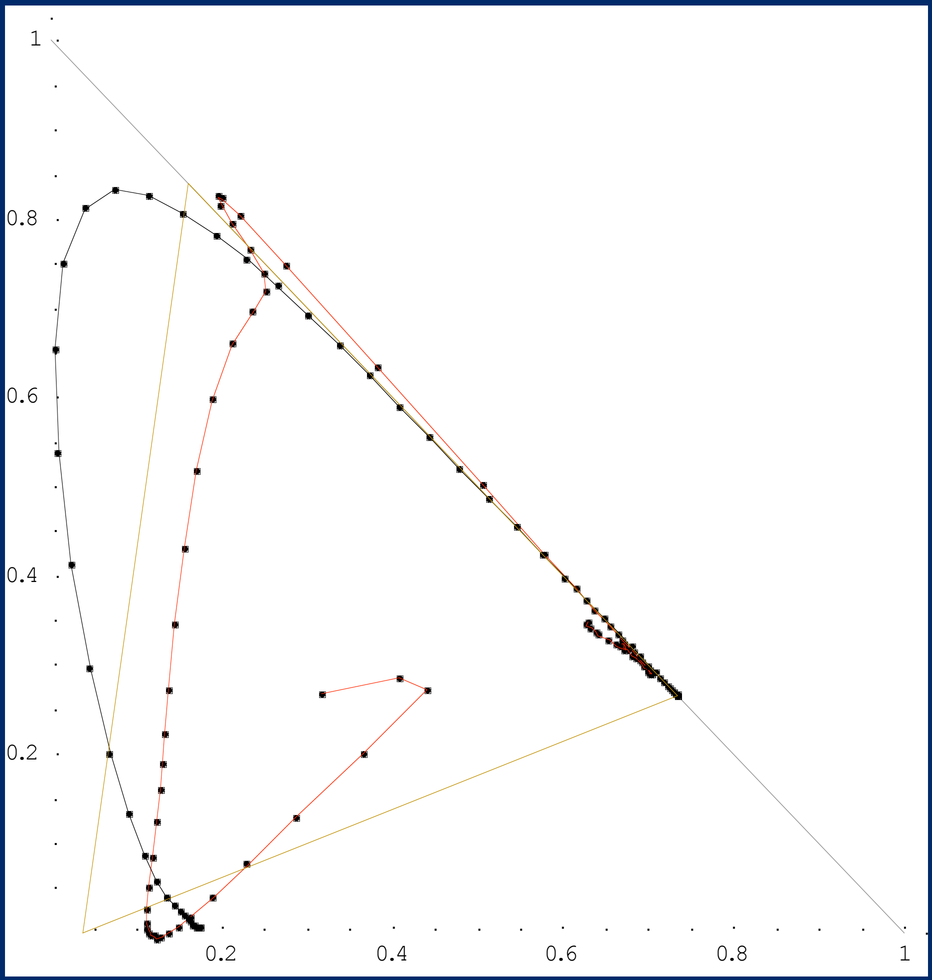
Capture Color Analysis Gamuts

Jack Holm
Hewlett-Packard Company
Palo Alto, CA

What is a “capture color analysis gamut”

- The gamut of scene colors as analyzed by the capture device
- If the camera is colorimetric, the capture color analysis gamut will be identical to the scene color gamut
  - but very few capture devices are colorimetric
- When the capture device is not colorimetric, the capture color analysis gamut will depend on the camera spectral sensitivities and the color analysis transform used
- The capture color analysis gamut is before color rendering

A color gamut at different image states



- Scene to scene-referred

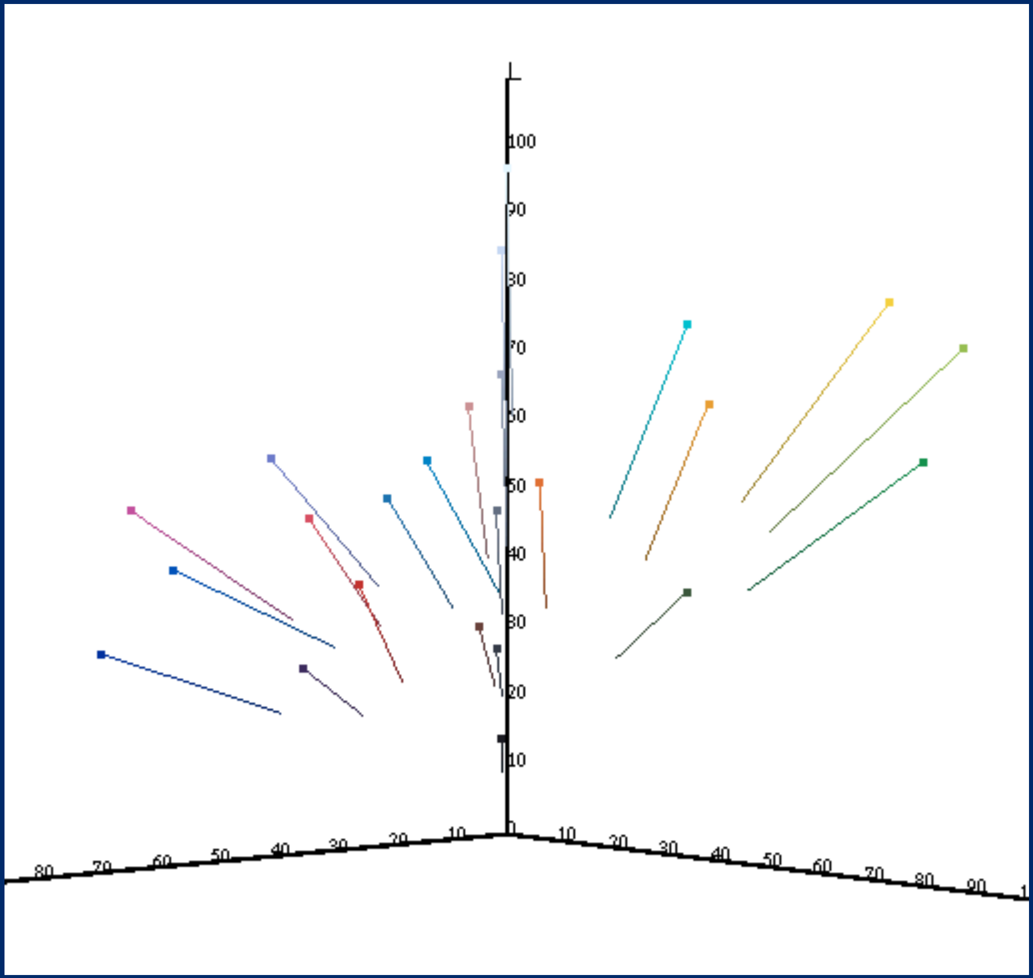
  black - possible scene gamut

  red - color analysis gamut

  (Canon 20D, nlPCRGBmin)

  yellow – RIMM RGB gamut

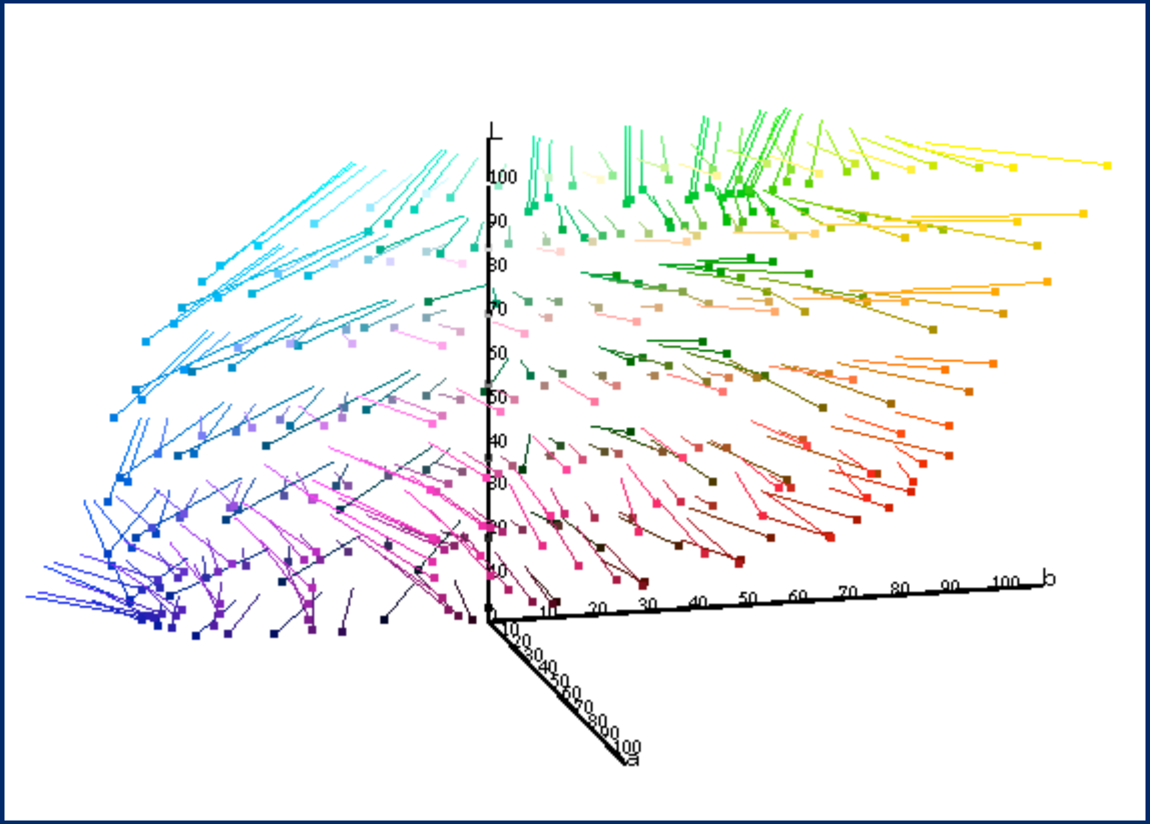
A color gamut at different image states



- Scene-referred to sRGB

A color gamut at different image states

- sRGB to Print



Color analysis transform determination

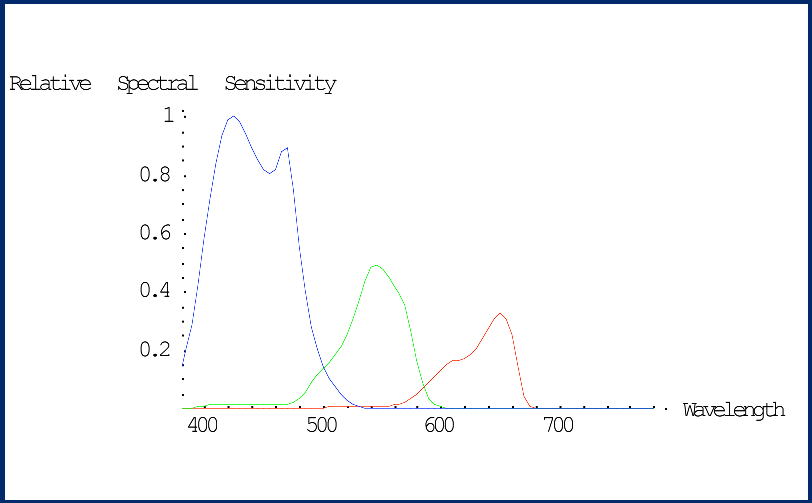
- Parameters
  - “training” stimuli
    - spectral colors, in-situ real world colors, test target colors
  - constraints
    - neutral preserving, non-negative result
  - weights
    - illuminant power, memory colors, problem colors
  - error minimization color space
    - XYZ, L*a*b*, L*u*v*, nonlinear RGB
  - error minimized
    - distance (e.g. delta E), least squares error

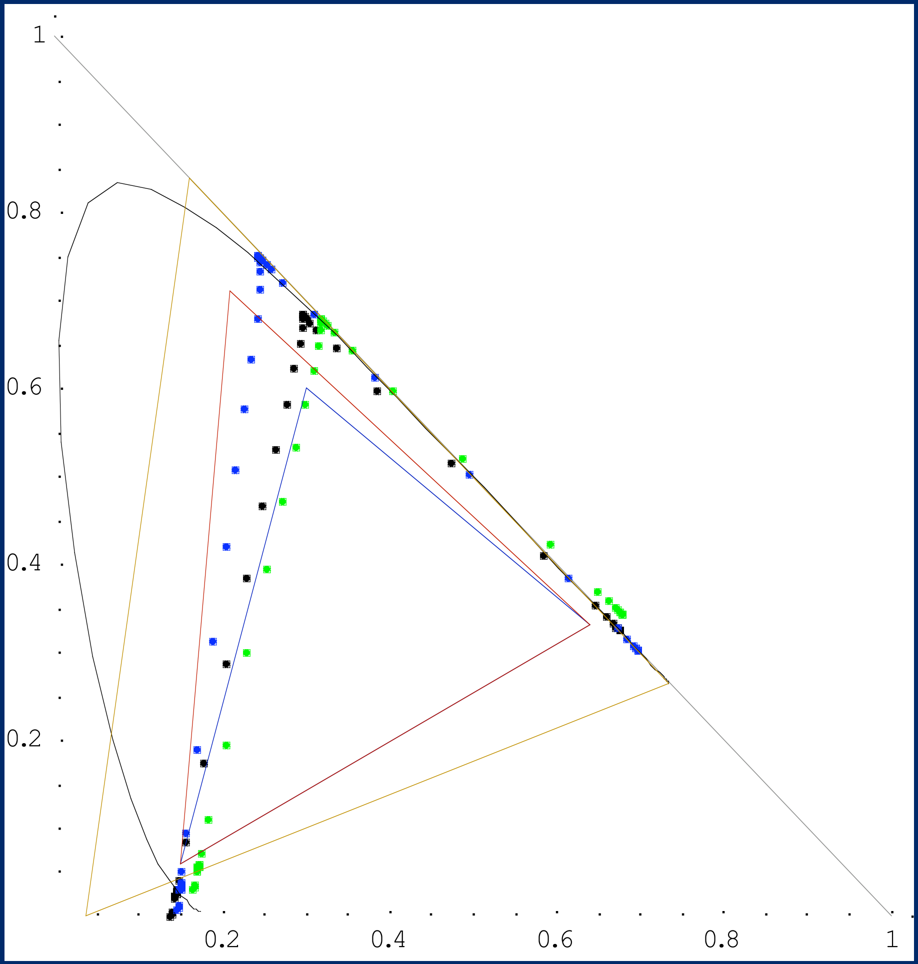
Color analysis transforms illustrated

- In this paper
  - Least-squares error minimization in XYZ
  - Equi-energy white point preserving least-squares error minimization in XYZ
  - Equi-energy white point preserving least squares error minimization in nonlinear prime colors RGB, weighted by illuminant power
  - Adobe DNG matrix (determination method unknown)

Kodak 5218 color negative film

- tungsten balanced





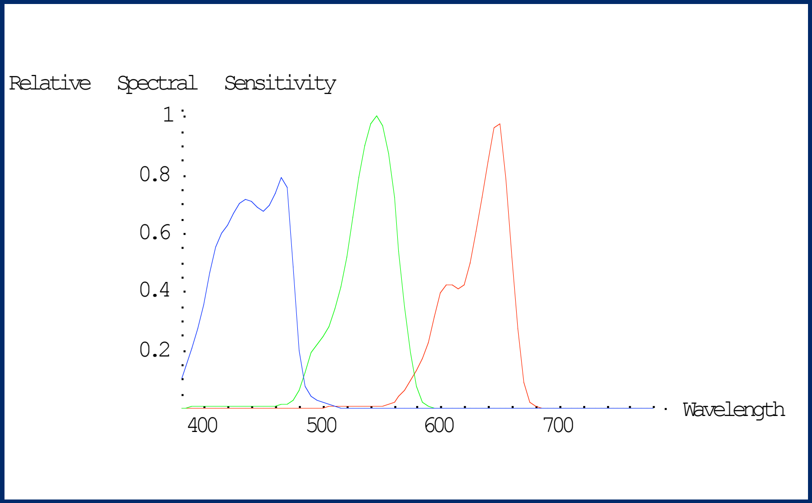
black – spectral, XYZ, least-squares

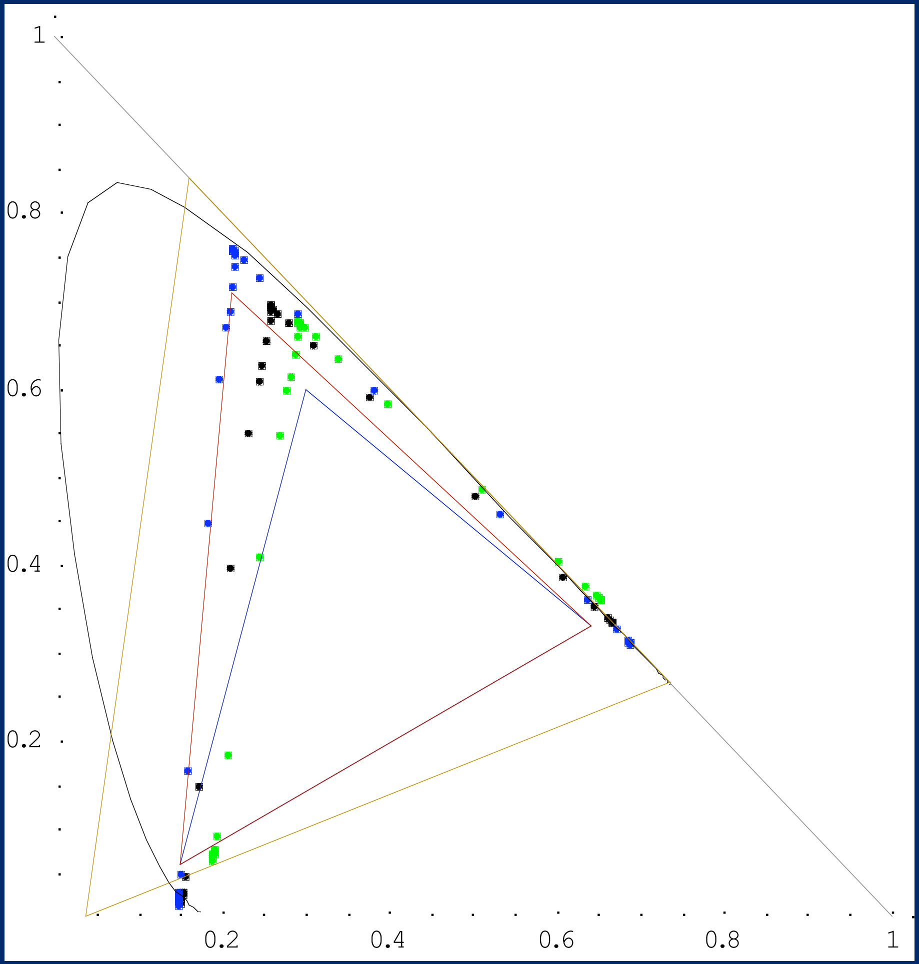
green – spectral, XYZ, WPPLS

blue – spectral, nlPCRGB, WPPLS, illuminant power weights

Kodak 5246 color negative film

- daylight balanced





black – spectral, XYZ, least-squares

green – spectral, XYZ, WPPLS

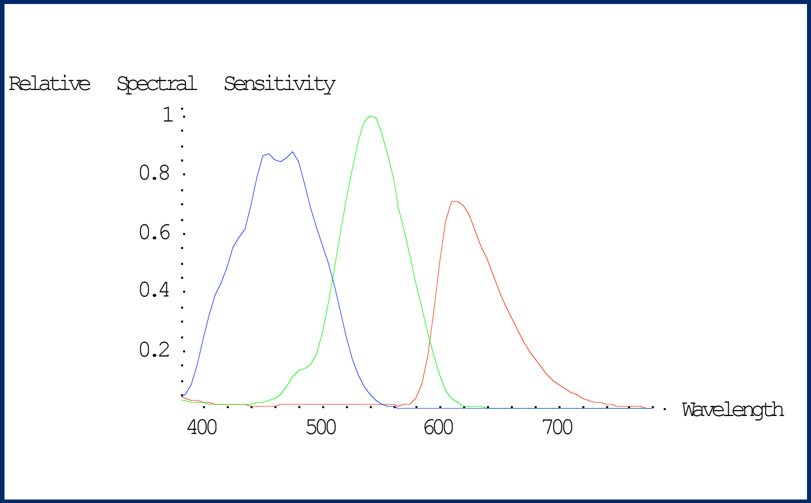
blue – spectral, nlPCRGB, WPPLS, illuminant power weights

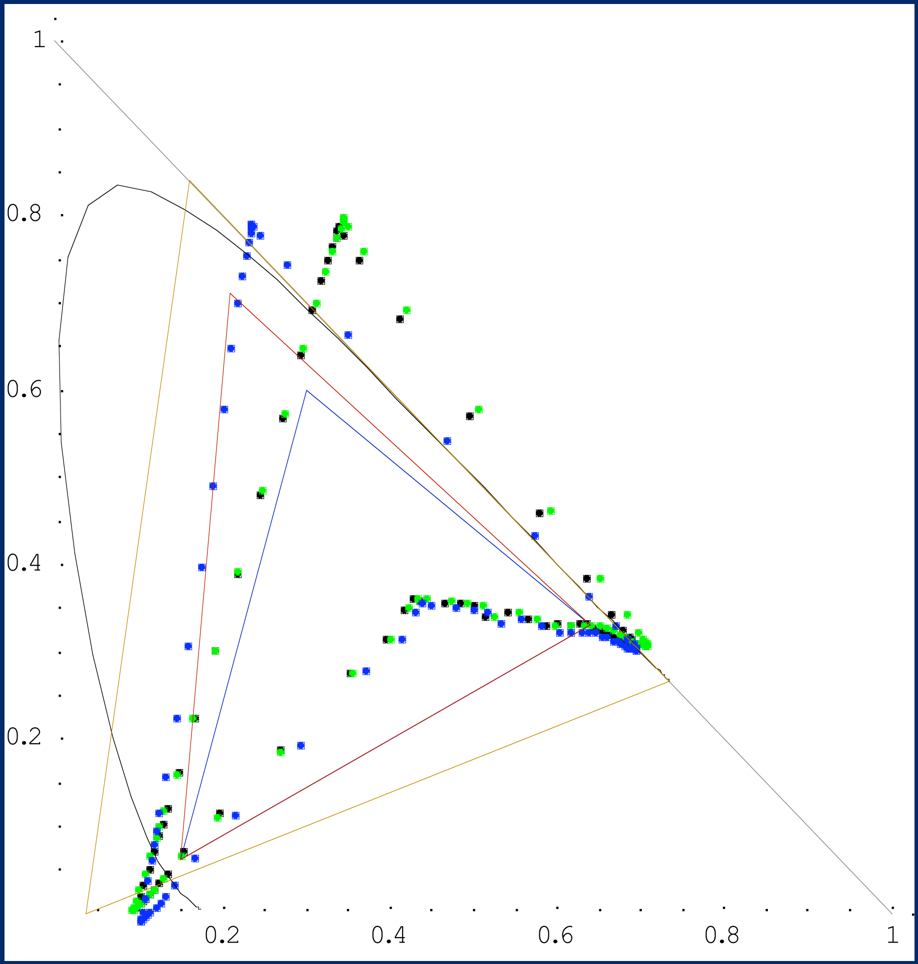
Film capture inter-image effects

- Scene analysis transforms based on film spectral sensitivities are applicable to integrated “channel” film exposure
- Inter-image effects complicate the relation between film densities and film exposures
- At the recent ICC meeting, Urabe reported that matrixing in log/density/dye concentration space may reasonably account for inter-image effects

Better Light digital scanning back

- RGB separation filters





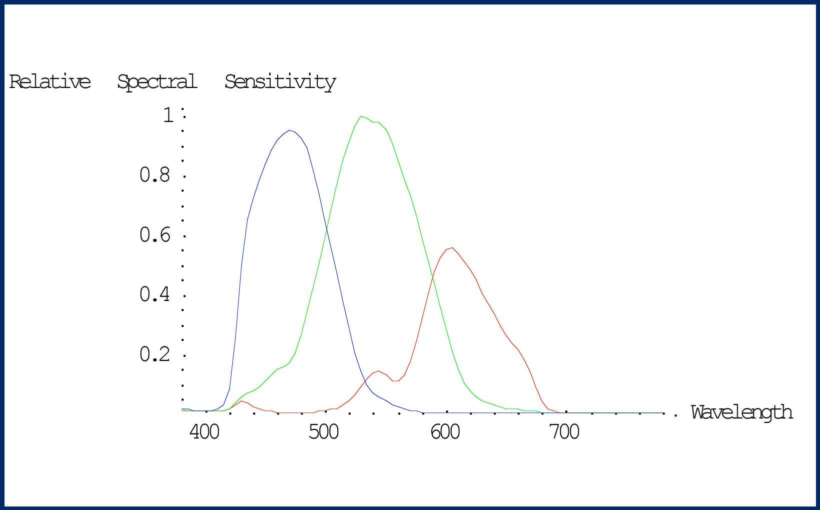
black – spectral, XYZ, least-squares

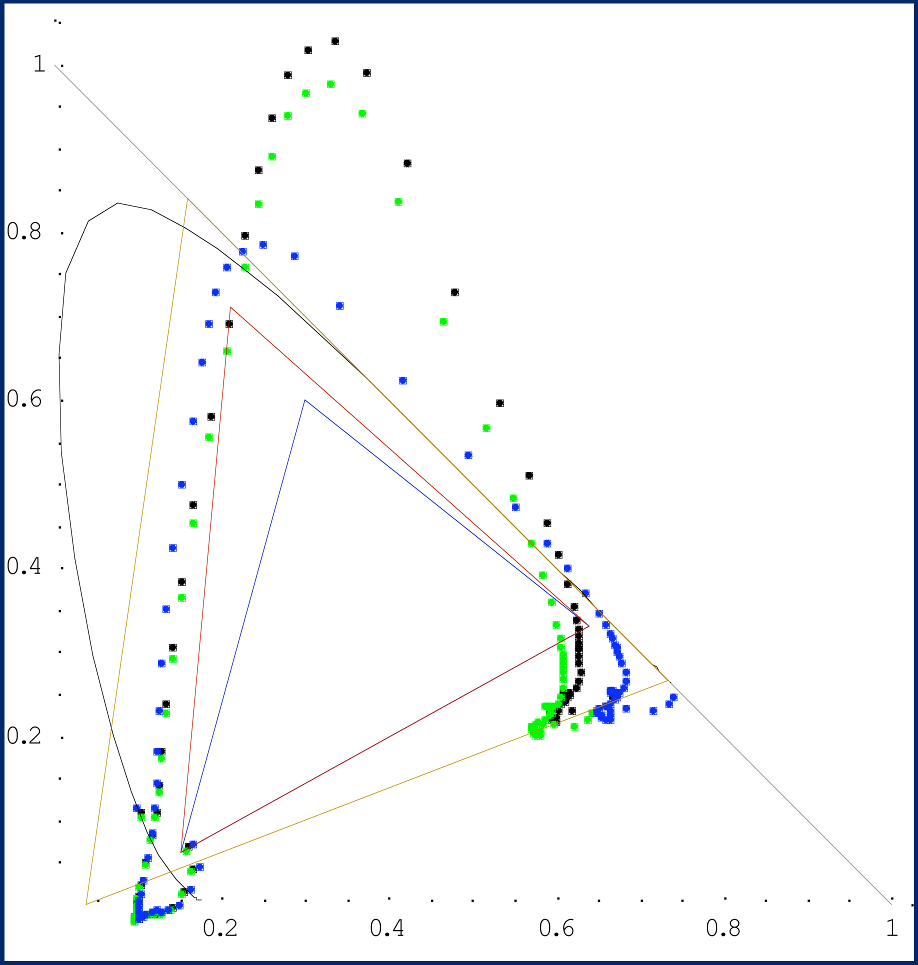
green – spectral, XYZ, WPPLS

blue – spectral, nlPCRGB, WPPLS, illuminant power weights

Megavision digital back for Hasselblad

- CFA CCD (frame transfer)





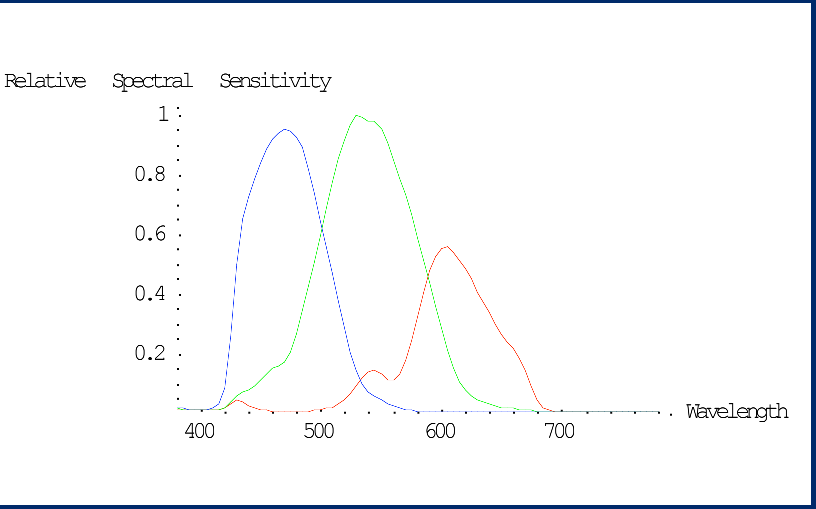
black – spectral, XYZ, least-squares

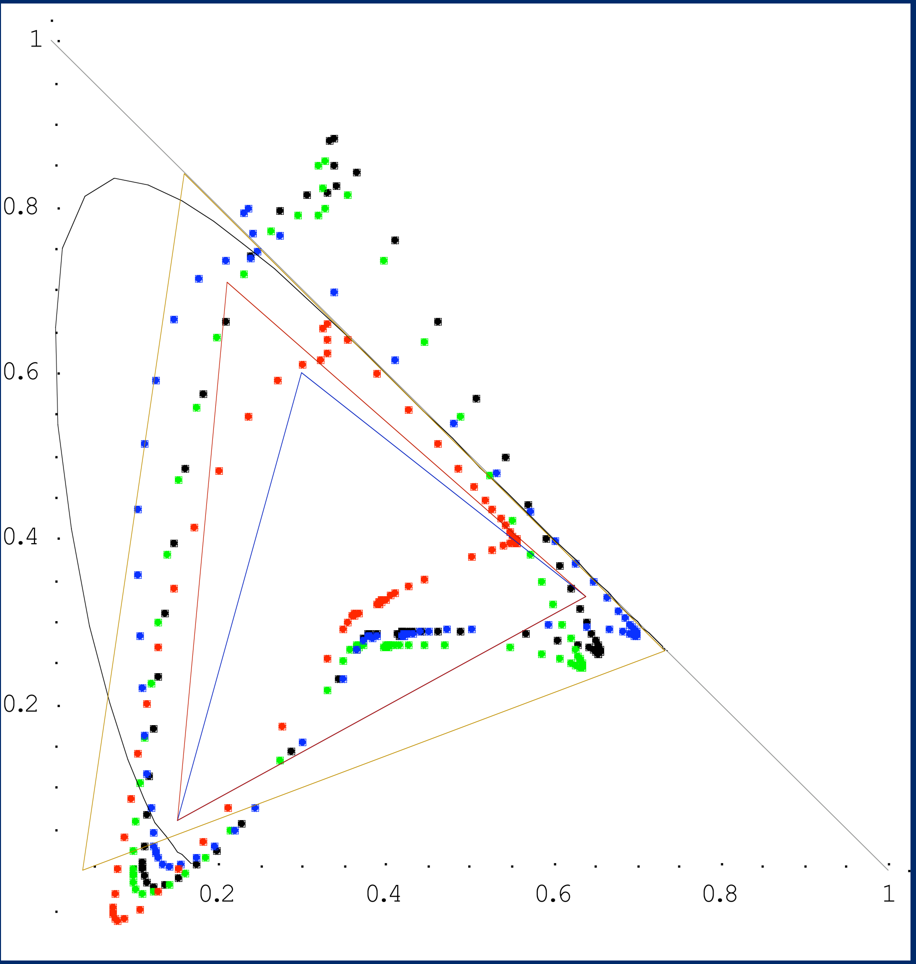
green – spectral, XYZ, WPPLS

blue – spectral, nlPCRGB, WPPLS,
illuminant power weights

Nikon D70 digital SLR

- CFA CCD





black – spectral, XYZ, least-squares

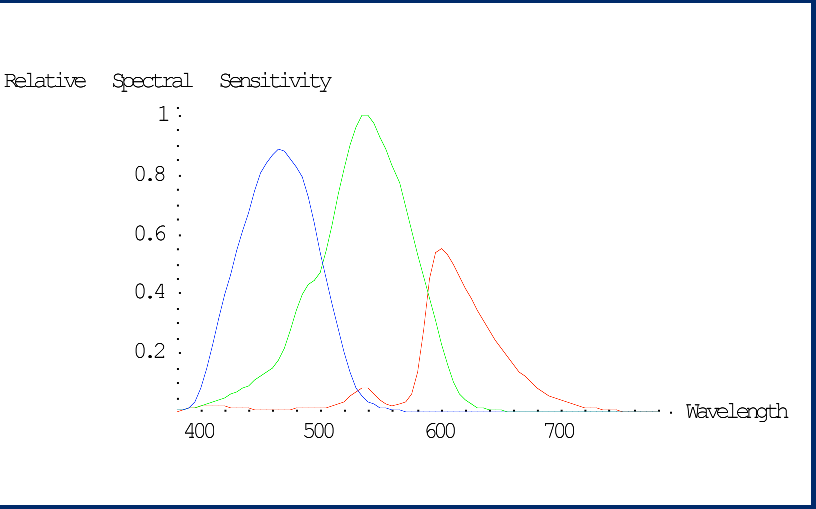
green – spectral, XYZ, WPPLS

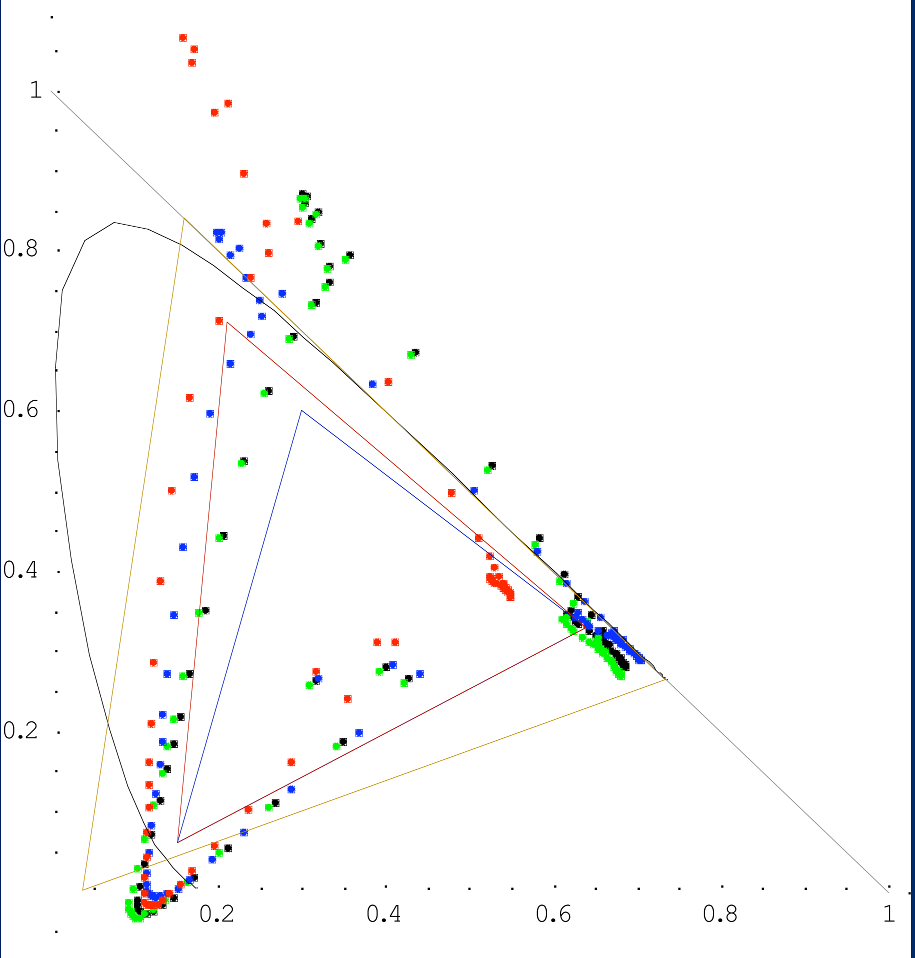
blue – spectral, nlPCRGB, WPPLS, illuminant power weights

red – Adobe DNG D65

Canon 20D digital SLR

- CFA CMOS





black – spectral, XYZ, least-squares

green – spectral, XYZ, WPPLS

blue – spectral, nlPCRGB, WPPLS, illuminant power weights

red – Adobe DNG D65

Summary & Conclusions (1)

- Popular capture media (film and digital cameras) deviate significantly from colorimetric analysis, but at the same time are commercially successful
- When the white balance and color rendering are optimized, the limiting factor in color reproduction quality is color analysis
- Usually color analysis is not the limiting factor
  - but poor color analysis results in a lowered quality ceiling
  - poor color analysis may result from a poor choice of the color analysis transform determination parameters, as there seems to be some flexibility in spectral sensitivities
- It is important to address color analysis and color rendering problems separately

Summary & Conclusions (2)

- Film (and color separation filter) spectral sensitivities tend to "spectrally gamut map" the scene gamut to smaller color analysis gamuts that are within the spectral locus and triangular
  - this may reduce the need for gamut mapping prior to color rendering
- Digital camera spectral sensitivities produce color analysis gamuts that are larger, somewhat more irregular, and extend further outside the spectral locus
- Generally, current capture color analysis gamuts fit the RIMM primary triangle better than the XYZ triangle
  - the RIMM color space is also better for application of some color rendering methods (e.g. RGB tone curve color rendering)

Summary & Conclusions (3)

- The color analysis transform determination parameters have a significant effect on the capture color analysis gamut
  - Quite different results are obtained with different reasonable parameters
- Some capture color processing systems need to be able to deal appropriately with “colors” that are analyzed to be significantly outside the spectral locus, or even the XYZ triangle