Color optimization of different fruits and vegetables for computer displays

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ABSTRACT

The aim of the research was to apply the spectral reflection distributions of color stimuli of different vegetables and fruits onto computer displays with the help of the color management methods. At the first stage of the research we measured the spectral reflection distributions of color stimuli of several different vegetables and fruits with a spectrophotometer and we calculated the color coordinates in the CIELAB color space. Based on the measured values we created each color on a calibrated LCD monitor by using the four "rendering intents" of the Color Management System. The displayed color stimuli were then remeasured by means of spectrophotometer and the results were compared to the original values. The final results of the calculations shall give recommendation on the method providing the lowest color difference when visualizing color stimuli of fruits and vegetables on computer displays.

1. INTRODUCTION

With the spreading of modern CAD applications, printing technologies and the conquest of the internet the appropriate display of colors has become very important in several applications. One example from the marketing point of view is that today when observing a product catalogue photo not only the shape and resolution is important but the picture also should reflect original colors. The common experience is that the colors of the products do not appear the same on the monitor or in the catalogue as in reality (Fairchild 2005). Although color sensation is a subjective perception it can be measured in objective ways (De Cusatis 1997). Moreover it can be communicated and controlled when displayed on digital screens.

The color management system (Fraser, Murphy and Bunting 2005) gives solutions to represent colors on the computer monitor close to their real appearance. With the application of adequate color management methods we can ensure that color information on a given object will not become distorted to great extent while it migrates from one device to another. On the other hand we have to take into account that human vision can perceive much more colors than the color gamut of the monitor or printer can realize, therefore device parameters also have to be considered.

2. COLOR RENDERING INTENTS

There are four different methods in the color management system (Cambridge in Color) that provide ways of calculation when transforming colors outside the color gamut of a specific device:

- **Relative colorimetric:** Any colors that fall outside the device color gamut area are replaced by one specific color within the target gamut while hue and brightness are being preserved. For most images this intent retains best the overall color quality of an image as it is transformed from one device color profile to another.
- **Perceptual:** When the color conversion or remapping is applied some colors may be shifted, but the relations between colors are retained to match human perception.
- **Absolute colorimetric:** Colors located outside of the device color gamut area are simply clipped or removed.
- **Saturation:** The color saturation is retained for the original color at the expense of hue and brightness.

The aim of our paper is to present the different color rendering intents' performance for the digital display of fruits and vegetables and to select the best method providing the lowest color difference.

3. MEASURING THE DIFFERENT FRUITS AND VEGETABLE COLORS

3.1 Color measurement

When observing fruits and vegetables, color is the first sensation that the consumer perceives and uses as a primary tool to accept or reject the food (Mendoza, Dejmek and Aguilera 2006, Nunes 2008).

To maintain adequate quantities and quality, we carried out the different vegetable and fruit color measurements in one of the largest hypermarkets in Budapest, Hungary where numerous fruits and vegetables were available at first-rate quality. Nearly 40 different kinds of vegetables and fruits were measured considering data acquisition on at least five pieces from each kind. The spectral reflection distributions of the different vegetables and fruits were measured with a CM2600d type Konica Minolta spectrophotometer. From the measurement results we calculated the color coordinates of each color stimuli in the CIELAB color space (De Cusatis 1997). The measuring range was between 380 and 730 nm with 10 nm spectral resolution.

3.2 The calculation of CIELAB color coordinates

The sequence of calculation from spectral reflection distributions to CIELAB space coordinates was the following (Fairchild 2005):

- **Spectral data to XYZ tristimulus values:** The spectral power distribution of the reference illuminant is *I(λ)*, the spectral power distribution of the sample is *P(λ)*; the $\bar{x}$, $\bar{y}$ and $\bar{z}$ are the CIE standard observer functions (for 2°). The integrals are computed over the visible spectrum (from 380 to 730 nm).

$$X = K\int_{380}^{730} I(\lambda)\,\bar{x}(\lambda)P(\lambda)d\lambda;\ Y = K\int_{380}^{730} I(\lambda)\,\bar{y}(\lambda)P(\lambda)d\lambda;\ Z = K\int_{380}^{730} I(\lambda)\,\bar{z}(\lambda)P(\lambda)d\lambda$$

where 'K' is the normalizing constant between radiometric and photometric values.

- **XYZ tristimulus values to CIELAB:** This conversion required a reference white, which in our case was ($X_w = 96.40$; $Y_w = 100$; $Z_w = 82.5$).

$$L = 116\left(\frac{Y}{Y_W}\right)^{\frac{1}{3}} - 16 \; ; \; a = 500\left[\left(\left(\frac{X}{X_W}\right)^{\frac{1}{3}}\right) - \left(\left(\frac{Y}{Y_W}\right)^{\frac{1}{3}}\right)\right] \; ; \; b = 200\left[\left(\left(\frac{Y}{Y_W}\right)^{\frac{1}{3}}\right) - \left(\left(\frac{Z}{Z_W}\right)^{\frac{1}{3}}\right)\right]$$

4. CALCULATING THE COLOR RENDERING INTENTS

The next step was to display the calculated CIELAB coordinates on the calibrated LCD monitor (Samsung SyncMaster931BF) with the help of the Photoshop software and the specific ICC profile (Adobe Creative Team 2007).Using the color rendering intents of the Color management system, we created all the colors and remeasured them on the display. The measuring instrument was a Gretag-Macbeth X-Rite i1-Pro spectroradiometer. We have used all four color management system methods to display color stimuli and measured their spectral power distribution, calculated the XYZ tristimulus values and the CIELAB coordinates (Figure 1).

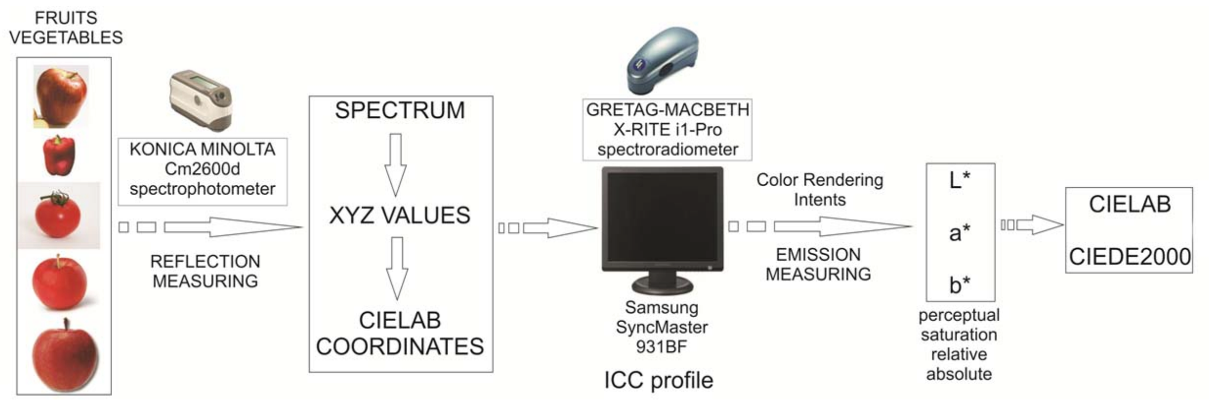

Figure 1. Measurement and calculation sequence.

5. RESULTS

Color differences between the original and displayed color stimuli were calculated using the CIE ΔE*ab and the CIEDE 2000 methods (Johnson and Fairchild 2003). With the help of these methods we were able to determine the color management method providing the lowest color difference when displayed on the monitor. Table 1 shows the color difference calculation results for some specific fruits and vegetables with different color appearances.

6. CONCLUSION

In our work we have compared the four color management system methods applied when displaying color stimuli of fruits and vegetables on the computer monitor. The differences between the original and displayed colors were determined using CIE color difference calculation methods. For all samples we have found that the ΔE^*_{ab} and the CIEDE 2000 values correlate to a high extent ($R^2 > 0.96$ for intents Perceptual, Relative Colorimetric and Saturation and $R^2 > 0.92$ for Absolute Colorimetric) which has proven to be a similar result to other studies (Lee 2005). ΔE^*_{ab} values were also found to be significantly higher (25% for intents Perceptual, Relative Colorimetric and 34% for Absolute Colorimetric).

Comparing the values between the four intent types no significant differences were detected between the Perceptual, Relative Colorimetric and the Saturation intents. On the other hand the Absolute Colorimetric intent differed significantly ($p < 0.01$) from all others providing larger color difference values for both ΔE^*_{ab} and the CIEDE 2000 thus this latter is not recommended when displaying fruit or vegetable colors.

Summarizing the results we can say that the expectations were fulfilled meaning that color stimuli will appear different from their originals on the computer display. However based on our results we are able to recommend color management methods to be applied for providing fruit and vegetable color appearances closer to reality.

Table 1. Typical results for some of the measured fruits and vegetables.

Fruit/vegetable	Intent	CIEDE2000	ΔE^*_{ab}
Garlic	perceptual	12.85	18.36
	saturation	12.49	18.09
	relative	12.65	18.36
	absolute	21.31	34.91
Lemon	perceptual	8.96	13.70
	saturation	8.93	13.65
	relative	8.97	13.75
	absolute	10.10	18.47
Green California Pepper	perceptual	8.41	9.77
	saturation	8.47	9.84
	relative	8.63	10.02
	absolute	13.23	15.70

Fruit/vegetable	Intent	CIEDE2000	ΔE^*_{ab}
Orange	perceptual	5.61	8.20
	saturation	5.48	8.19
	relative	5.67	8.31
	absolute	7.07	15.76
Tomato	perceptual	7.48	9.75
	saturation	7.54	9.77
	relative	7.46	9.62
	absolute	10.29	14.84
Purple onion	perceptual	7.00	10.35
	saturation	7.19	10.58
	relative	6.91	10.18
	absolute	11.03	17.44

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