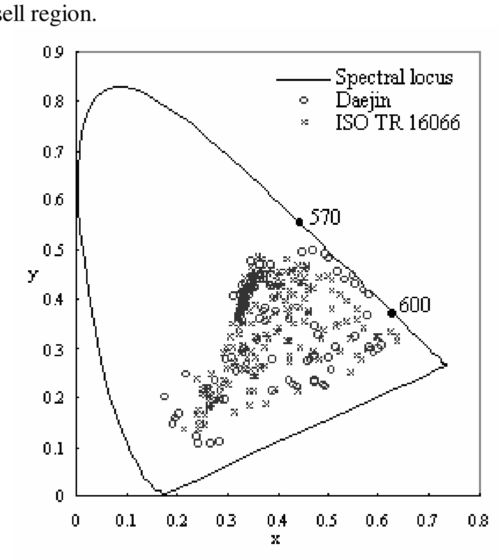


Figure 4. Comparison of the color distributions on the x,y chromaticity diagram for flowers & leaves between our and ISO TR 166066 data.

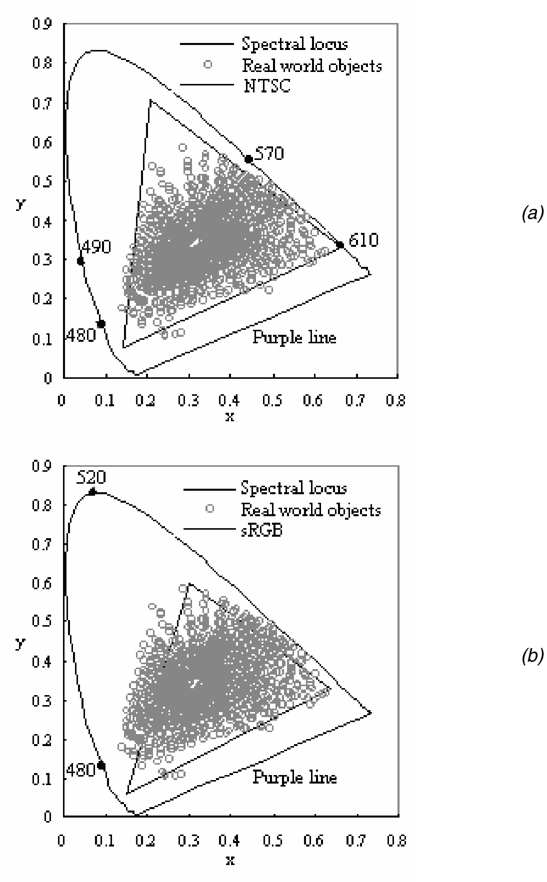


Figure 5. Comparison of the approximated real object colors with currently used standard gamuts a)NTSC, b)sRGB

Optimum boundary of real object color region

The approximated real world object colors, which are composed of 1294 standard data of Munsell color and 86 measured data from natural objects, are plotted on Figure 5. Figure 5(a) and (b) show the comparison with the currently used standard gamuts, NTSC[10] and sRGB[11], respectively. Nor standard gamut can include all the data. NTSC gamut doesn't include some colors located to very near to spectral locus between 570m and 610nm or closer to spectral locus between 480m and 490nm as well as purple line. This means that the display having NTSC gamut cannot reproduce pure natural colors vividly. SRGB gamut doesn't include much more than NTSC gamut. Especially, a considerable number of colors located to closer to spectral locus between 480m and 520nm are out of sRGB gamut. Therefore, a standardization of a new gamut, which comprises the approximated real world object colors completely, is positively necessary.

In figure 6, the thick lined triangle shows the optimum boundary that surrounds the approximated real world object colors as well as two standard gamuts. There are two rules in determining three vertices of the triangle. The prior rule is that both of sRGB gamut and NTSC gamut should be included, and the next is to comprise the approximated real world object colors as much as possible. Figure 7 shows the rules in detail. The left vertex is firstly determined as a cross point of the spectral locus and the line parallel with the purple line, on which the blue primary of sRGB is located as shown in Figure 7(a). Then the top vertex is determined by drawing a line, which is parallel with the left side of NTSC triangle, from the left vertex to the opposite spectral locus as shown in figure 7(b). Finally the right vertex of triangle can be determined by extending the line, which connects the left vertex and the outmost data, to the spectral locus. Accordingly three vertices are defined with three monochromatic wavelengths: 630nm (Right), 537nm (Top), and 468nm (Left).

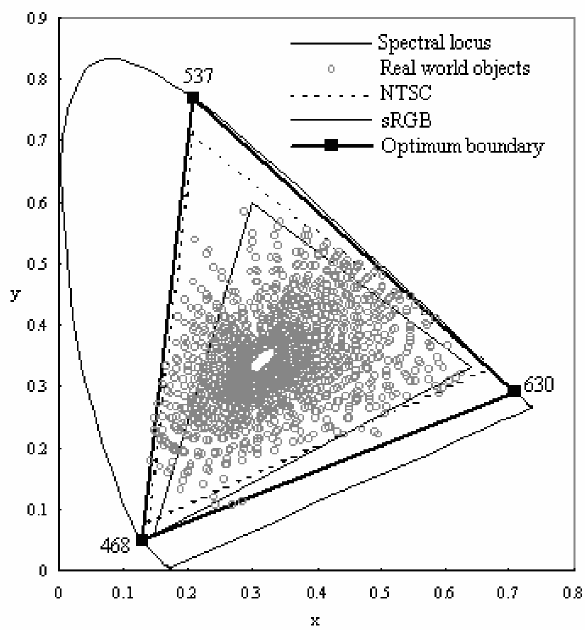
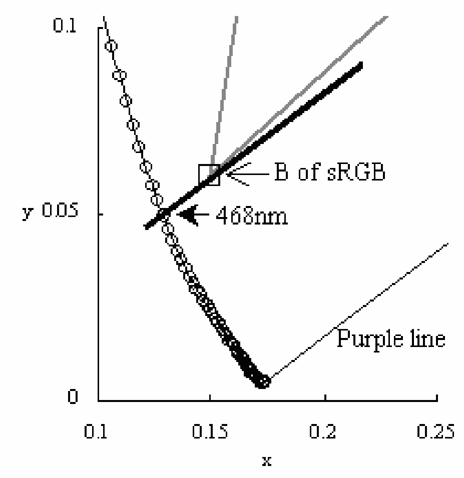
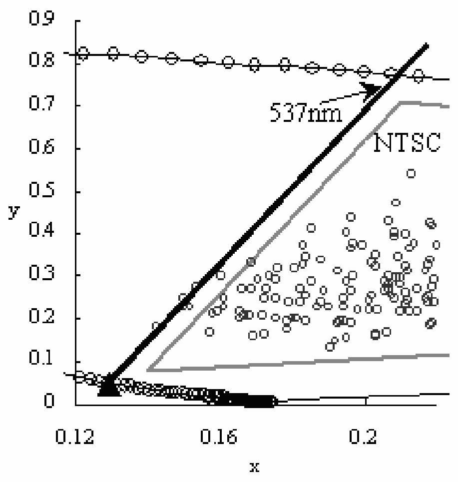


Figure 6. Optimum boundary of approximated real world object colors



(a)



(b)

Figure 7. *Determination of wavelength for a) left vertex, b) top vertex*

Conclusion

The real world object colors could be approximated with Munsell standard data and some natural object colors. The boundary of approximated real world object colors could be optimised as a triangle, whose vertices are located on the spectral locus on the x,y chromaticity diagram. Accordingly, three vertices of the triangle were defined as three monochromatic wavelengths: 630nm (Right), 537nm (Top), and 468nm (Left). A new set of RGB primary defined by each wavelength is proposed as a guideline on designing laser display, which can reproduce all real world object colors.

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Author Biography

Seung Ok Park received the B.S. degree in Physics from Ewha Woman University (Korea) in 1979 and Ph.D. degree in Physics from Korea Advanced Institute of Science and Technology in 1987. She worked in Korea Research Institute of Standards and Science as a senior researcher from 1987 to 1992. At present she belongs to Department of Physics of Daejin University as a professor. Her main interest is in optimum display setting for accurate characterization.

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