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III.7

AN INEXPENSIVE METHOD OF SETTING THE MONITOR WHITE POINT

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Calibrating a color television monitor in terms of the CIE *XYZ* color notation system has assumed an increasingly important role in computer graphics. This adjustment has been shown to be useful in applications as diverse as two-dimensional page layout for the graphic arts and three-dimensional realistic image synthesis for commercial animation. Part of the calibration process involves setting the individual brightness and contrast controls for the three monitor guns so that a white color with known chromaticity coordinates is produced whenever $R = G = B$ (Meyer, 1990). Typically, this is thought to require an expensive color measurement device, such as a colorimeter or a color comparator (SMPTE, 1977).

In this gem, we show how a relatively inexpensive luminance meter can be used to establish this setup. We also show how the luminance meter may only need to be used once if a simple light meter with arbitrary spectral sensitivity but linear response is available. We have made use of this technique in our research for some time (Meyer, 1986). Recently, it was shown how this approach can be adapted to postpone the need for a complete monitor calibration (Lucassen and Walraven, 1990).

To employ a luminance meter in setting the monitor white point, the luminance ratio between the red, green, and blue monitor guns at equal drive must be determined. This ratio can be found by noting that the following relationship holds between the tristimulus values of the white point and the component tristimulus values produced by each of the guns,

$$\begin{bmatrix} X_R \\ Y_R \\ Z_R \end{bmatrix} + \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} + \begin{bmatrix} X_B \\ Y_B \\ Z_B \end{bmatrix} = \begin{bmatrix} X_W \\ Y_W \\ Z_W \end{bmatrix}.$$

Using the fact that, for example,

$$X_G = Y_G \frac{x_G}{y_G},$$

where x_G and y_G are the chromaticity coordinates of the green monitor phosphor, this can be rearranged to yield

$$\begin{bmatrix} x_R/y_R & x_G/y_G & x_B/y_B \\ 1 & 1 & 1 \\ z_R/y_R & z_G/y_G & z_B/y_B \end{bmatrix} \begin{bmatrix} Y_R/Y_W \\ Y_G/Y_W \\ Y_B/Y_W \end{bmatrix} = \begin{bmatrix} x_W/y_W \\ 1 \\ z_W/y_W \end{bmatrix},$$

where x_w, y_w, and z_w are the white-point chromaticity coordinates and Y_w is the white-point luminance. From this expression, the required ratio between the gun luminances can be determined. A luminance meter can be used to set the individual brightness and contrast controls for each monitor gun so that the preceding luminance ratio is achieved.

A luminance meter may not always be available to establish these settings and, even if it is, it may not have the necessary sensitivity (due to its photopic response) to make these adjustments over the entire dynamic range of each monitor gun. It is possible, however, to make these measurements with a light sensing device of arbitrary spectral sensitivity; as long as the device responds linearly to changes in intensity, the device has a response time appropriate for the monitor refresh rate, and a luminance meter is available to calibrate initially the light sensing device.

To see how this is possible, consider the spectral emission curve $KP(\lambda)$ for one of the monitor phosphors, where $P(\lambda)$ is a relative spectral energy distribution curve that has the property,

$$\int P(\lambda)\,d\lambda = 1,$$

and K is a constant with unit watts m^{-2} sr^{-1} that scales $P(\lambda)$ to create an absolute spectral energy distribution. A luminance meter has spectral sensitivity $\bar{y}(\lambda)$ identical to the human photopic response curve and performs the following integration:

$$Y = \int KP(\lambda)\bar{y}(\lambda)\,d\lambda = K\int P(\lambda)\bar{y}(\lambda)\,d\lambda = KI_y.$$

A light sensing device with arbitrary spectral sensitivity $\bar{a}(\lambda)$ performs the following integration:

$$A = \int KP(\lambda)\bar{a}(\lambda)\,d\lambda = K\int P(\lambda)\bar{a}(\lambda)\,d\lambda = KI_a.$$

Dividing these two expressions by one another and rearranging, we see that

$$Y = \frac{I_y}{I_a}A.$$

The luminance of the phosphor, therefore, can be measured using the light sensing device with arbitrary spectral sensitivity as long as the ratio I_y/I_a has been determined. This can be done by taking the ratio of the two meter readings at several fixed phosphor intensities and averaging the result.

Given the chromaticity coordinates of the monitor phosphors, a light sensing device with linear response but arbitrary spectral sensitivity, and the short term loan of a luminance meter, it is possible to calibrate completely a color television monitor in terms of the CIE *XYZ* system. As was shown previously the light sensing device can be used to set the monitor white point and balance the monitor over its entire dynamic range. A light sensing device with flat spectral sensitivity is preferred even over a luminance meter in performing this operation because of its greater sensitivity, particularly for low blue phosphor intensities. This same light sensing device also can be used to measure the nonlinear relationship that exists between the voltage applied to the monitor guns and the amount of light that the phosphors emit (i.e., *gamma correction*) (Cowan, 1983; Brainard, 1989). In this way, a complete monitor calibration can be accomplished using one relatively inexpensive light measurement device.

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