

# CSE 591: Visual Analytics

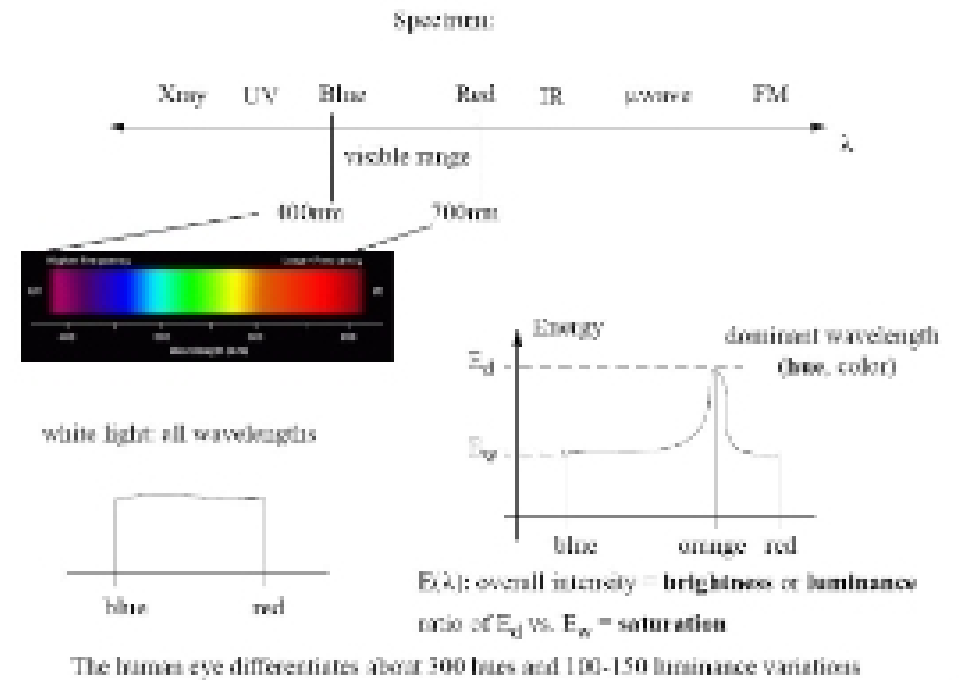
## Lecture 3: Color

Klaus Mueller

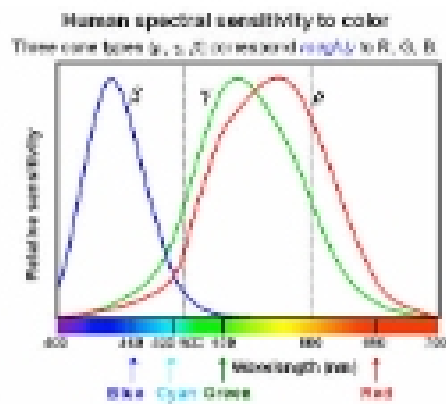
Computer Science Department  
Stony Brook University

With some material from Robert Kosara, UNCC, and Daniel Keim, U Konstanz

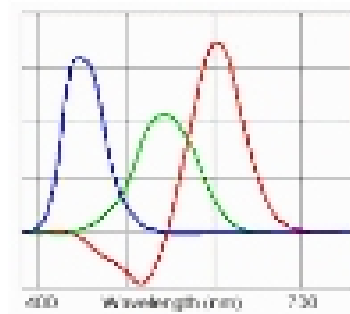
### Spectrum of Wavelengths



### Perception Curves



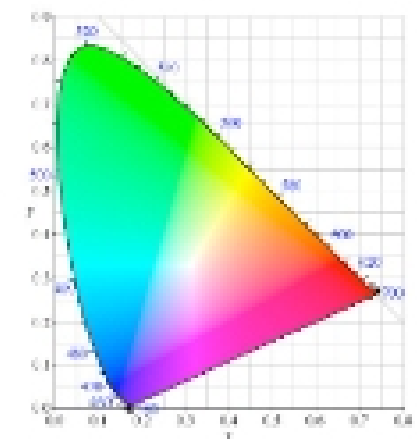
human color sensitivity curves



color generation with primaries

### Perceptual Color Spaces

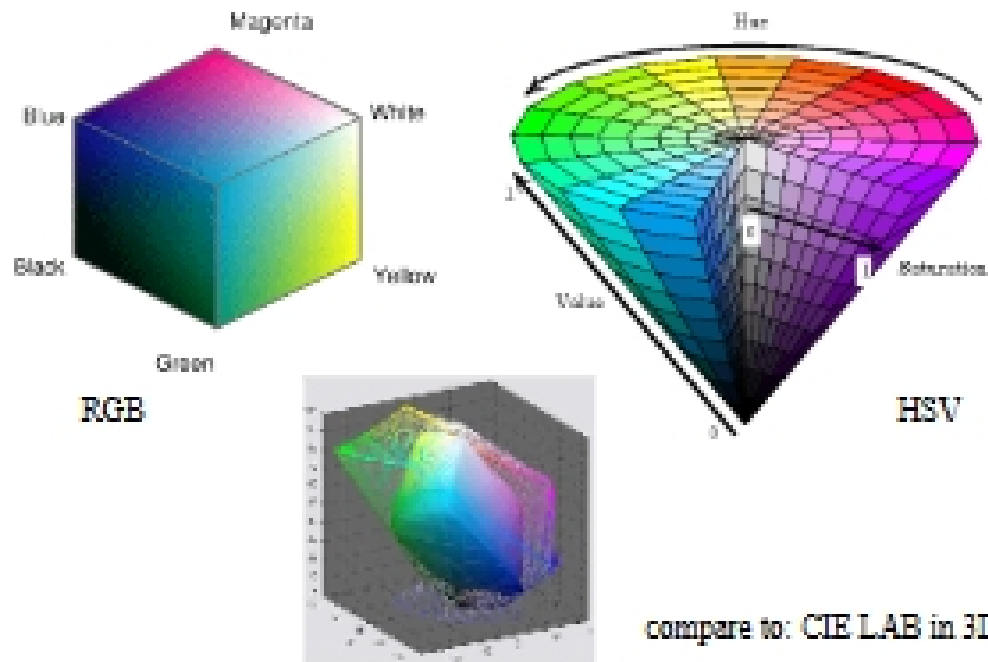
- Commission Internationale de l'Eclairage
- Model that combines rod information and removes luminance
- 2D horseshoe shape
- white in center
- Saturated colors around perimeter



Scott Koss

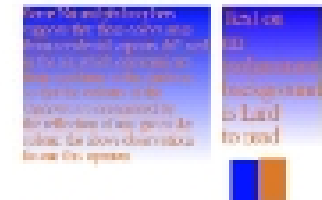
Visual Analytics  
http://www.vizualytics.com/visualanalytics.html

## Non-Perceptual Color Spaces



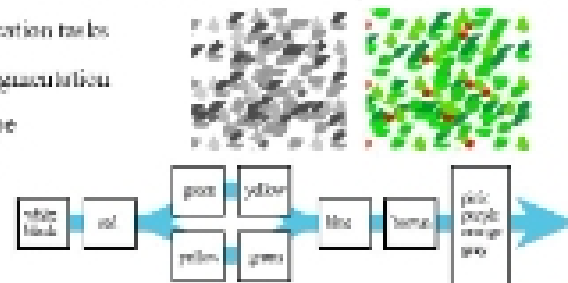
## More on Color

- Color resolution
  - the human eye differentiates about 300 hues and 100-150 luminance variations
  - best resolution is for green and red, low resolution for blue
- Color response
  - the time to response to a signal varies according to the color used
  - color ranking (from best to worst): yellow > white > red > green > blue
  - important features should be visualized in light colors, such as yellow and white
  - background information is best visualized in dark colors, such as green and blue
- Channel properties:
  - luminance channel: detail, form, shading, stereo, motion
  - color: surfaces of things, labels, categories (about 10)
  - red, green, blue, yellow are special (unique hues)
- Chromatic channels have low resolution
  - luminance contrast needed to see detail (3:1 recommended, 10:1 for small text)



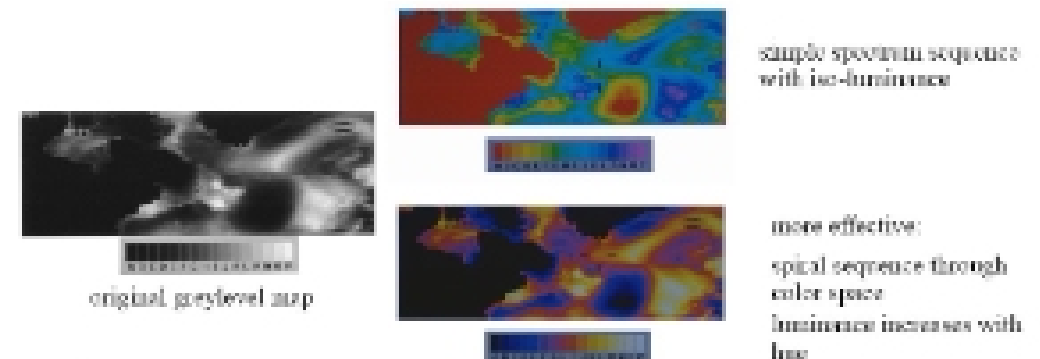
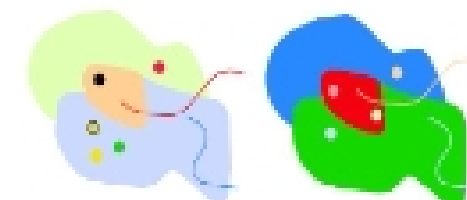
## More on Color

- Color blindness
  - a 3D to 2D space
  - 8% of males is R-G color blind
  - Y-B violation is OK
- Color resolution
  - color perception is relative
  - we are sensitive to small differences => hence need millions of colors
  - but we are not sensitive to absolute colors => hence we can only use < 10 colors for coding
- Color is very helpful for classification tasks
  - color aids in rapid visual segmentation
  - color helps to determine type
  - only about 6-11 categories



## More on Color

- Color coding
  - large areas: low saturation
  - small areas: high saturation
  - maintain luminance contrast
  - break iso-luminances with borders
- Pseudo-coloring: assign colors to grey levels by indexing the grey levels into a color map



## Use of Color

What is color for?

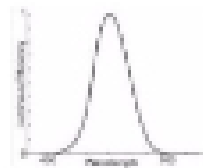
- labeling vs. aesthetics
- defines importance, function, set attention, mark controls
- but must keep luminance in mind!

Note: HSV, HSL are NOT perceptual models

- they cannot predict perceived lightness
- one must use CIE LUV or CIE LAB for this

Intensity vs. Luminance

- Intensity: integral of spectral distribution (power)
- Luminance: integral of spectrum x luminous efficiency

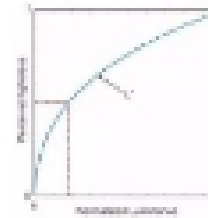


green and blue lights of equal intensity have different luminance values

example: cockpit

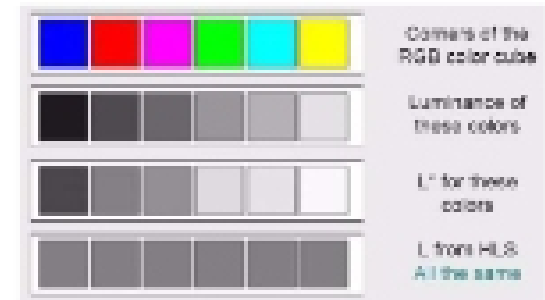


## Luminance Contrast



$L^*$  is a function of normalized luminance

$$L^* = 116(Y/Y_{ref})^{1/3} - 16$$



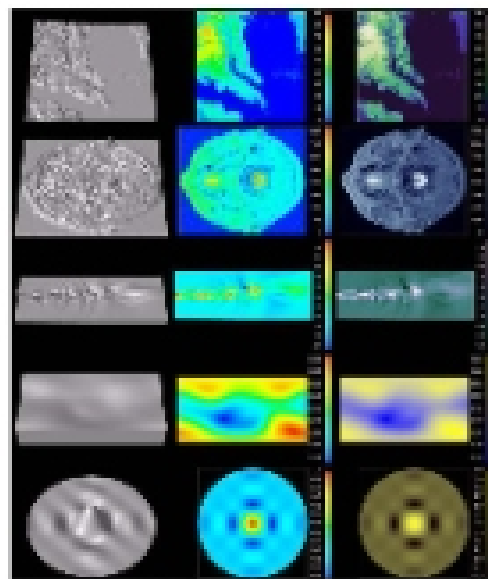
Use  $\Delta L^*$  for contrast

- 1 is ideally visible
- 10 is easily visible
- 20 is legible for text

What is value (luminance) for? (recall, color was for labeling, primary attention, etc.)

- perceived lightness/darkness
- no edge without lightness change
- no shading without lightness variation
- value difference defines contrast: defines legibility, controls attention

## Luminance Contrast



luminance mapped to RGB

just hue

hue and luminance

removes high frequency information by L

## Color Contrast and Harmony

**Definition**

- Acromatopsia
- RGB and YB are a
- Separate lightness from chroma channels

**First level encoding**

- Linear combination of LMS
- Define optic nerve
- Basis for perception
- Define "color cones"

**Acid-Dipole-Neutral Color**

- Dark with light
- Red with green
- Blue with yellow

These stamp on will have color blindness and low contrast

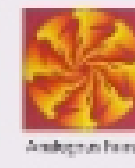
### Color Harmony

Apply contrast and analogy to text, values, elements



Color harmony

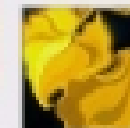
Color harmony: <http://www.its.uci.edu/~david>



Analogous colors



Step of color



Color harmony