Ink Jet Printer Gamut Visualization

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Abstract

The number and the diversity of ink jet color printers makes more and more important the problem of accuracy of color reproduction. In order to compare and study the range of colors that can be reproduced on different printers, a visualization procedure was designed and implemented. The procedure enables to visualize the shape and volume of the color gamut as well as the colors of some region of interest of the gamut of the investigated printer. The visualisation is dynamically performed enabling to rotate, translate and scale the gamut volume in real time. The gamut of different color devices can be visualized simultaneously, emphasizing the outside gamut colors of each device. The procedure is usefully in case of color simulation and mapping of out of gamut colors. Examples and results of visualization are provided. An analysis concerning of mapping of the out of gamut colors of ink jet printer based on the CIELAB and CIELUV gamut representation is provided.

Introduction

The number and the diversity of color printers makes more and more important the problem of accuracy of color reproduction. Different color printers have different gamuts. This conducts to the fact that same image data without information about the device that reproduces the color, may render the image colors in different ways. As an example, same image data can look very different from one reproduction to another, according to the parameters of printing process, even if the images are seen under same observation conditions. For all the reproduction devices, it makes sense to have a representation of their color gamut that enables to compare the devices or to detect what colors of an image will be correctly reproduced and what colors will be distorted.

This paper describes a method of visualization and the implementation of a tool that enables a dynamically visualization of color gamut of different color reproduction devices in different color coordinates. The procedure is simple, easy to implement with minimum software

effort. It can be additionally used to display the histogram of an image, to compare different color processing algorithm, to design strategies of mapping of the out of gamut colors.

Visualization Method

The idea of visualization of color data is not new. Rolleston[1] and Kalra[2] presents different tools for visualization of color gamut. For the color engineer that has not available these tools, visualization is a problem that he has to design and to implement by himself.

The visualization procedure enables the visualization in a simplified form of the shape of the color gamut. A device color space is represented by edges of the RGB (or CMY) cube. Based on a calibration procedure[3-5] that enables the accurate transformations between color spaces, the device color space faces can be converted for visualization in a device independent color space[6]. The faces are approximated with a number of polygons that can be dynamically adjusted.

Figure 1 shows an example of gamut visualization for Canon Pixel Jet printer in CIELAB and CIELUV color spaces. The visualization procedure enables to change dynamically the visualization parameters: magnification, position and viewing angle. It enables to rotate the space around three axis, translate and scale the color space in order to get maximum advantage for visualization of any details. Animation of the color space enables to get an overview of the device gamut appearance.

It is important to note that the calibration of color transformations represents the essential element for the accuracy of visualization and comparison of color device gamuts in device independent spaces. Analytical or empirical models can be used. The empirical models based on LUT and interpolations[5] use a set of calibration data resulted from measurement of sample patches reproduced on the particular device that is calibrated. Different interpolation techniques[8] are used for colors that differ from the color specified in the calibration set. The prediction accuracy of the empirical models can be increased enlarging the set of calibration data. The empirical models can include the nonlinearity of the practical devices and can be adapted to any new device if the calibration data set can be measured. A more simple calibration can be achieved using analytical models. The analytical models require a much smaller set of calibra-

tion data, but they do not include the nonlinearity of practical devices.

The visualization procedure can be applied to compare the gamuts of different reproduction devices. Simultaneously visualization emphasizes the differences between gamuts. Reproduction of color on different ink jet printers, and in general case, on different devices is susceptible to color distortions due to the colors that may result outside of the gamut of the device in case of exact colorimetric mapping procedures. In this case, the out of gamut colors of a device must be mapped into a gamut color and this may conduct to color distortions. The color distortions can be more or less observable, according to the contents of the image but also to the strategy used for gamut mapping.

Results of Visualization

Figure 2 represents the visualization and comparison between the SuperMac Dual Mode CRT Display and the Canon Pixel Jet printer in CIELAB and CIELUV spaces (frontal and top views). The CRT gamut is represented with segments and the printer gamut as a solid volume. For CRT calibration, the RGB and ref. white chromaticity coordinates and gamma are used. For ink jet printer calibration, the chromaticity coordinates of the CMYK inks and the overlapped color combinations printed on paper substrate are used, in the analytical Neugebauer model. The Neugebauer model is used in this approach
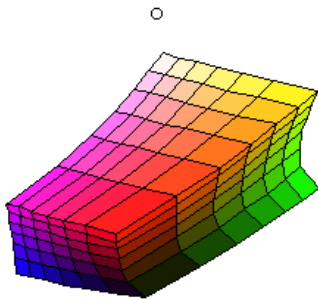
Figure 1a. CIELAB Gamut of Canon Ink Jet printer
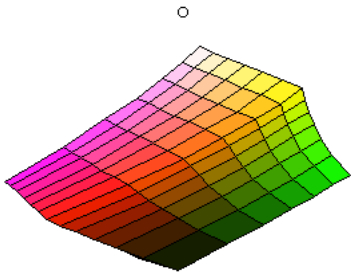
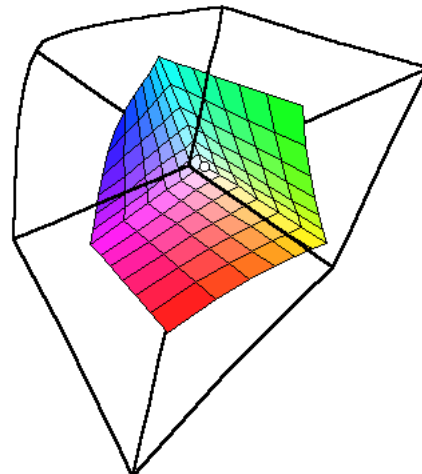Figure 1b. CIELUV Gamut of Canon Ink Jet printer
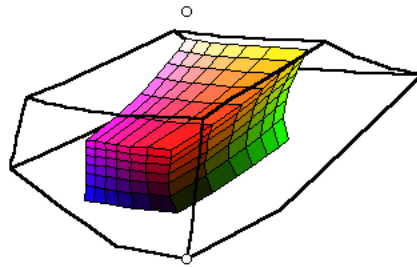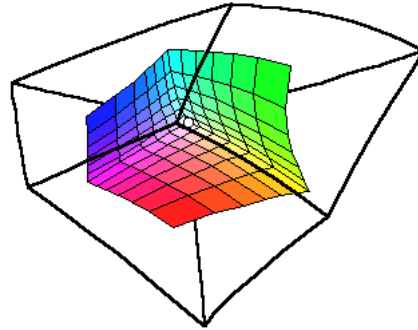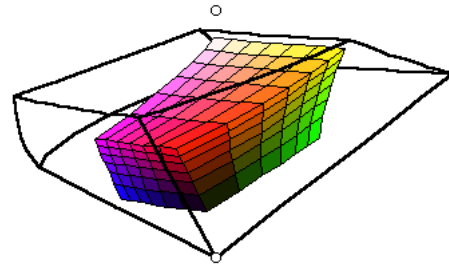
Figure 2. Simultaneous visualization of gamut of Canon Ink Jet Printer (colored volume) and CRT SuperMac DualMode device used for color simulation

just to test and to illustrates the method, but for real applications, the measured data are recommended in order to get accurate results of visualization process. Empirical LUT models[5] can take into account the nonuniformities of the real devices.

The comparison of gamut of different color devices is a very delicate problem. The color gamut of one device varies with the conditions of observation. For example, the gamut of printer can have different shape and size if the illuminat is changed. This is reflected in the calibration process. Changing the conditions of observation conducts to other set of calibration data and consequently to other shape, size and volume of the color gamut of that device. Every time when the appearance of the reproduced colors is changing, the position of these colors in the color space is modified, so the representation of color gamut must be performed again, based on new calibration data. The difficulty in achieving the proper calibration data set as well as the difficulty of identification of changing of the observation conditions is one of the delicate problem related to the accuracy of gamut visualization.

Comparison of Color Spaces for Mapping the Out of Gamut Colors

The goal of mapping of outside gamut colors of one device depends on the application. Colorimetric, perceptual and saturation mapping strategies are most used. For mapping of out of gamut colors of a device, constant chroma sections are required in order to minimize the hue error introduced when an out of gamut color is approximated with a gamut color. For colorimetric mapping procedure, the procedure of mapping of outside gamut colors proposed in[5] and briefly illustrated in figure 3, selects the gamut color at the cross point between the gamut boundary and one straight line that connects the outside gamut color with an achromatic point on the lightness axis of the gamut. Recently, more general applyable strategies were proposed[9,10].
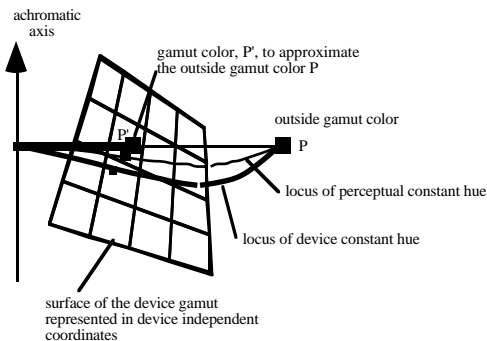
Figure 3. A possible strategy for mapping of outside gamut colors

In order to find the best procedure of mapping of the outside gamut colors, the visualization procedure can be used to analyze the constant hue locus for different hue values. For each gamut the locus of test colors with

constant device hue, or constant perceptual hue or constant space angle can be visualized for maximum saturation and variable lightness. In figure 4 as an example, the device constant hue loci is represented as a gray line on the gamut boundary from black to white point.

The CIELAB and CIELUV color spaces used for gamut representation can give different shape of the same device gamut. The perceptual parameters of color have different representation in different spaces. Figure 4 represents in CIELAB and CIELUV device independent color spaces, same image data (a test image containing the red device hue) as it is reproduced on Canon Pixel Jet printer. Figure 4 shows that the device dependent hue does not correspond to a constant hue angle in the device independent CIELAB and CIELUV. It can be observed that the locus of device constant hue is not exactly contained in constant hue vertical section of CIELAB space, but the plane shape approximation is better than the corresponding representation in CIELUV color space. Using the constant space angle as a plane in which the mapping of outside gamut color is performed, our analysis concludes that CIELAB offers smaller hue error than CIELUV for the ink jet printer device.
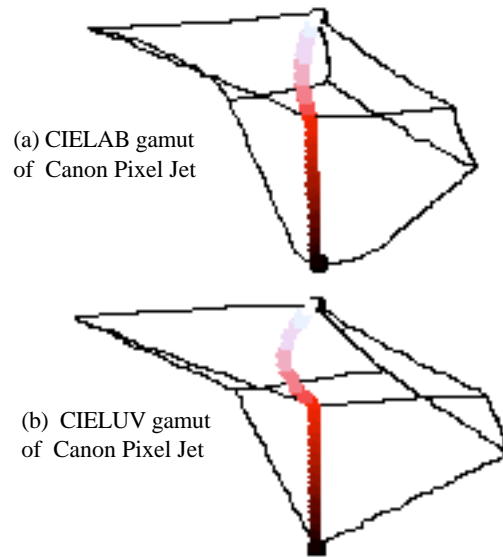
Figure 4. The device constant hue representation for Canon Pixel Jet printer in CIELAB (a) and CIELUV (b) spaces.

Conclusions

A dynamically visualization procedure for color devices was presented and used for comparison of ink jet printer devices. Analytical model was used for exemplification but the method is extendible to more accurate empirical models. The applications of the visualization procedure are not limited to gamut visualization and can be extended to other color analysis problems[6]. This extends the application of the visualization procedure, with the advantage that the color representation can be performed in other color spaces like RGB, HSV, HSL, YIC, XYZ.

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