International Color Consortium

Metameric solutions in a Spectral PCS

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Issues

- Today’s colorimetric profiles provide no clues to the spectral data for any given set of tristimulus values.
- Colorimetric Consumers deserve better that a single standard observer.
- Illuminant metamerism is a high ticket item in color workflows
- Spectral Profiles and a Spectral PCS provides a good cost effective solution.
- Spectral data is a key requirement of the packaging market for spot color identification and overprint processing.
- No ability to handle color database (Cxf - Color eXchange format) data inside an ICC profile.

The King is dead. Long live the King.

- Color inconstancy between processes with non D50 SPD's is expensive and requires a real world solution.
- Virtual or Monitor based proofing comparisons to Hard copy proofing issues.
- ICC Device link profiles where source and destination spectra are different. D50 profiles can easily be off 10 + dE.
- In most cases today imaging systems are asked to provide a metameric match without the spectral data to calculate if the results actually do provide the best representation.
- Narrow band LED lighting and Laser primaries do not integrate accurately in a XYZ world.
- A better solution is needed.

ICC v2 -v4 - Issues

- N Channel Multi ink support: spectral data must be used for optimal color matching of overprint areas and simulated spot colors.
- Unless the camera spectral sensitivities closely match the color matching functions, metamers for the human visual system are not the same metamers as in a camera system.
- Metamers in trichromatic systems like XYZ, or LAB also prove difficult to correct without spectral data, because once the dimensionality is lost reconstructing it is difficult.

Characterizing the Consumer

- **This equation is the basis of all colorimetric computations in basic and applied colorimetry. Practically, all mathematical representations of color in applied colorimetry originate from this equation.**

$$X = k\sum_{\lambda} S_{\lambda} R_{\lambda} \bar{x}_{\lambda} \Delta\lambda; \quad Y = k\sum_{\lambda} S_{\lambda} R_{\lambda} \bar{y}_{\lambda} \Delta\lambda; \quad Z = k\sum_{\lambda} S_{\lambda} R_{\lambda} \bar{z}_{\lambda} \Delta\lambda$$

$$k = \frac{100}{\sum_{\lambda} S_{\lambda} \bar{y}_{\lambda} \Delta\lambda}$$

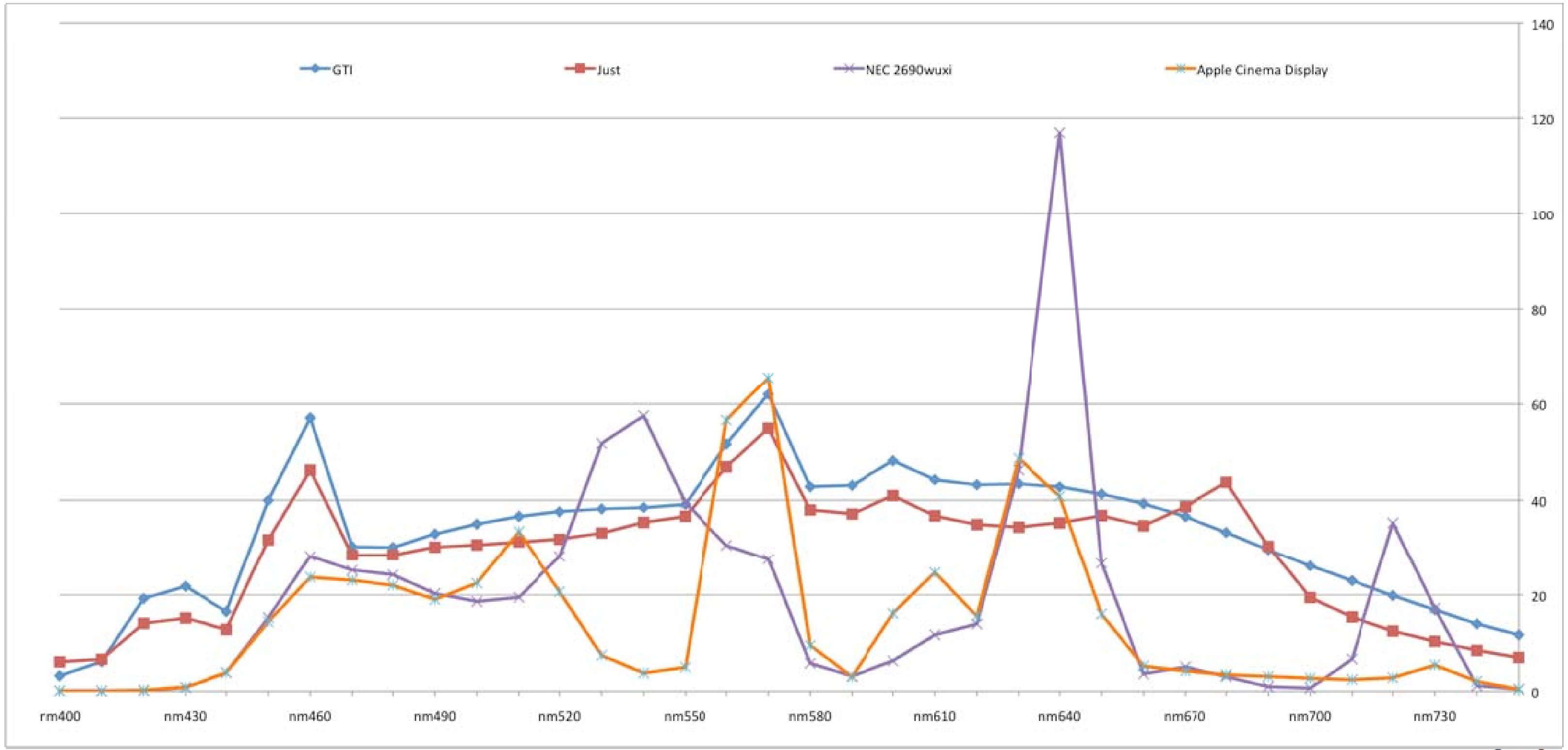
- **XYZ values are computed by integration, two stimuli with very different SPD can provide identical cone response for a given observer, leading to a color match that should be metameric, but ultimately may not be.**

Managing Appearance

- Appearance phenomena are far too complex to be regulated to a single CFM, D50 only white point PCS.
- The differences in the wavelength distribution between the d50 standard and any real world light source causes color matching issues in real world workflows.
- Any two spectra that “look” the same even though the spectra are different are called metamers and are metameric to each other only in that trichromatic system. So the metamers may be different between human observers, or more certainly between different trichromatic measurement systems.
- The same object that looked the same to our eye under different illumination, will not have the same appearance in a digital camera sensor.

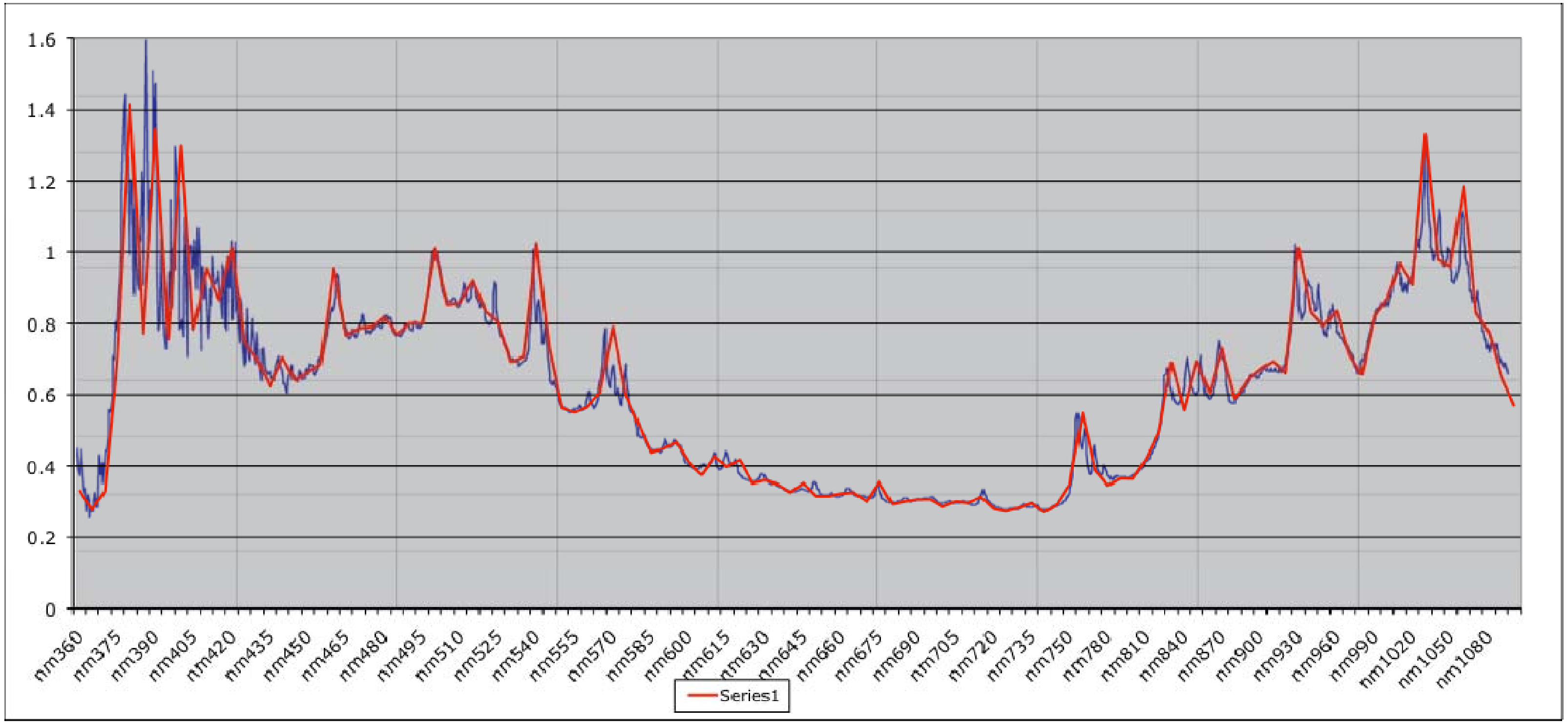
Colorimetric matching in Displays

- **Two D50 calibrated displays & two 5000k standard booths**
- **Display systems don't have identical colorimetric behavior after.**



Colorimetric matching in photography

- **Xenon Photo Lighting balanced to 5000k**



Spectral workflows: The Road to Color Accuracy

- **A spectral PCS allows for spectral data to be recorded for devices, and key scene components, then corrected for in image processing.**
- **Key image data can then be properly rendered and recorded.**
- **A spectral PCS is needed to even begin to accurately describe simply illuminated scenes, and product colors**
- **A CFM for a device, and Illuminant information will provide a good starting point for this process, but it must be noted that sensor responses are not linear and also vary with lens and aperture choice, so a 3D model of camera sensitivities is better starting point for this wok flow.**

A Variety of problems

- **Today's CMS's experience observer, illuminant, and geometric metamerism.**
- **Goals are spectral input to PCS and best spectral output to remove any observer or device or lighting metameric effects.**
- **Sample ICC is the start of a working example of ICC .2 the next generation of ICC profile and color management.**
- **An Extension of today's color management processes to enable increased accuracy in color transforms.**

Spectral Processing Workflow

- Camera correction is only requires for sensors who's spectral sensitivities are not equal to the color matching functions.
- Without this step there will be no single correct transformation from camera values to colorimetry.
- Making spectral data profitable in a metameric workflow.
- Spectral imaging systems allow light or object spectra to be distinguished, in situations where a metameric imaging system may completely fail to match color accurately.
- If scene spectral reflectance is needed PCA can be used to compare color-signal information to produce reconstructed spectra from a camera sensor.

ICC .2 to the Rescue

- Spectral profiles will provide a home for object as well as illuminant data.
- Custom Viewing conditions
- Support for bi-spectral data allows for more accurate transforms where UV excitation is an issue.
- Regular Euclidian n-dimensional vector space PCS transforms.
- Real and reference illuminant support.
- Standard and custom CMF's
- – Normal spectra => n-dimensional vector
- – bi-spectral data => m-dimensional vectorSupport for future work from CIE Div 1 "The Color Size Effect"

Conventional Spectral transform

For Conventional Spectra

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \frac{100}{\sum_{i=1}^{n} Y_i \, I_i} \begin{pmatrix} X_1 \cdot I_1 & X_2 \cdot I_2 & & X_n \cdot I_n \\ Y_1 \cdot I_1 & Y_2 \cdot I_2 & \dots & Y_n \cdot I_n \\ Z_1 \cdot I_1 & Z_2 \cdot I_2 & & Z_n \cdot I_n \end{pmatrix} \begin{pmatrix} R_1 \\ R_2 \\ \cdot \\ R_n \end{pmatrix}$$

With (XYZ) Tristimulis Values

(X_i, Y_i, Z_i) for the CMF's at a given wavelength i

I_i = the power spectrum of the illuminant at wavelength i

R_i = The reflectance or trasmission curve of the object color

bi-spectral and emission spectra

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \frac{100}{\sum_{i=1}^{n} Y_i I_{i+s-1}} \begin{pmatrix} X_1 & X_2 & & X_n \\ Y_1 & Y_2 & \dots & Y_n \\ Z_1 & Z_2 & & Z_n \end{pmatrix} \begin{pmatrix} D_{11} & & D_{1m} \\ D_{21} & \dots & D_{2m} \\ . & & . \\ D_{n1} & & D_{nm} \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ . \\ I_m \end{pmatrix}$$

with (XYZ) Tristimulis Values

(X_i, Y_i, Z_i) = for the CMF's at a given wavelength i

I_i = the power spectrum of the illuminant at wavelength i

D_{ij} = The ijth element of the Donaldson matrix with the dimension n by m

s = an index

Emission spectra

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \frac{100}{\sum_{i=1}^{n} Y_i W_i} \begin{pmatrix} X_1 & X_2 & & X_n \\ Y_1 & Y_2 & \dots & Y_n \\ Z_1 & Z_2 & & Z_n \end{pmatrix} \begin{pmatrix} E_1 \\ E_2 \\ . \\ E_n \end{pmatrix}$$

with (XYZ) Tristimulis Values

(X_i, Y_i, Z_i) = for the CMF's at a given wavelength i

E_i = the emission spectrum at wavelength i

W_i = the reference emission spectrum at wavelength i

Future Issues

- The failures of the CIE D50 systems occur throughout the color space.
- Color inconstancy issues will continue to become progressively greater as narrow band LED lighting and Laser primaries increase in use.
- Spectral imaging's advantages will eclipse the current tristimulus systems mainly because this data is needed for increased manufacturing efficiencies.
- Color matching and verification between different processes will become more complex.

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