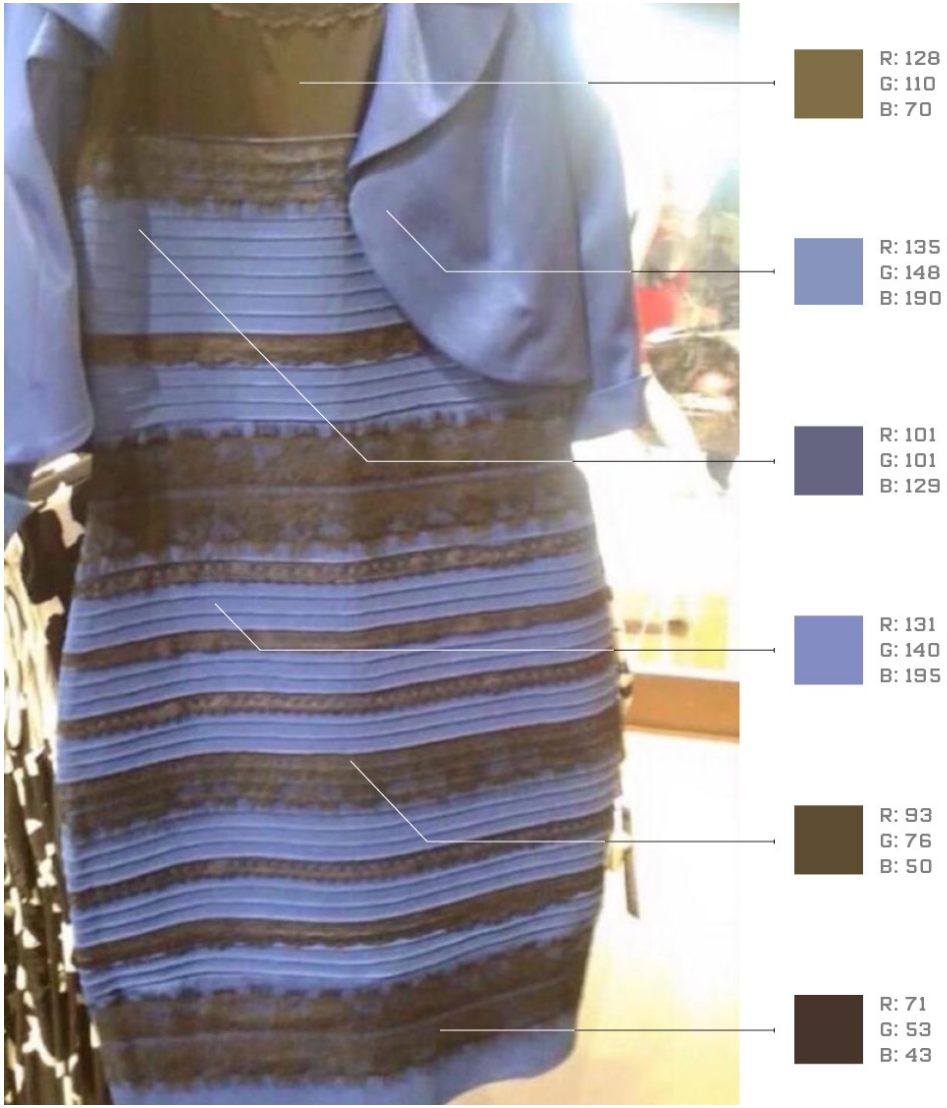
What's the color of the dress?

http://www.wired.com/2015/02/science-one-agrees-color-dress/

What's the color of the dress?



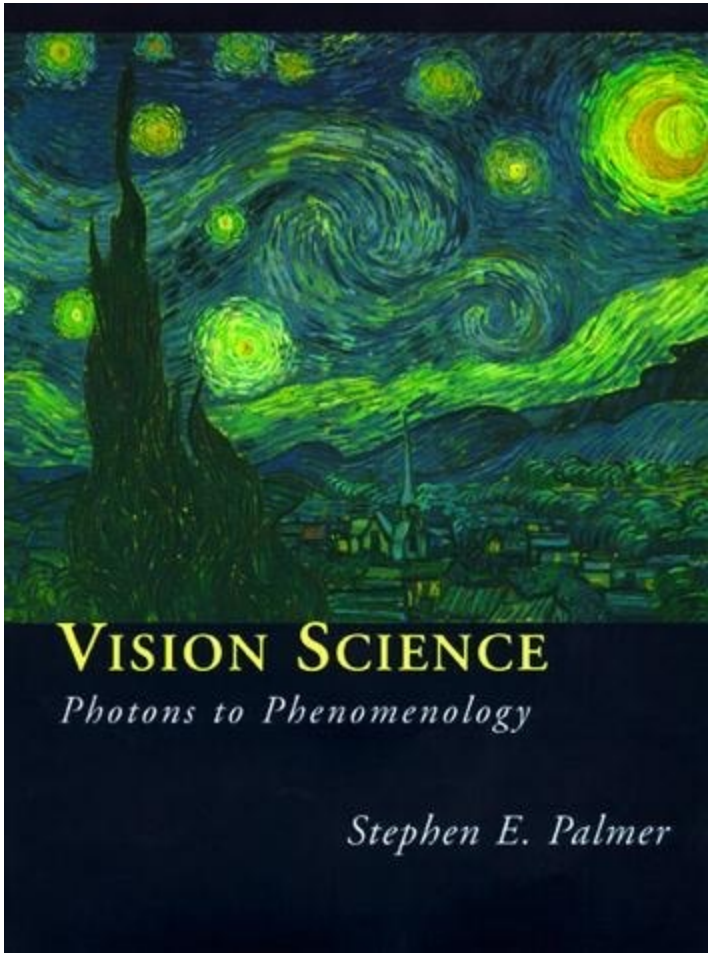
Color and light

- **Color of light** arriving at camera depends on
  - Spectral reflectance of the surface light is leaving
  - Spectral radiance of light falling on that patch

- **Color perceived** depends on
  - Physics of light
  - Visual system receptors
  - Brain processing, environment

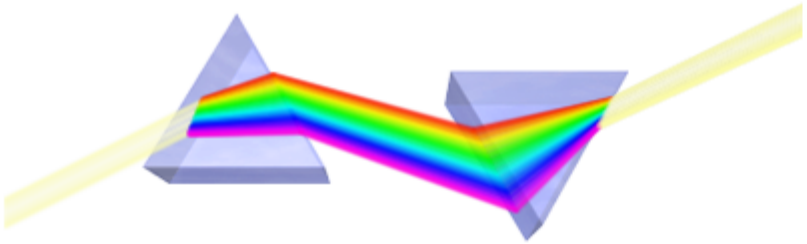
What is color?

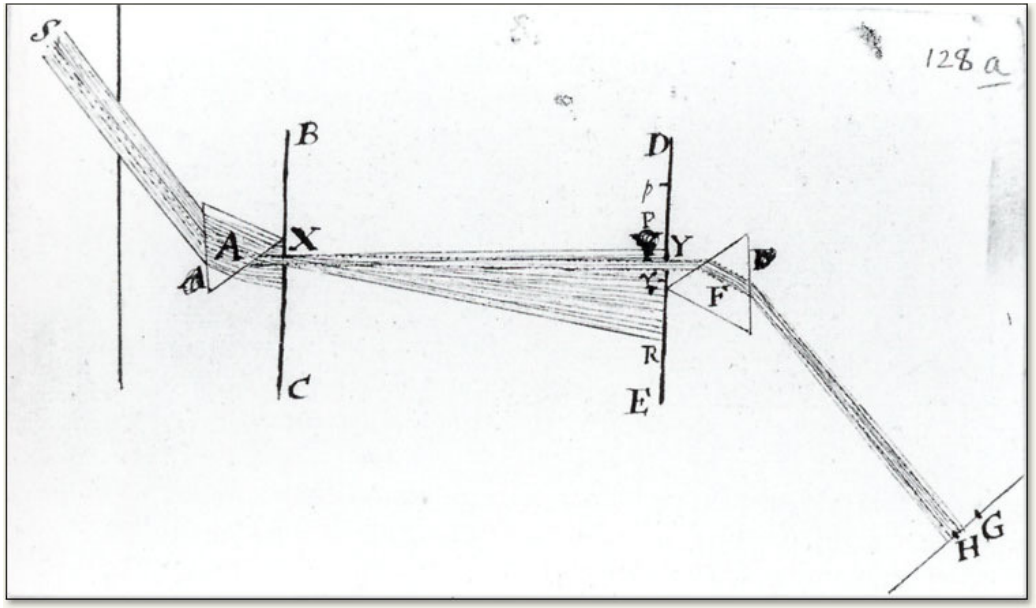
- Color is the result of interaction between physical light in the environment and our visual system
- Color is a psychological property of our visual experiences when we look at objects and lights, *not* a physical property of those objects or lights (S. Palmer, *Vision Science: Photons to Phenomenology*)



Color and light

White light:
composed of about equal energy in all wavelengths of the visible spectrum

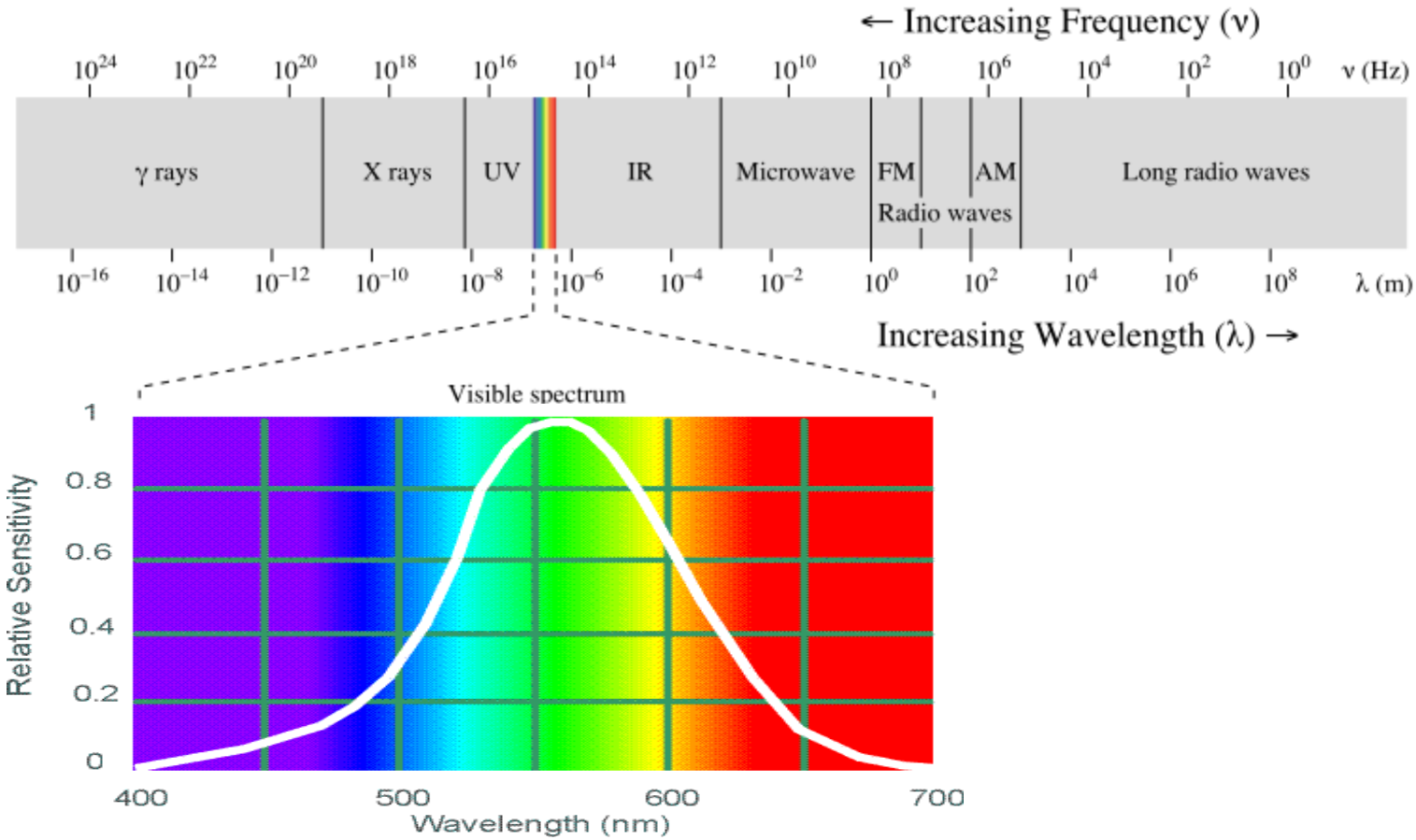




Newton 1665

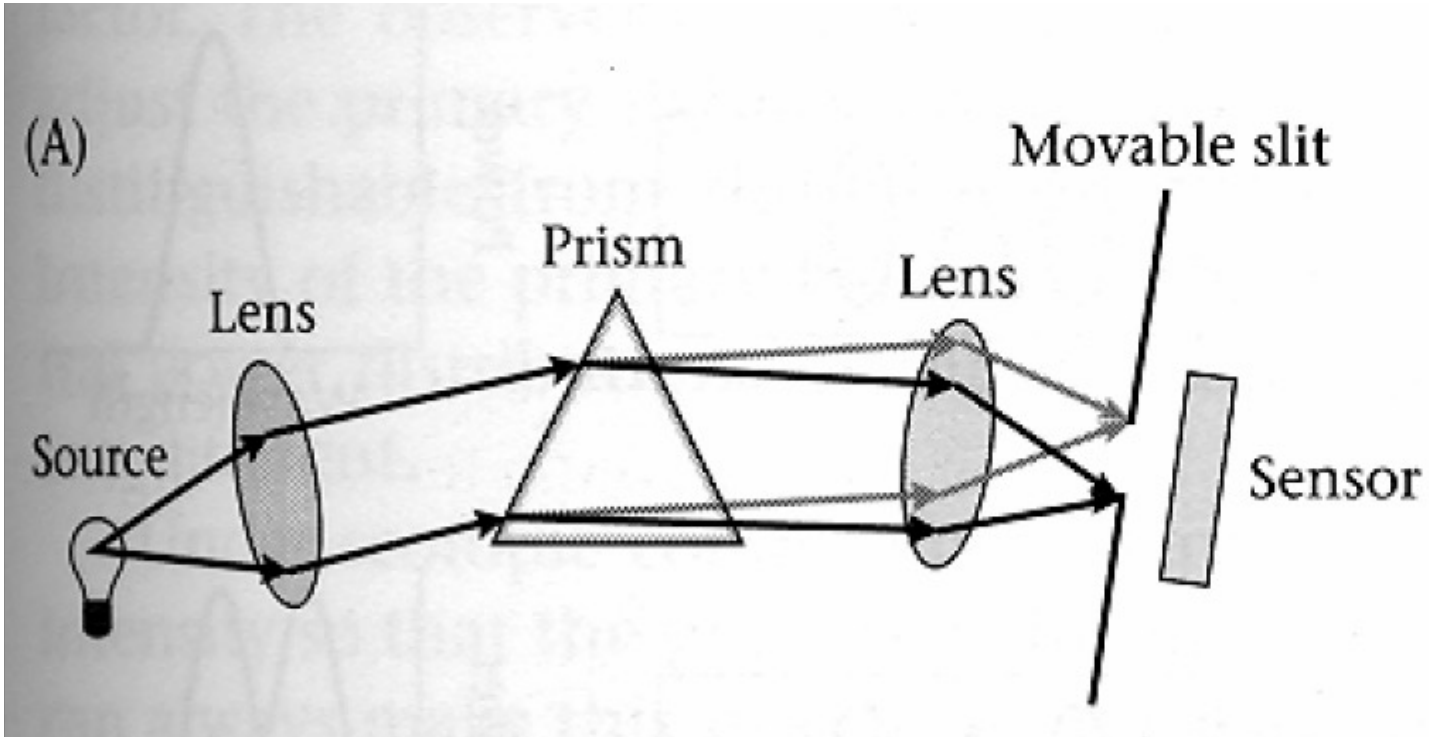
Image from http://micro.magnet.fsu.edu/

Electromagnetic spectrum



Human Luminance Sensitivity Function

Measuring spectra

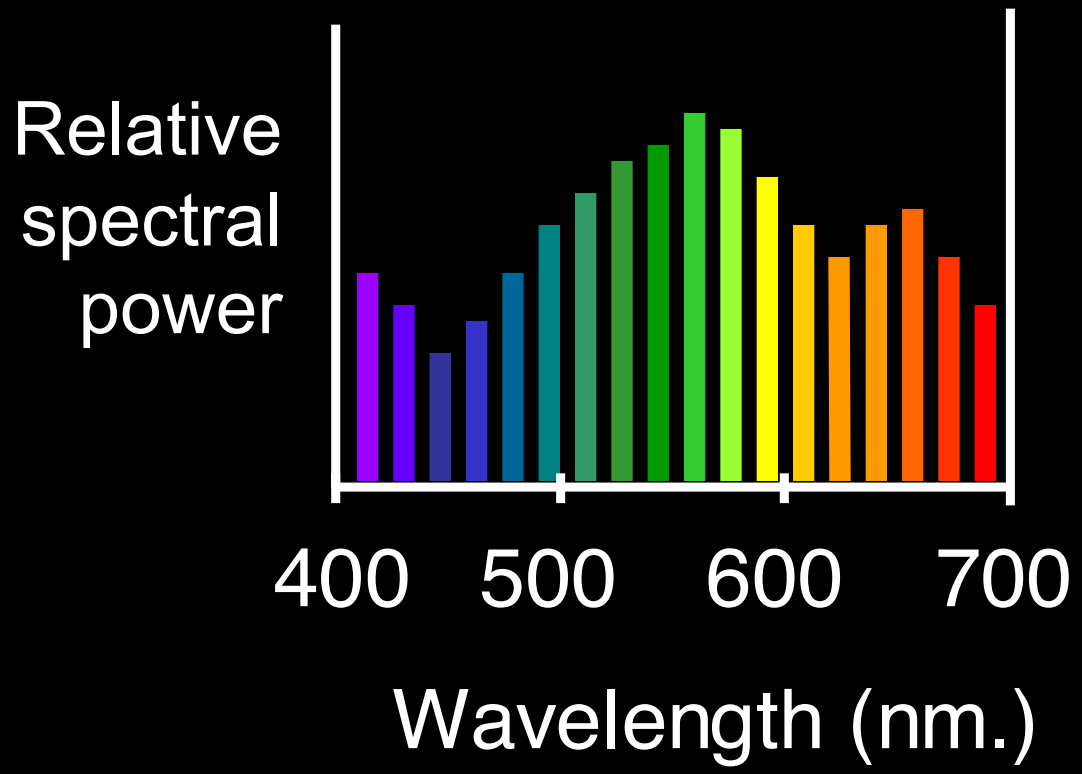


Spectroradiometer: separate input light into its different wavelengths, and measure the energy at each.

Foundations of Vision, B. Wandell

The Physics of Light

Any source of light can be completely described physically by its spectrum: the amount of energy emitted (per time unit) at each wavelength 400 - 700 nm.

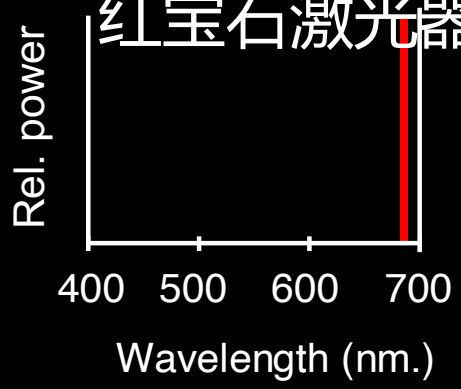


Spectra of Light Sources

Some examples of the spectra of light sources

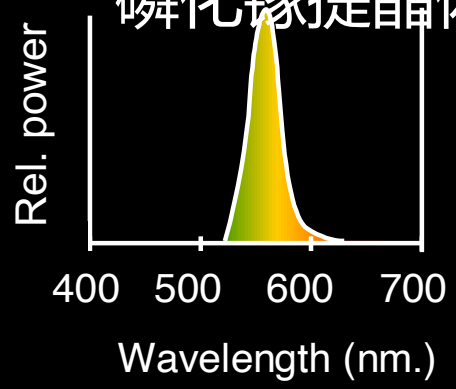
A. Ruby Laser

红宝石激光器



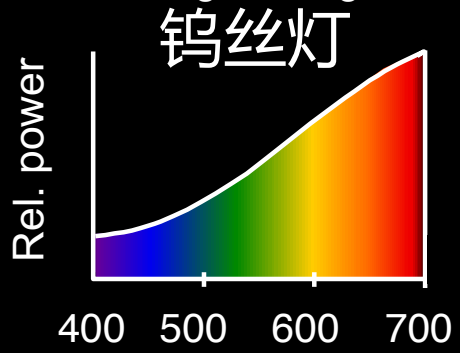
B. Gallium Phosphide Crystal

磷化镓提晶体



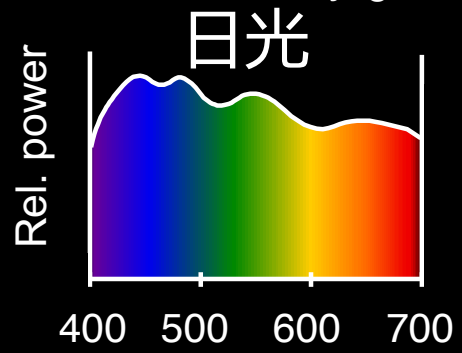
C. Tungsten Lightbulb

钨丝灯



D. Normal Daylight

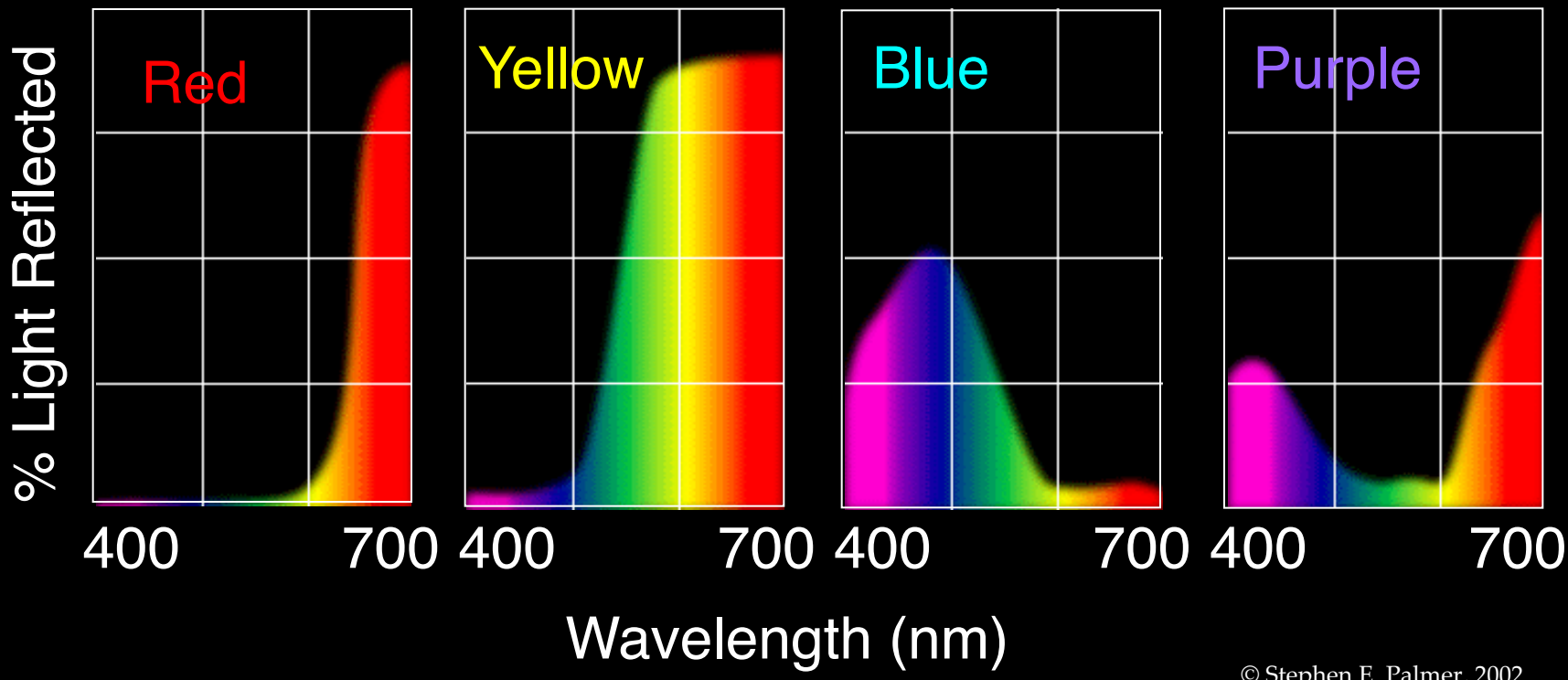
日光



Reflectance Spectra of Surfaces

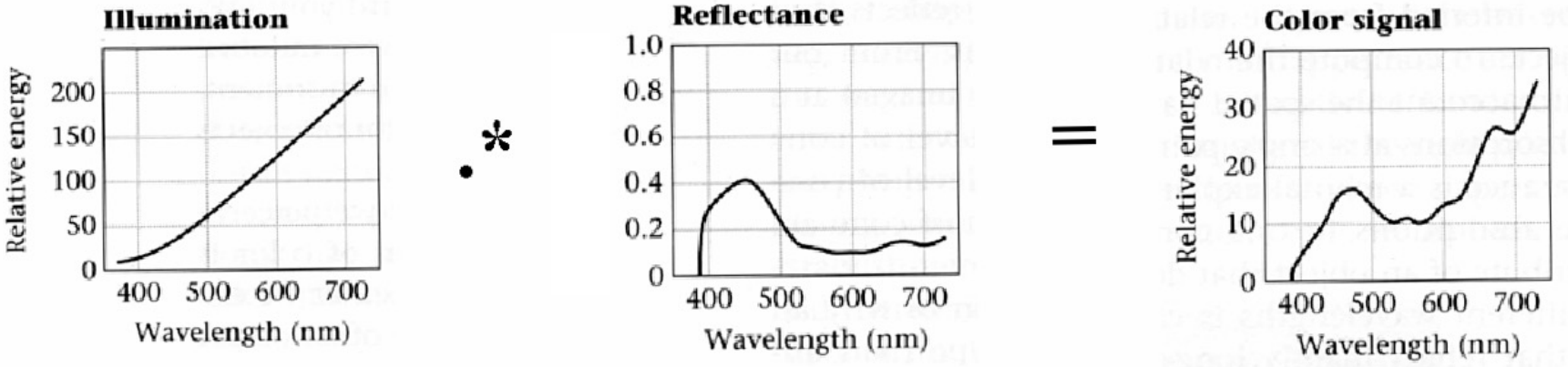
Some examples of the reflectance spectra of surfaces



Interaction of light and surfaces

- Reflected color is the result of interaction of light source spectrum with surface reflectance



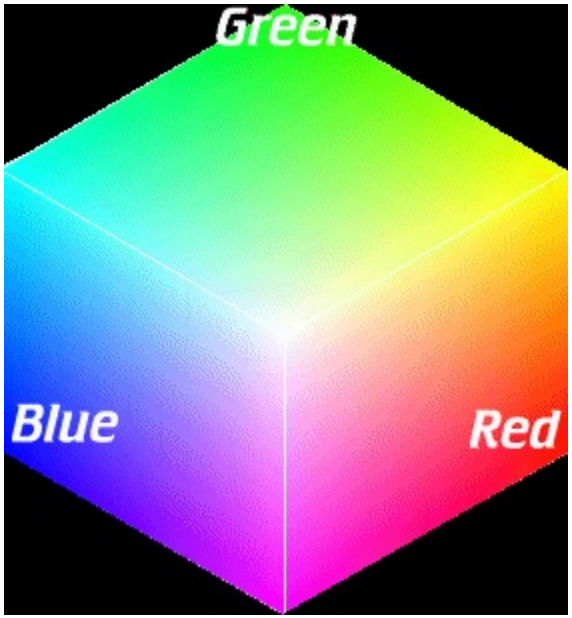
Standard color spaces

- Use a common set of primaries/color matching functions

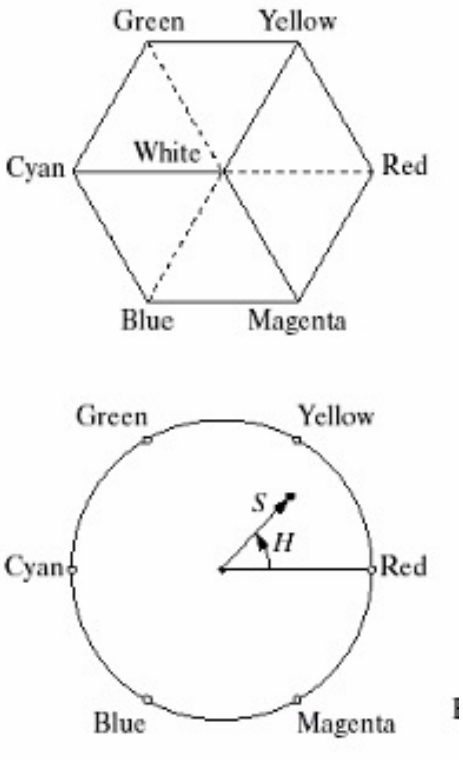
- Linear color space examples
  - RGB
- Non-linear color space
  - HSV

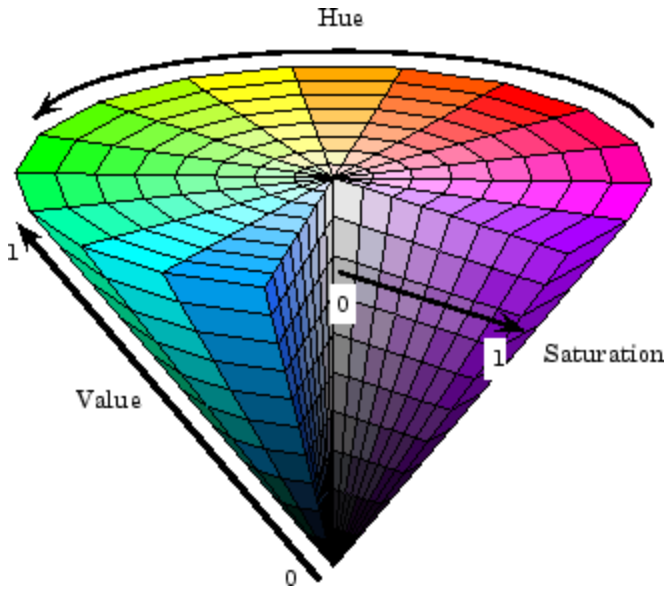
RGB color space

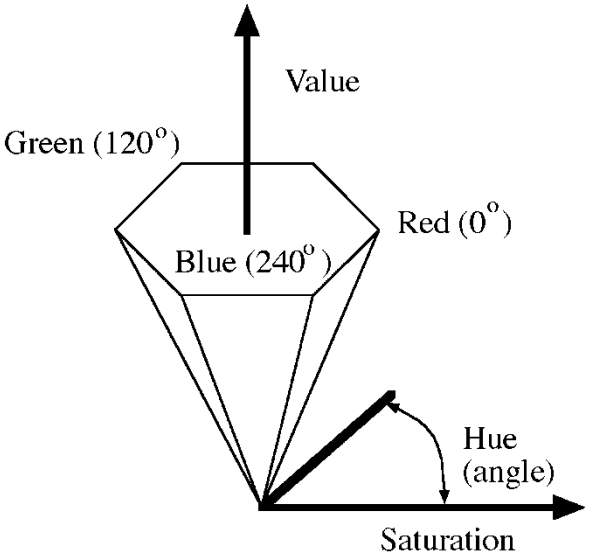
- Single wavelength primaries
- Good for devices (e.g., phosphors for monitor), but not for perception



Nonlinear color spaces: HSV







- Perceptually meaningful dimensions:

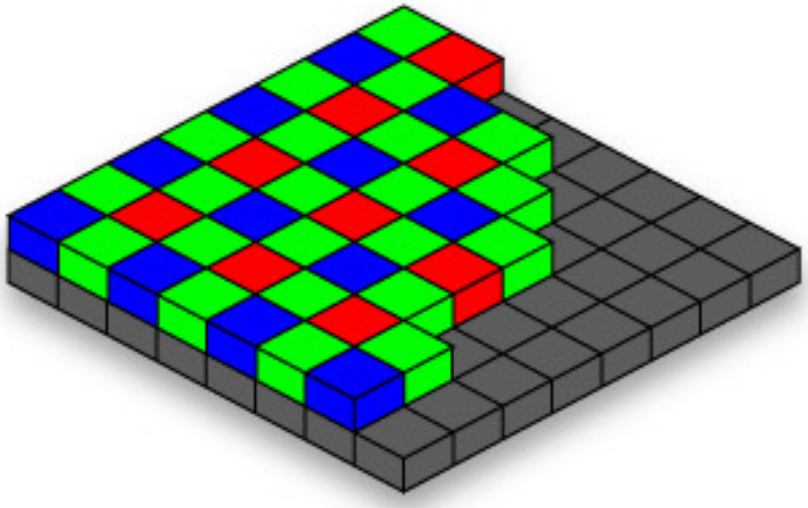
色彩 Hue (0-360°), Saturation (0-1), Value (Intensity 0-1)

色彩純淨程度

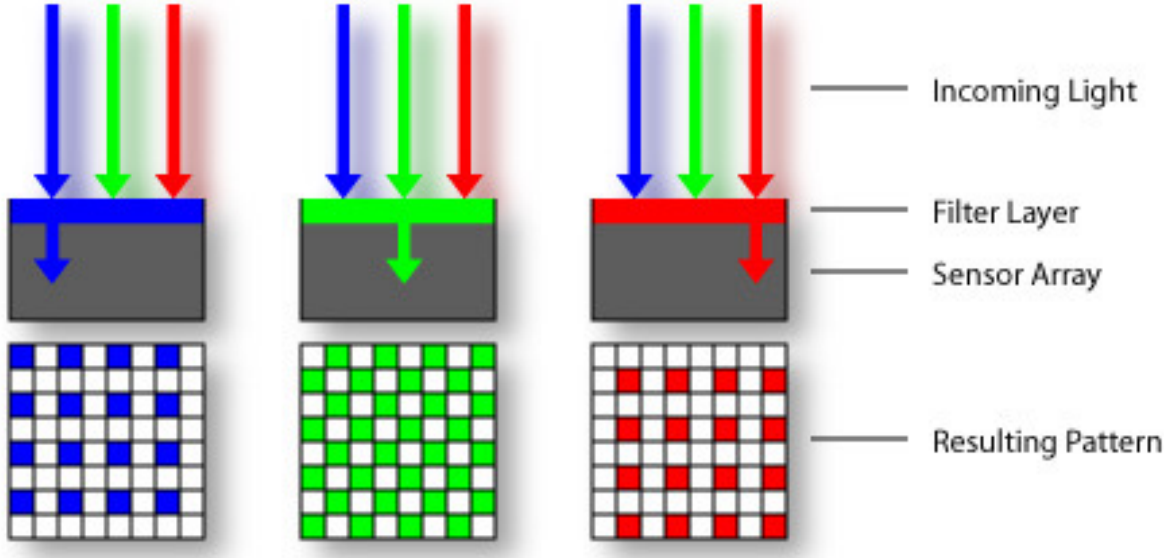
- RGB cube on its vertex

Color Sensing: Bayer Grid

空间差值



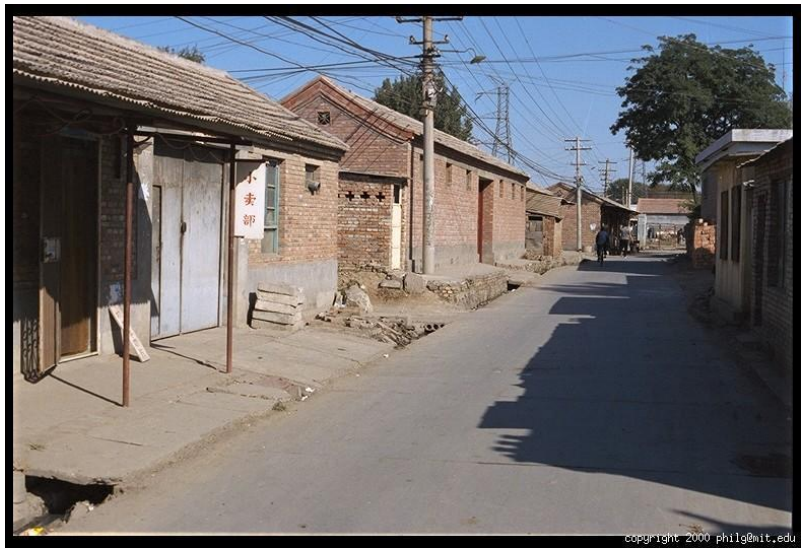
- Estimate RGB at each cell from neighboring values

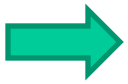


http://en.wikipedia.org/wiki/Bayer_filter

Slide by Steve Seitz

Color Image





R

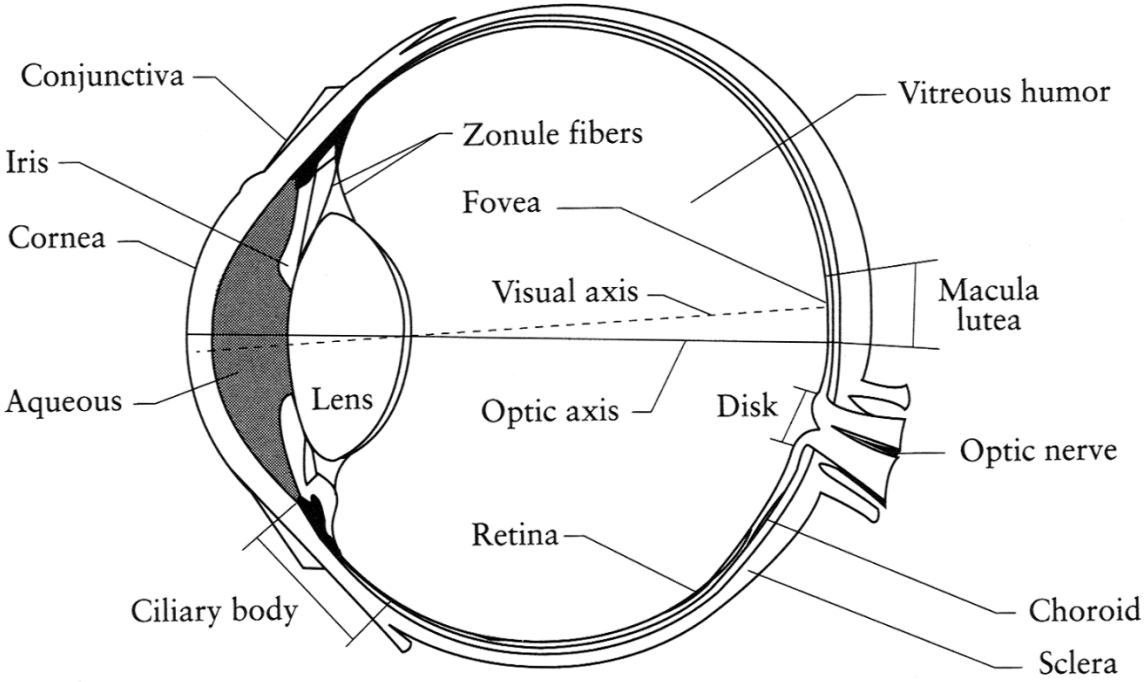
G

B

Why RGB?

If light is a spectrum, why are images RGB?

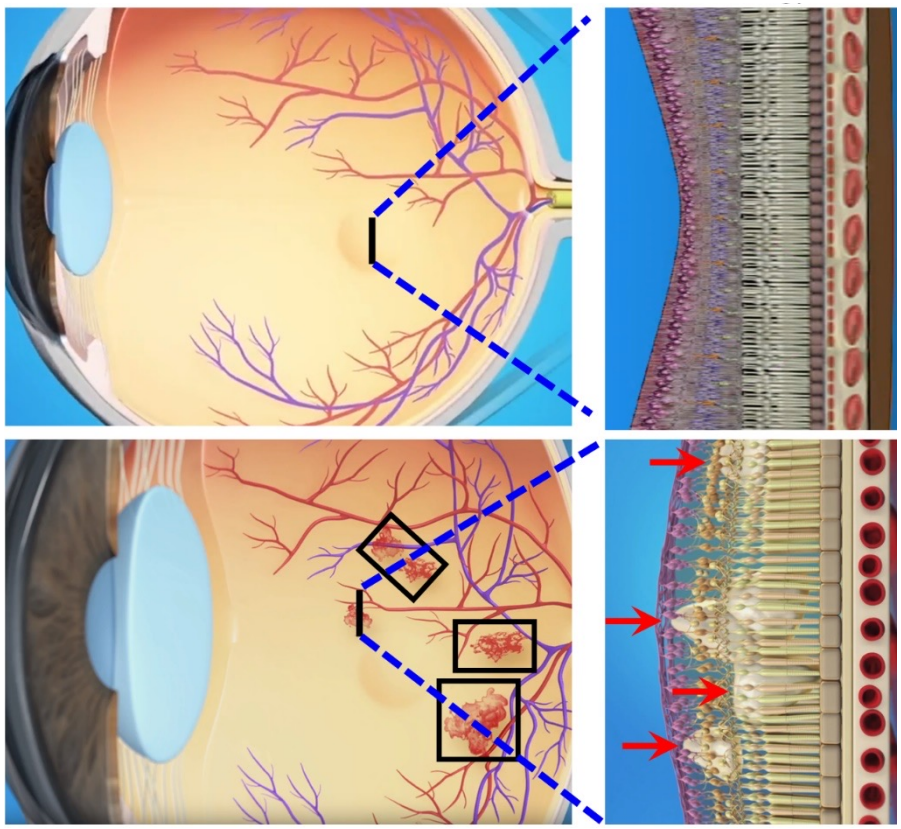
The Eye



The human eye is a camera!

- **Iris** （虹膜） - colored annulus with radial muscles
- **Pupil** （瞳孔） - the hole (aperture) whose size is controlled by the iris
- **Lens** （晶状体） - changes shape by using ciliary muscles (to focus on objects at different distances)
- **Retina** （视网膜） - photoreceptor cells 感光器

Slide by Steve Seitz



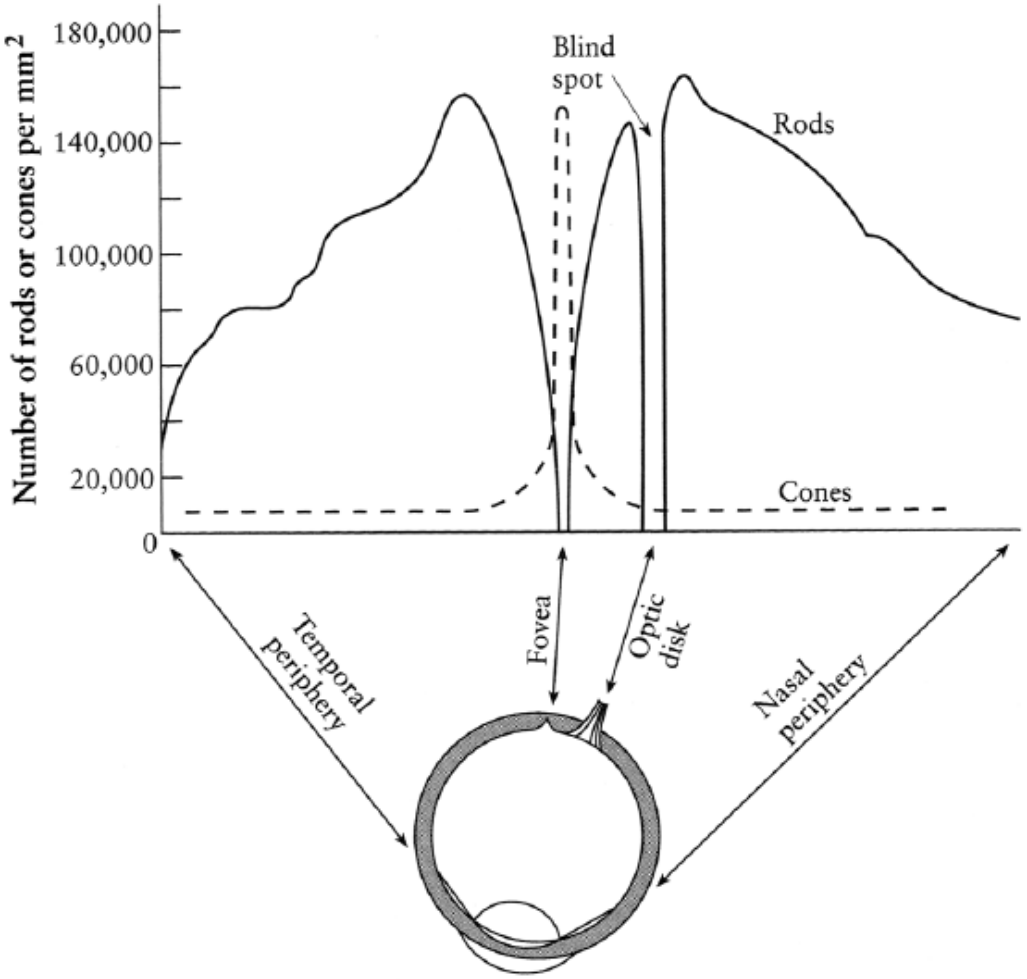
Types of light-sensitive receptors

Cones 视锥

cone-shaped
operate in high light
color vision

Rods 视杆

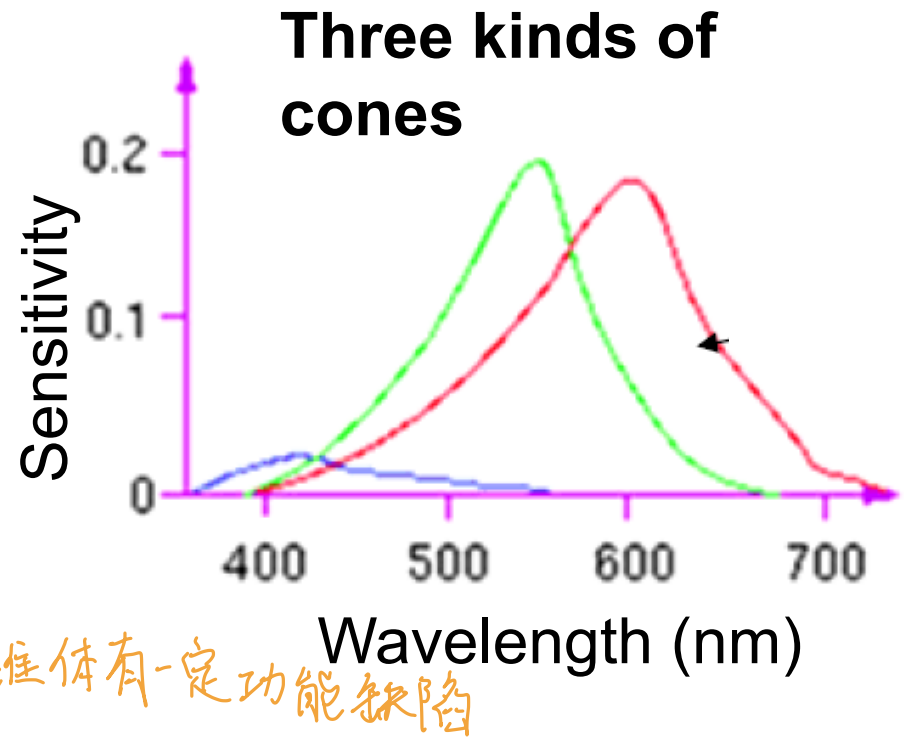
rod-shaped
operate at night
gray-scale vision



Slide credit: Alyosha Efros

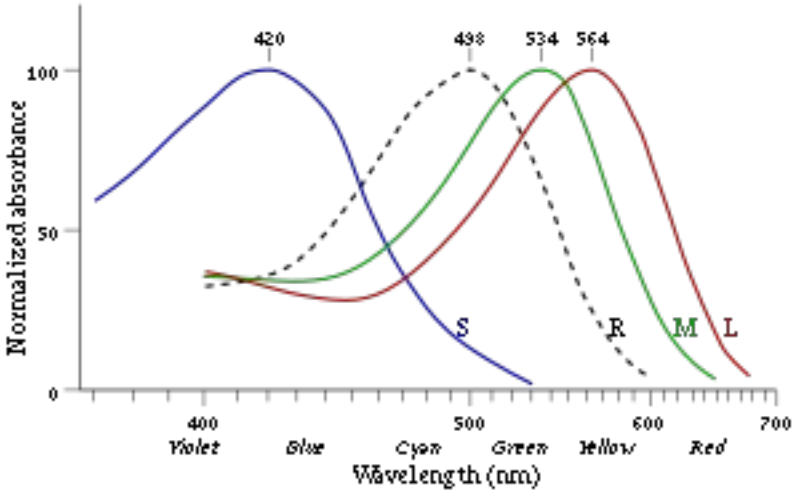
Types of cones

- React only to some wavelengths, with different sensitivity (light fraction absorbed)
- Brain fuses responses from local neighborhood of several cones for perceived color
- Sensitivities vary per person, and with age
- Color blindness: deficiency in at least one type of cone



锥体有一定功能缺陷

Human color receptors



- Long (red), Medium (green), and Short (blue) cones, plus intensity rods
- Fun facts
  - "M" and "L" on the X-chromosome
    - That's why men are more likely to be color blind (see what it's like: http://www.vischeck.com/vischeck/vischeckImage.php)
  - "L" has high variation, so some women are tetrachromatic
  - Some animals have 1 (night animals), 2 (e.g., dogs), 4 (fish, birds), 5 (pigeons, some reptiles / amphibians), or even 12 (mantis shrimp) types of cones

http://en.wikipedia.org/wiki/Color_vision

既然“**三原色的原理不是出于物理原因，而是由于生理原因造成的**”，那么通常所说的“**用三种原色的光以不同的比例加和到一起，形成各种颜色的光**”显然就不大合适。使用三原色并不足以重现所有的色彩，准确地说法应该是“**将三原色光以不同的比例复合后，对人的眼睛可以形成与各种频率的可见光等效的色觉。**”只有那些在三原色的色度所定义的颜色三角内的颜色，才可以利用三原色的光以非负量相加混合得到。

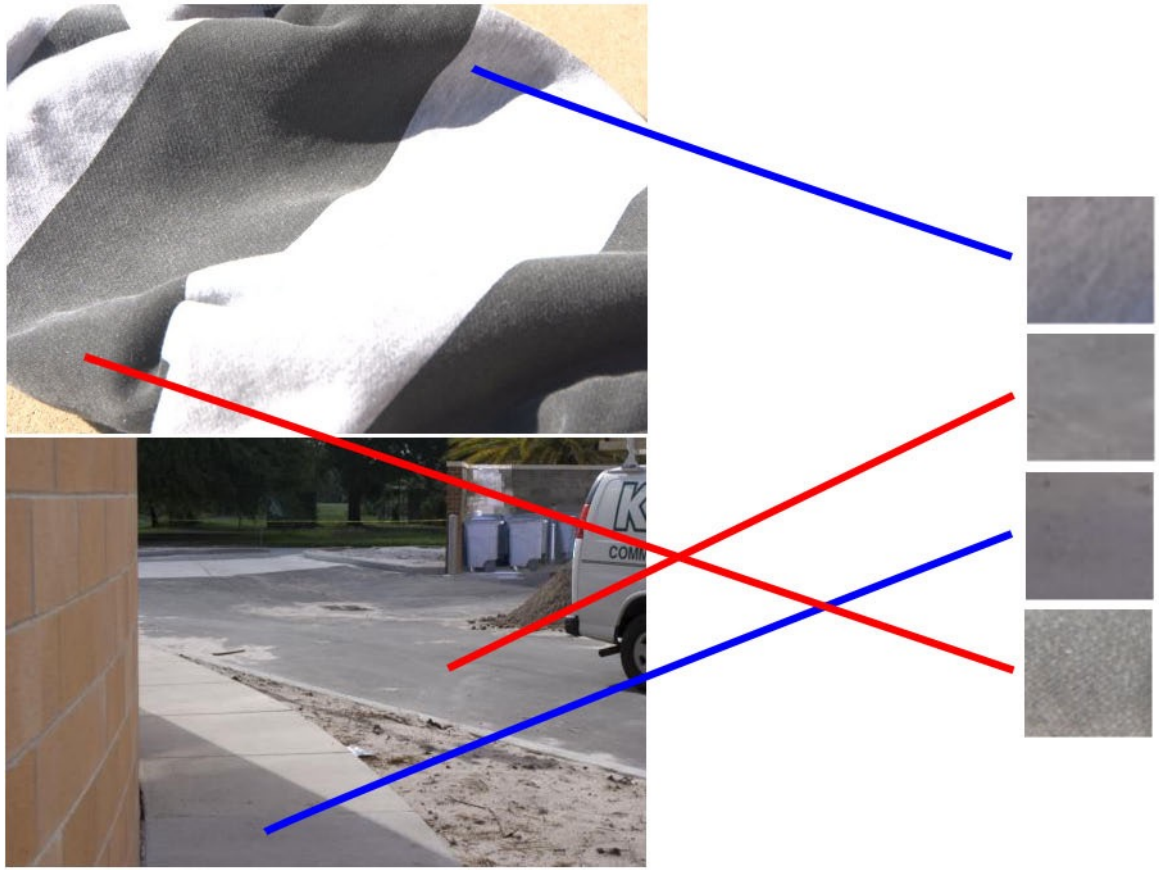
Color perception

- Color/lightness constancy
  - The ability of the human visual system to perceive the intrinsic reflectance properties of the surfaces despite changes in illumination conditions

J. S. Sargent, The Daughters of Edward D. Boit, 1882

Color constancy

- Interpret surface in terms of albedo or “true color”, rather than observed intensity
  - Humans are good at it
  - Computers are not nearly as good



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J. S. Sargent, The Daughters of Edward D. Boit, 1882

Color cues in computer vision

Image description and matching

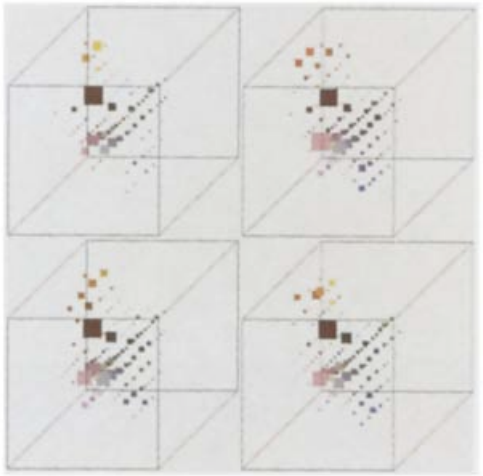


Image segmentation

Color histogram

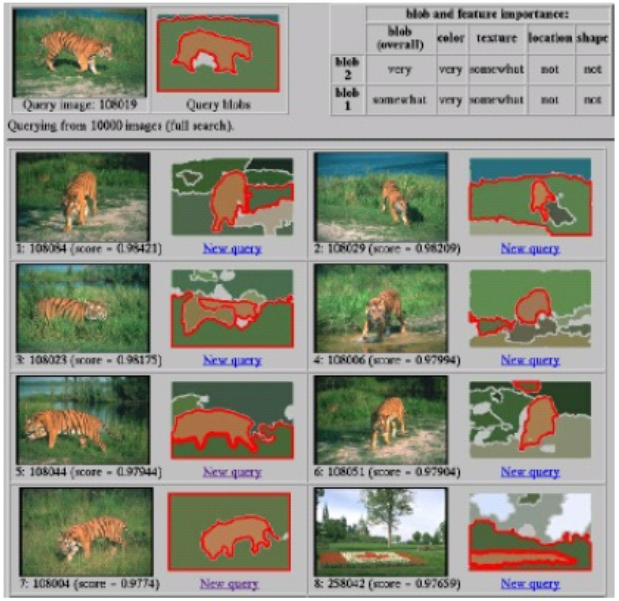
- A kind of feature descriptor： Use distribution of colors to describe image

- How to implement color histogram in Matlab?

- RGB space: 8 bins for each channel
- 16 bins for H, and 4 bins each for S and V

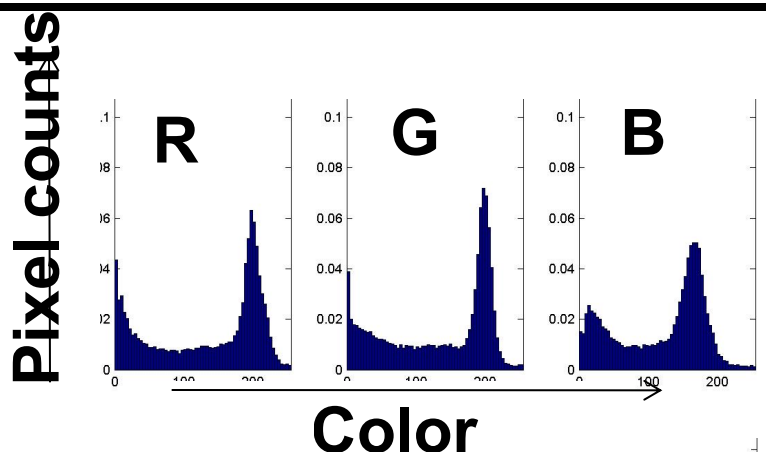
Color as a low-level cue for CBIR

Swain and Ballard, Color Indexing, IJCV 1991



Blobworld system
Carson et al, 1999

Color as a low-level cue for CBIR

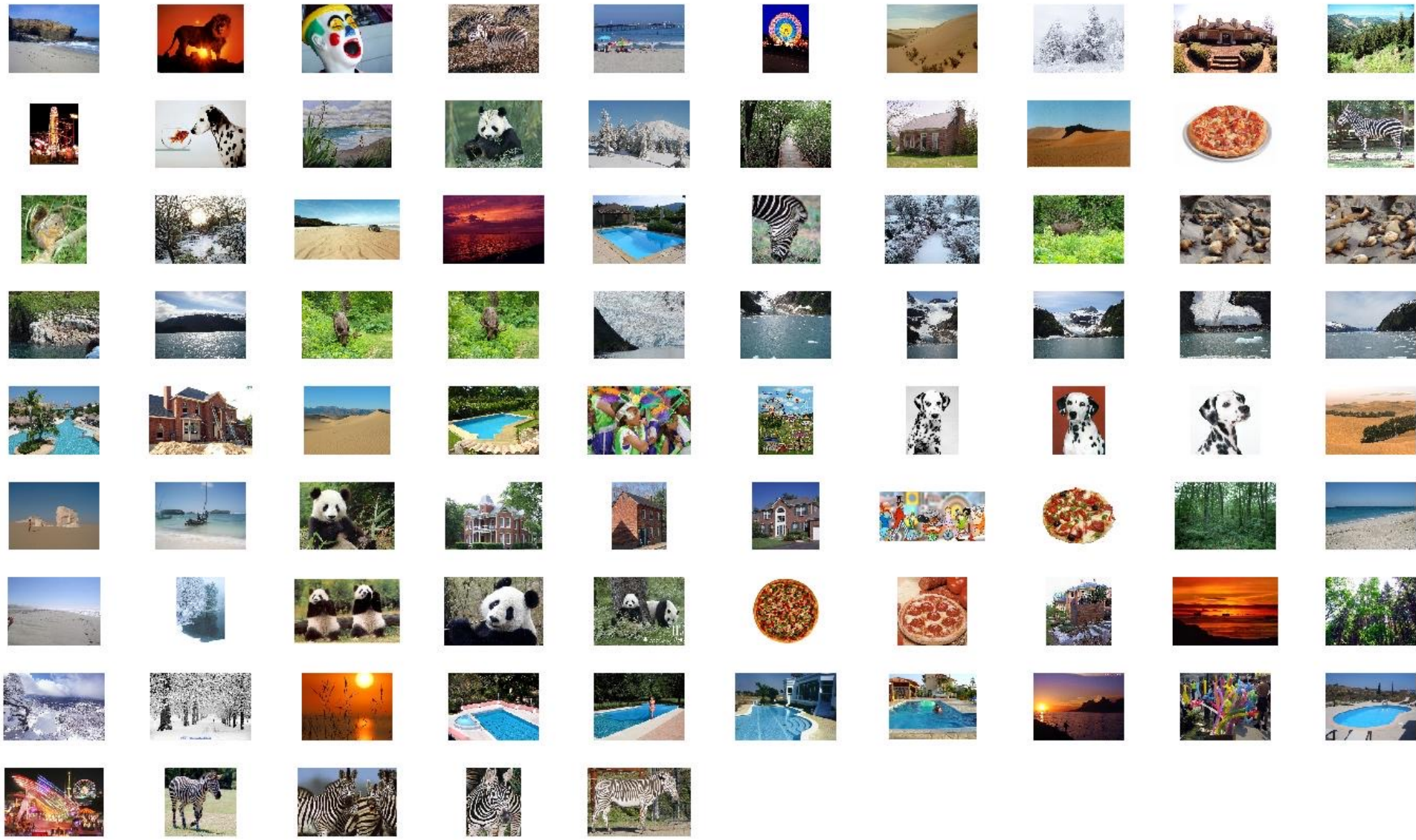


- Color histograms: Use distribution of colors to describe image
- No spatial info – invariant to translation, rotation, scale

Color-based image retrieval 检索

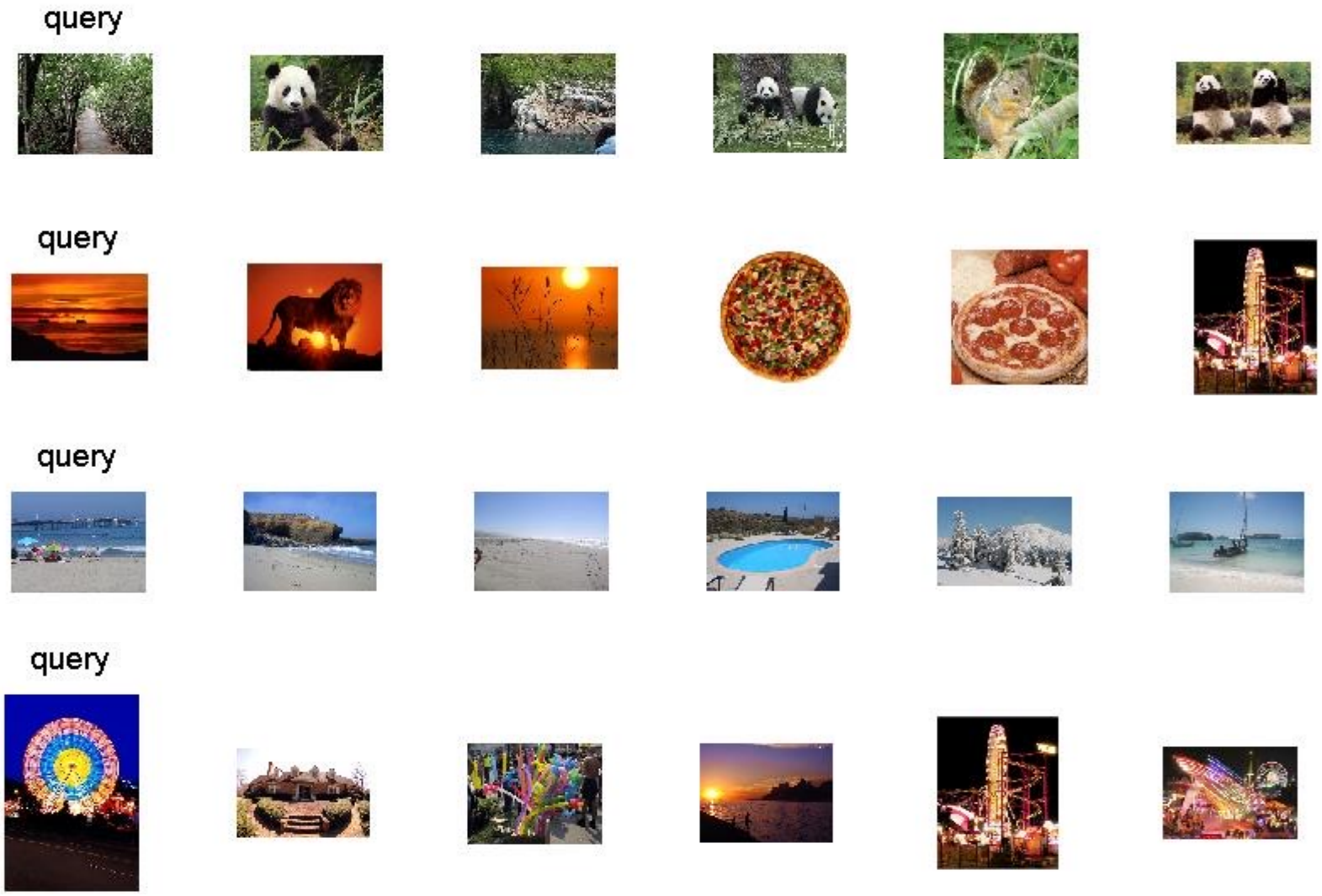
- Given collection (database) of images:
  - Extract and store one color histogram per image
- Given new query image:
  - Extract its color histogram
  - For each database image:
    - Compute intersection between query histogram and database histogram
  - Sort intersection values (highest score = most similar)
  - Rank database items relative to query based on this sorted order

Color-based image retrieval



Example database

Color-based image retrieval



Example retrievals

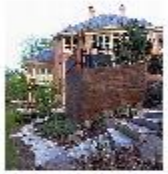
Color-based image retrieval

query






query



query






Example retrievals

Google

pizza

Search

SafeSearch moder

About 3,030,000 results (0.32 seconds)

Advanced search

- Everything
- Images
- Videos
- News
- Shopping
- More

Any size

Large
Medium
Icon
Larger than...
Exactly...

Any type

Face
Photo
Clip art
Line drawing

Any color
Full color
Black and white

Standard view

Show sizes

Reset tools

Green

Related searches: pizza **coupons** pizza **slice** **cartoon** pizza pizza **clip art** pizza **hut** pizza **italian** pizza











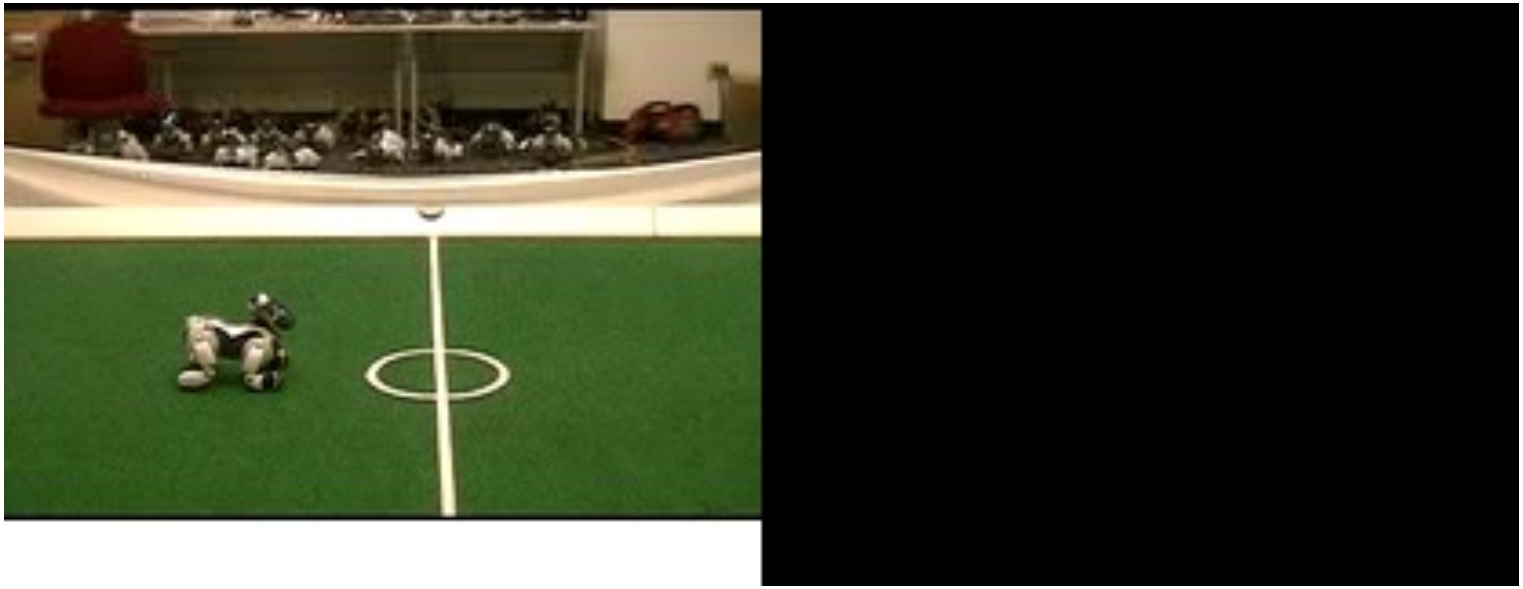





Color-based skin detection

M. Jones and J. Rehg, Statistical Color Models with Application to Skin Detection, IJCV 2002.

Color-based segmentation for robot soccer



Towards Eliminating Manual Color Calibration at RoboCup. Mohan Sridharan and Peter Stone. RoboCup-2005: Robot Soccer World Cup IX, Springer Verlag, 2006

http://www.cs.utexas.edu/users/AustinVilla/?p=research/auto_vis