اصول پردازش تصویر
Principles of Image Processing
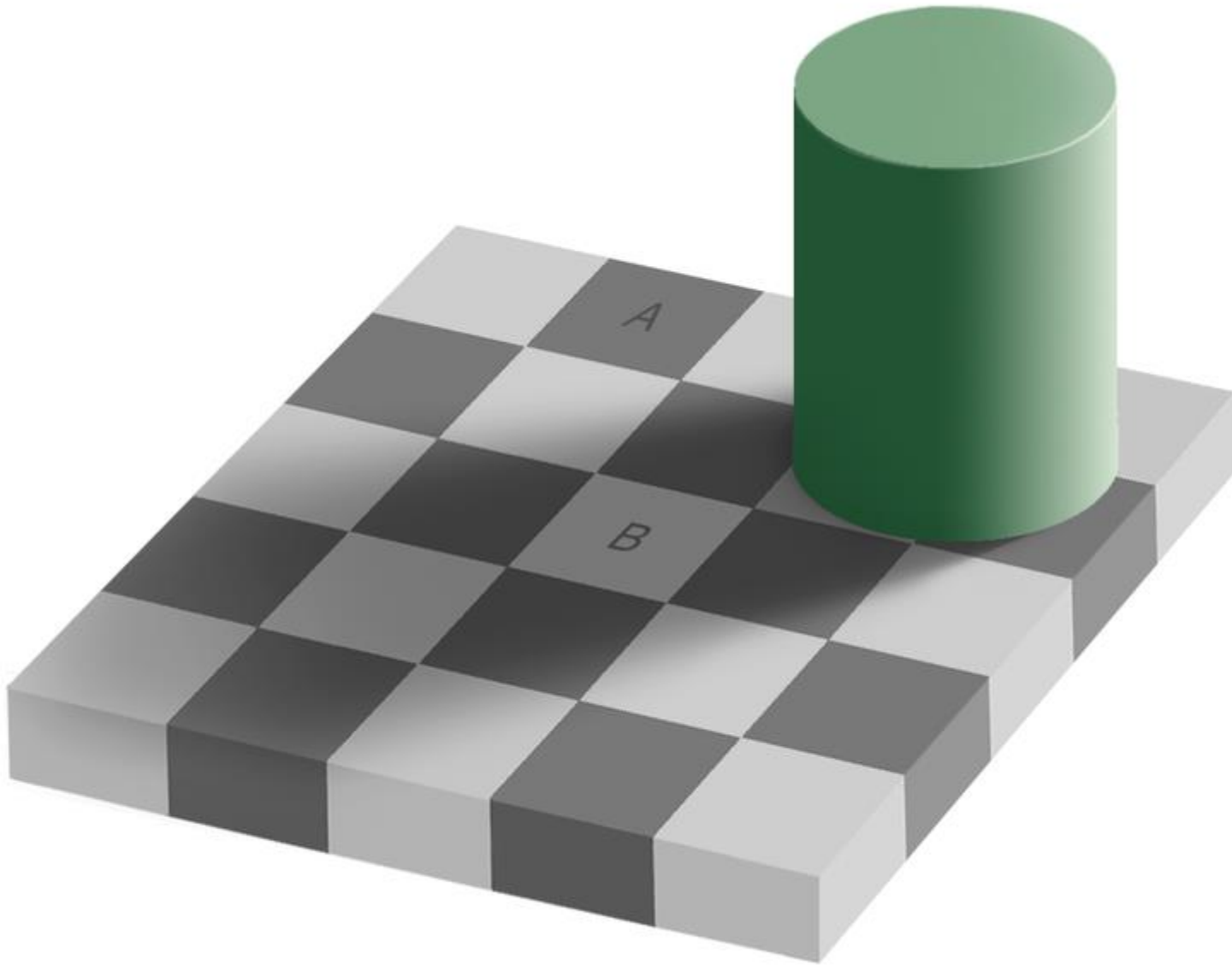
مصطفی کمالی تبریزی
۵ مهر ۱۳۹۹
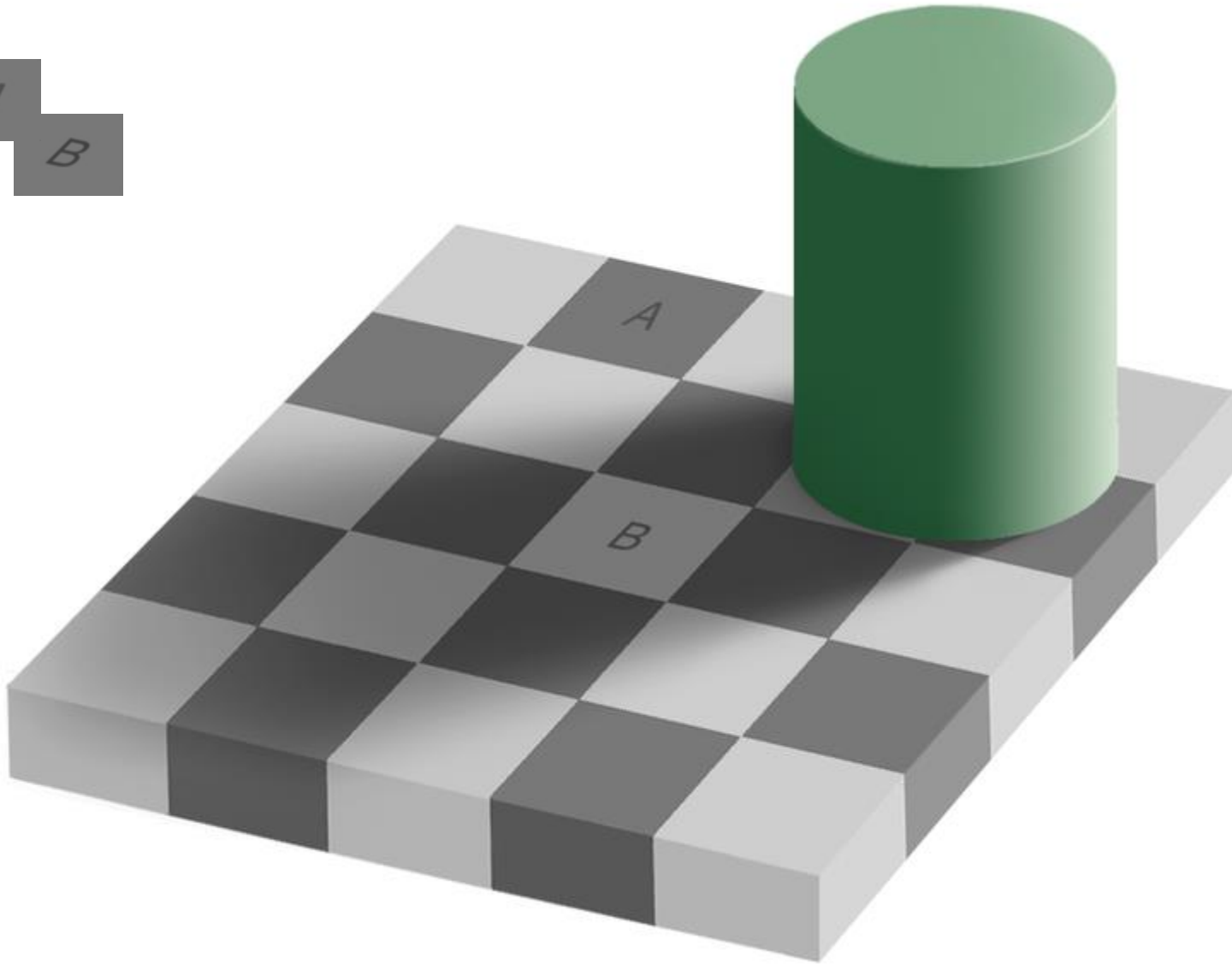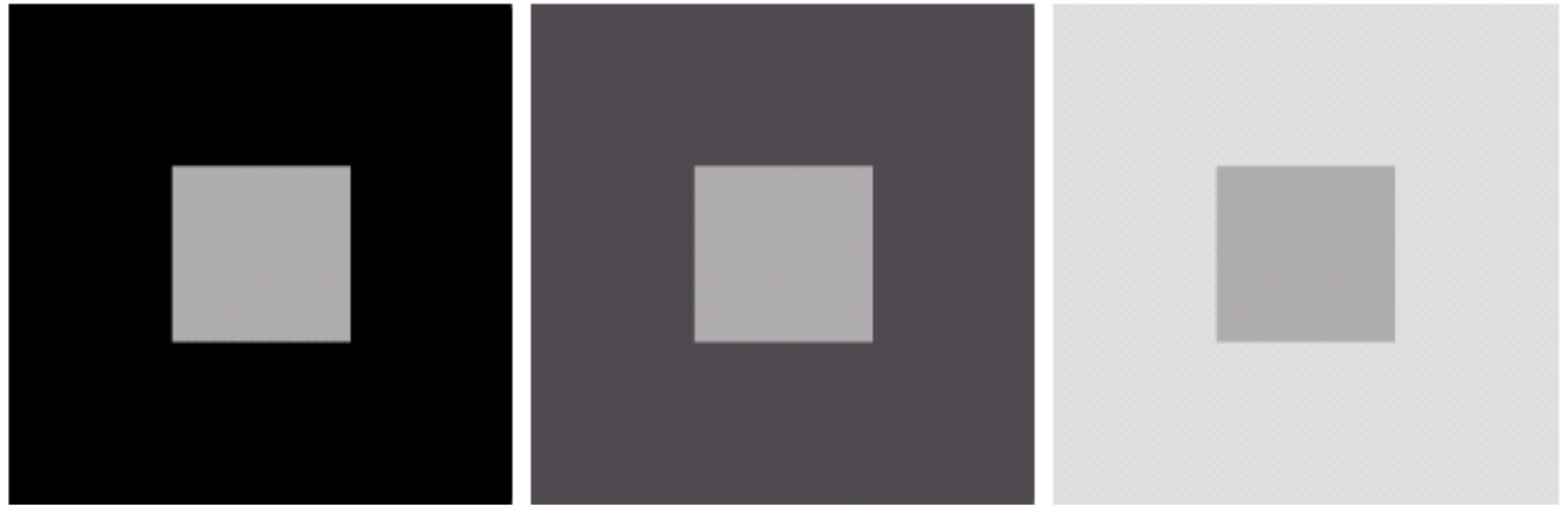جلسه سوم

Visual Perception

Perception of Intensity

Slide Credit: Ted Adelson

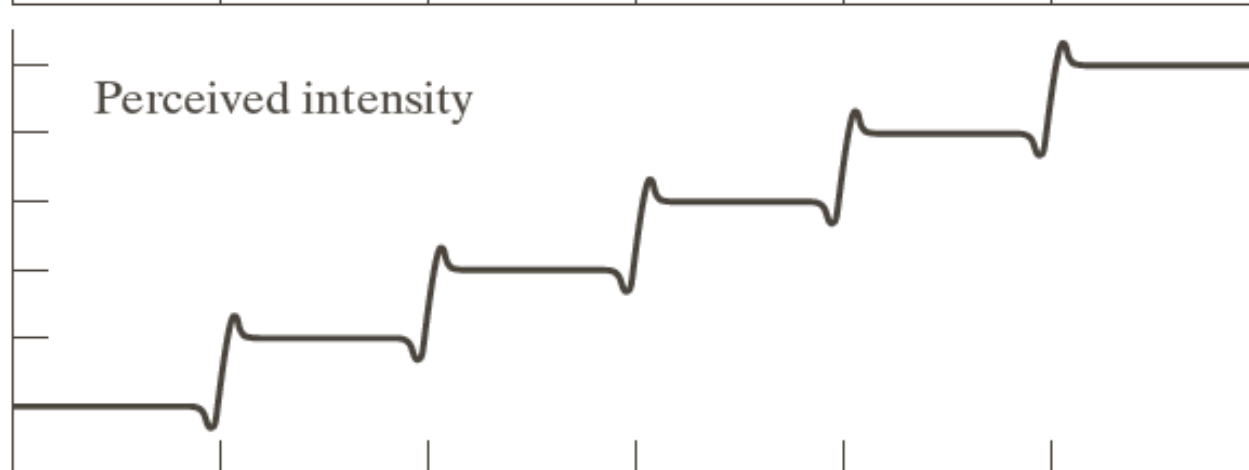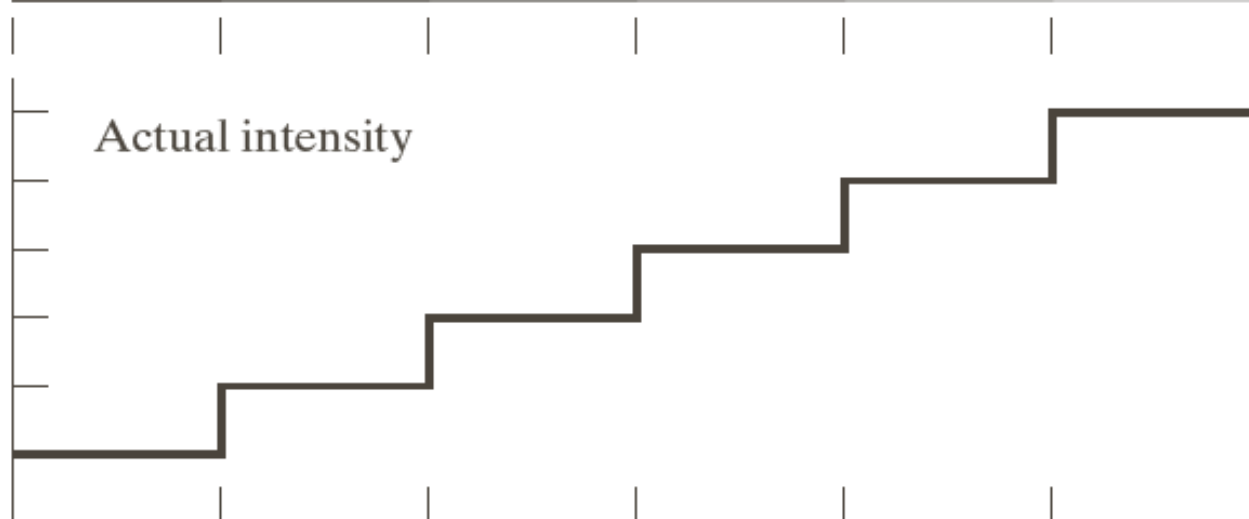# Perception of Intensity

Slide Credit: Ted Adelson

a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Actual intensity

Perceived intensity

FIGURE 2.7
Illustration of the
Mach band effect.
Perceived
intensity is not a
simple function of
actual intensity.

Aliasing in Video

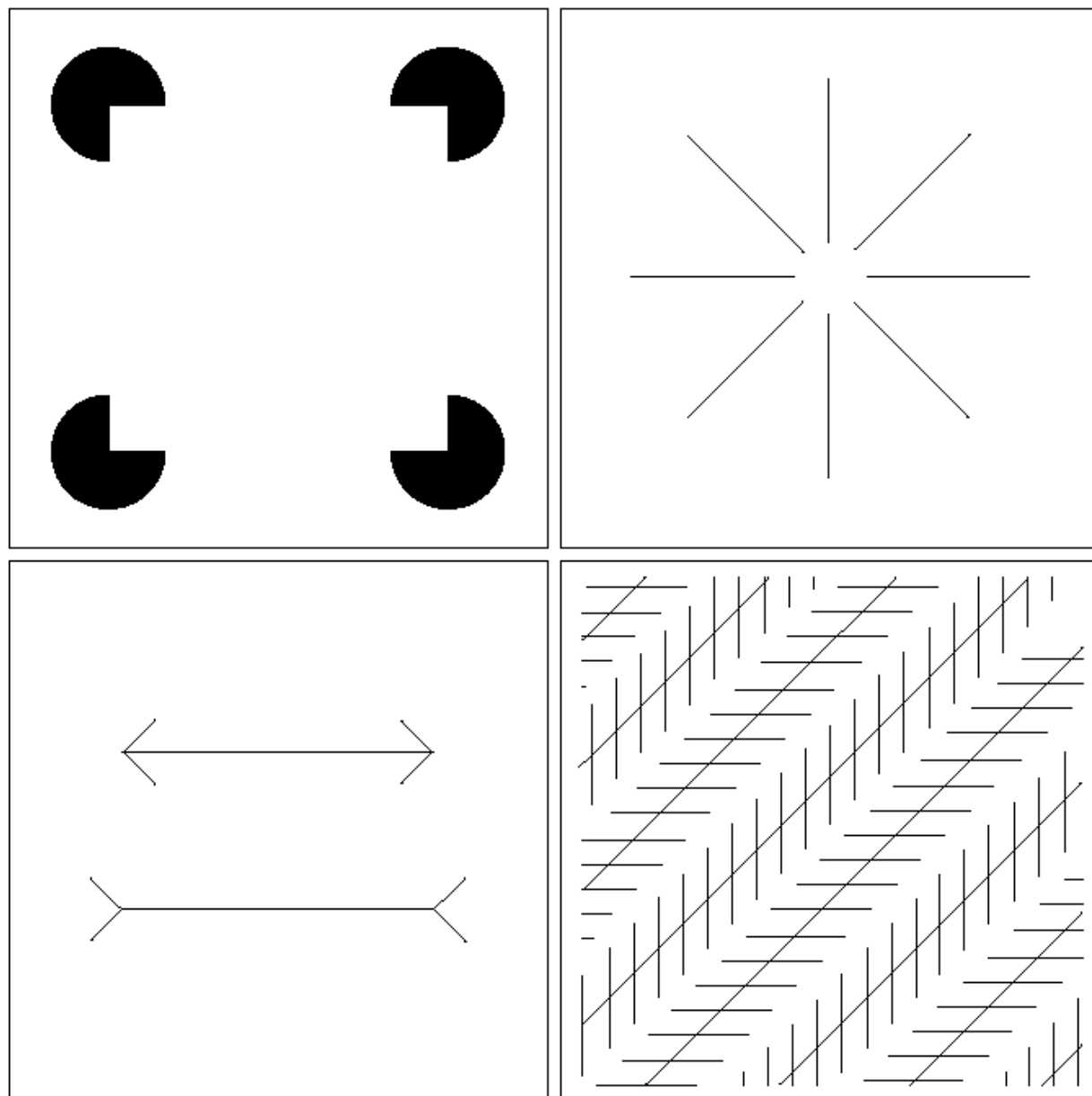Imagine a spoked wheel moving to the right (rotating clockwise). Mark wheel with dot so we can see what's happening.

If camera shutter is only open for a fraction of a frame time (frame time = 1/30 sec. for video, 1/24 sec. for film):

frame 0   frame 1   frame 2   frame 3   frame 4

shutter open   time
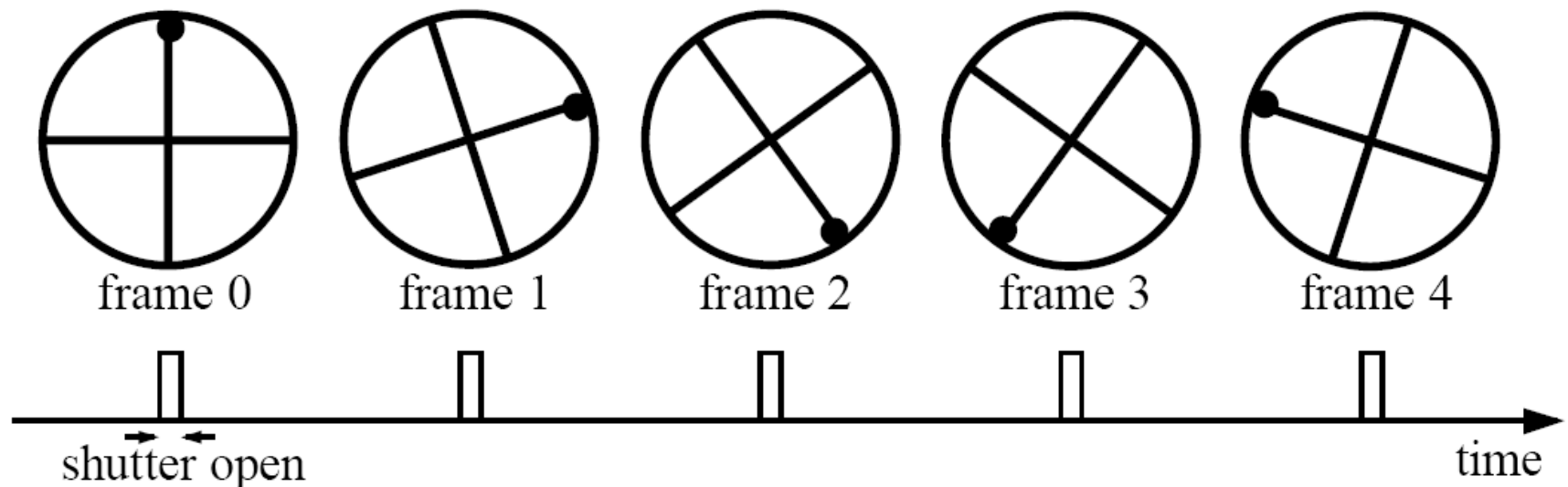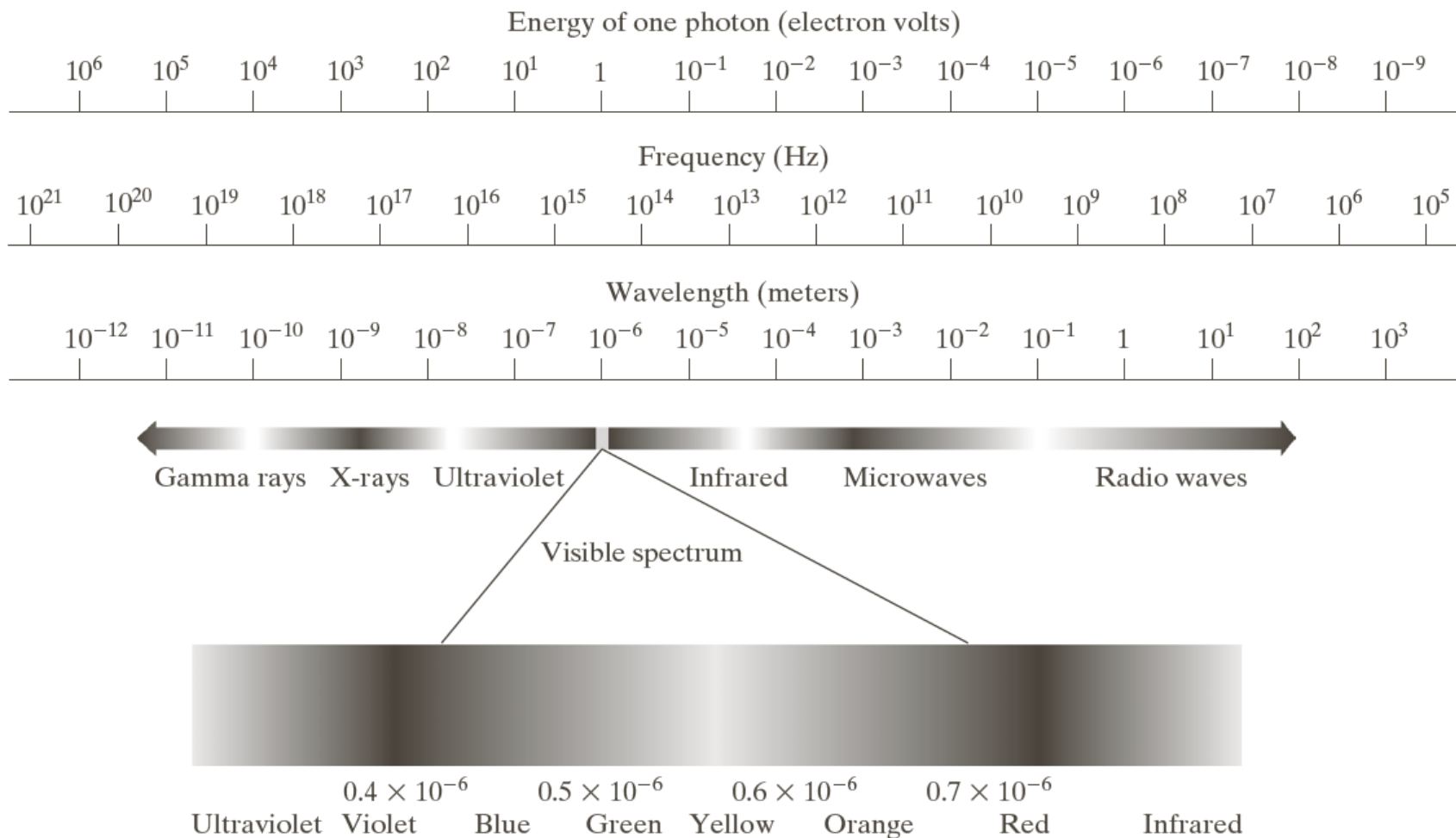
Without dot, wheel appears to be rotating slowly backwards! (counterclockwise)

Slide: Steve Seitz

FIGURE 2.9 Some well-known optical illusions.

a b
c d

Energy of one photon (electron volts)

| 10^6 | 10^5 | 10^4 | 10^3 | 10^2 | 10^1 | 1 | 10^{-1} | 10^{-2} | 10^{-3} | 10^{-4} | 10^{-5} | 10^{-6} | 10^{-7} | 10^{-8} | 10^{-9} |

Frequency (Hz)

| 10^{21} | 10^{20} | 10^{19} | 10^{18} | 10^{17} | 10^{16} | 10^{15} | 10^{14} | 10^{13} | 10^{12} | 10^{11} | 10^{10} | 10^9 | 10^8 | 10^7 | 10^6 | 10^5 |

Wavelength (meters)

| 10^{-12} | 10^{-11} | 10^{-10} | 10^{-9} | 10^{-8} | 10^{-7} | 10^{-6} | 10^{-5} | 10^{-4} | 10^{-3} | 10^{-2} | 10^{-1} | 1 | 10^1 | 10^2 | 10^3 |

Gamma rays   X-rays   Ultraviolet   Infrared   Microwaves   Radio waves

Visible spectrum

0.4×10^{-6} 0.5×10^{-6} 0.6×10^{-6} 0.7×10^{-6}

Ultraviolet   Violet   Blue   Green   Yellow   Orange   Red   Infrared

FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.
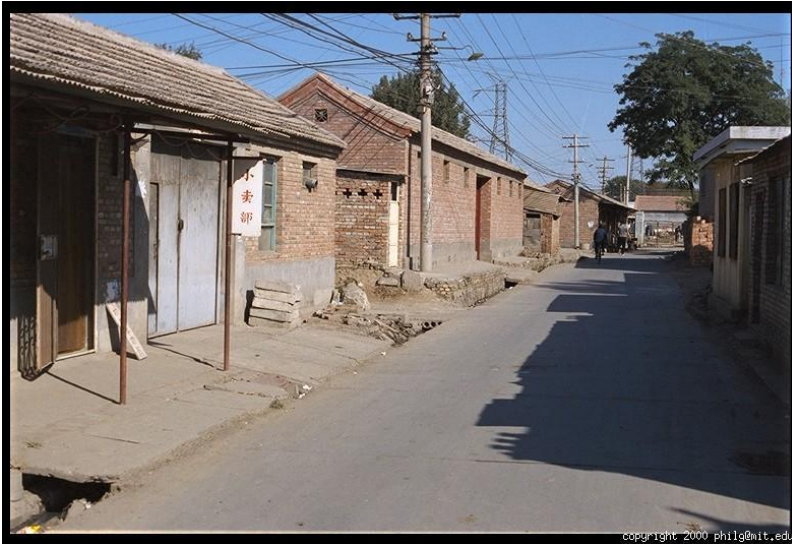
References

- Gonzalez, 4th Edition
  Chapter 1 and Chapter 2

- Szeliski
  Chapter 1 and Chapter 2

Color Image

R

G

B

Color Image

Red (R)

Green (G)

Blue (B)

# Color Images

عکس محمد عالم خان، امیر بخارا، سال ۱۲۸۱ شمسی
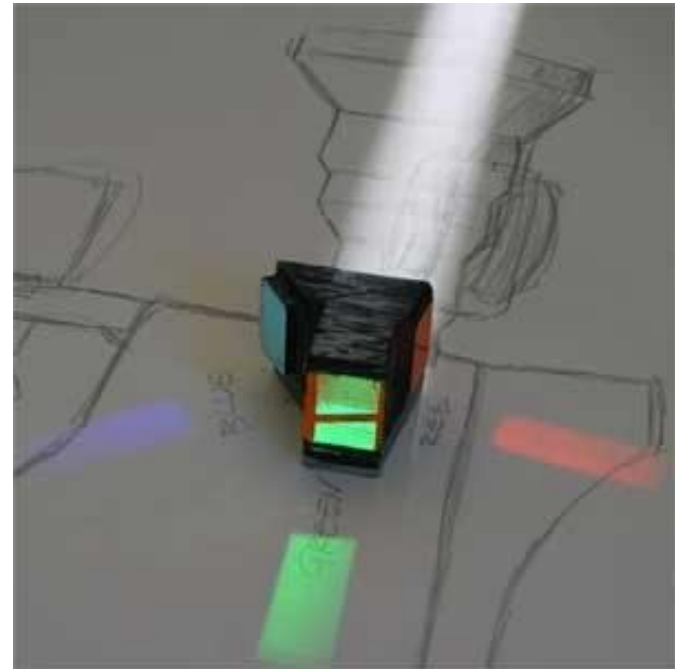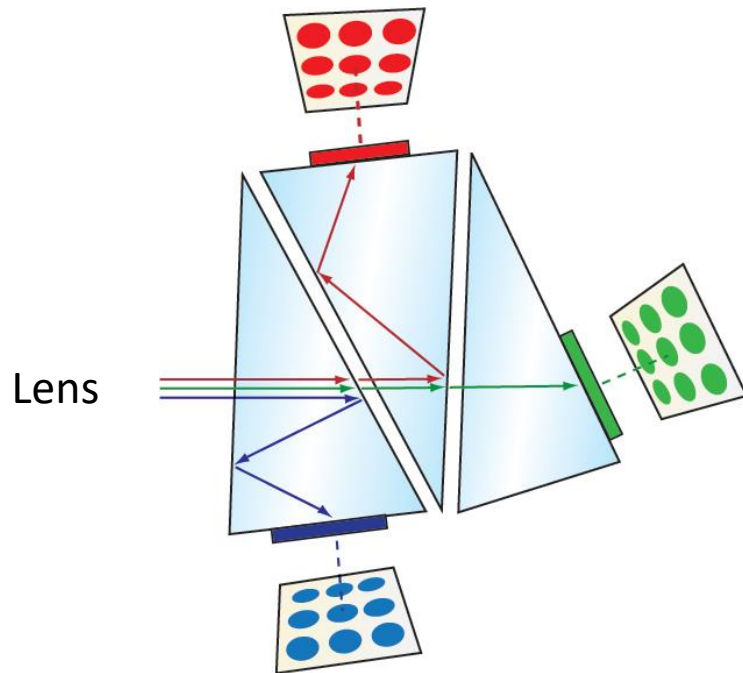
Images in Python

```
im = cv2.imread(filename)                  # read image
im = cv2.cvtColor(im, cv2.COLOR_BGR2RGB)   # order channels as RGB
im = im / 255                              # values range from 0 to 1
```

- RGB image `im` is a H x W x 3 matrix (numpy.ndarray)
- `im[0,0,0]` = top-left pixel value in R-channel
- `im[x, y, c]` = x+1 pixels down, y+1 pixels to right in the cth channel
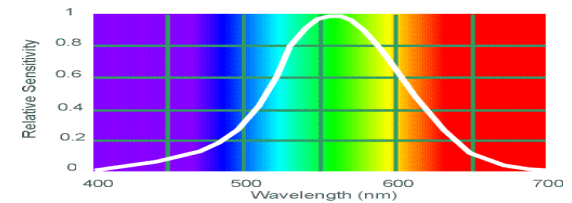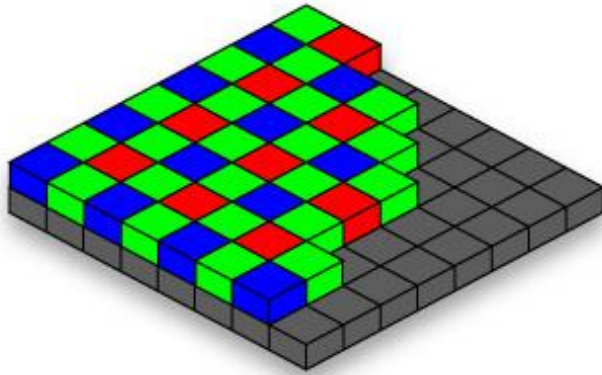- `im[H-1, W-1, 2]` = bottom-right pixel in B-channel
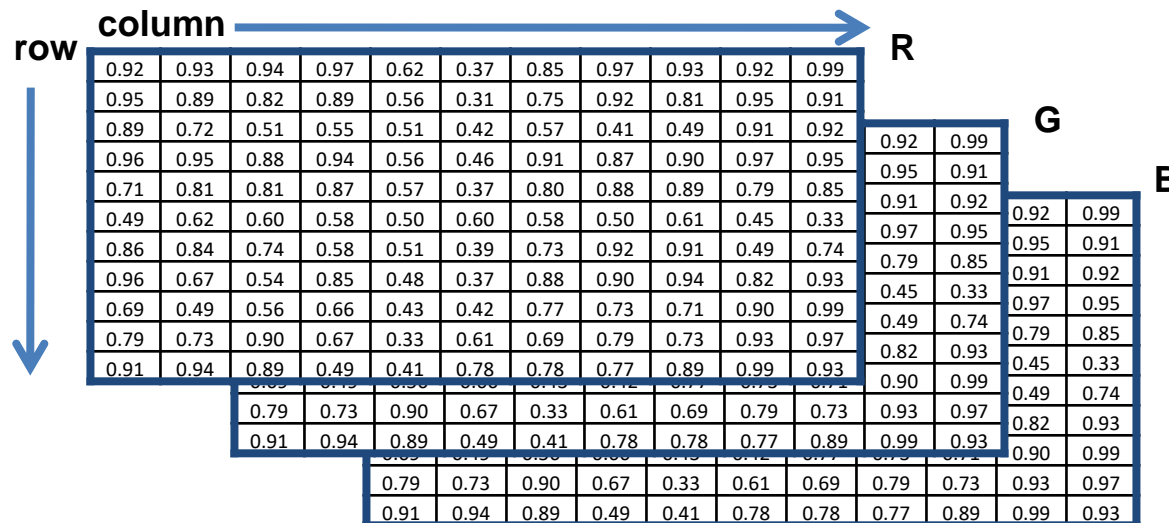
Cameras with Three Sensors

[Edmund Optics; Adam Wilt]

Cheaper / More Compact Color Sensing: Bayer Filter

Incoming Light

Filter Layer

Sensor Array

Resulting Pattern
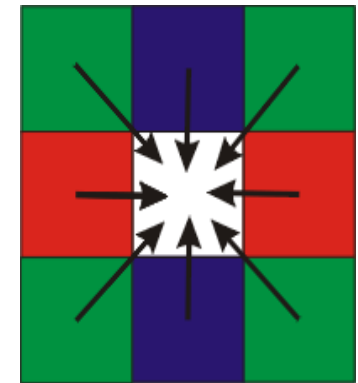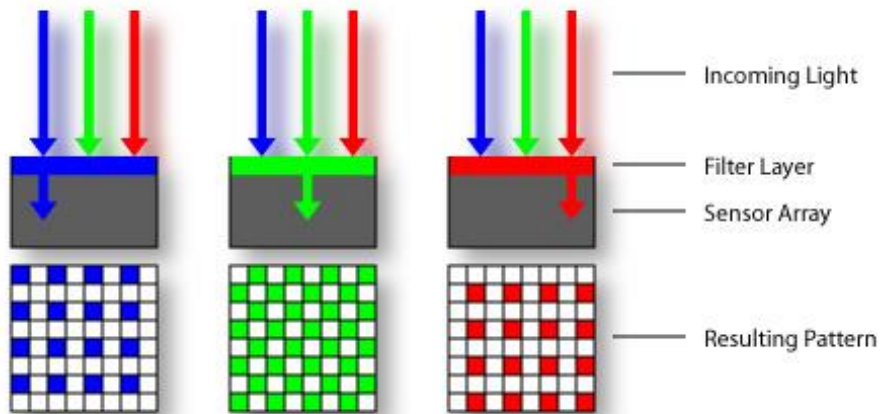
- Estimate RGB at 'G' cells from neighboring values
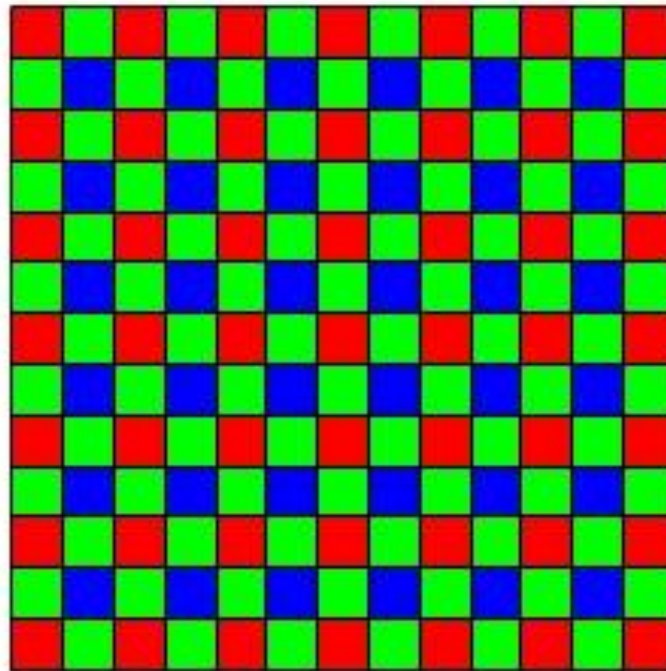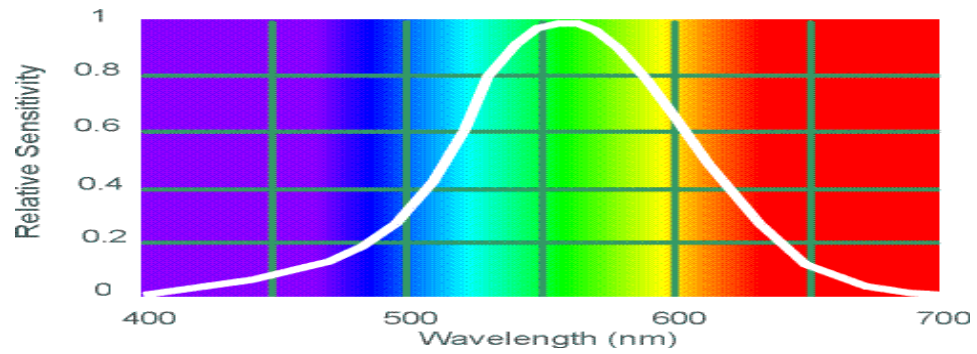
Bayer filter

© 2000 How Stuff Works

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Slide: Steve Seitz

Color Spaces: RGB

Default color space

0,1,0

1,0,0

0,0,1
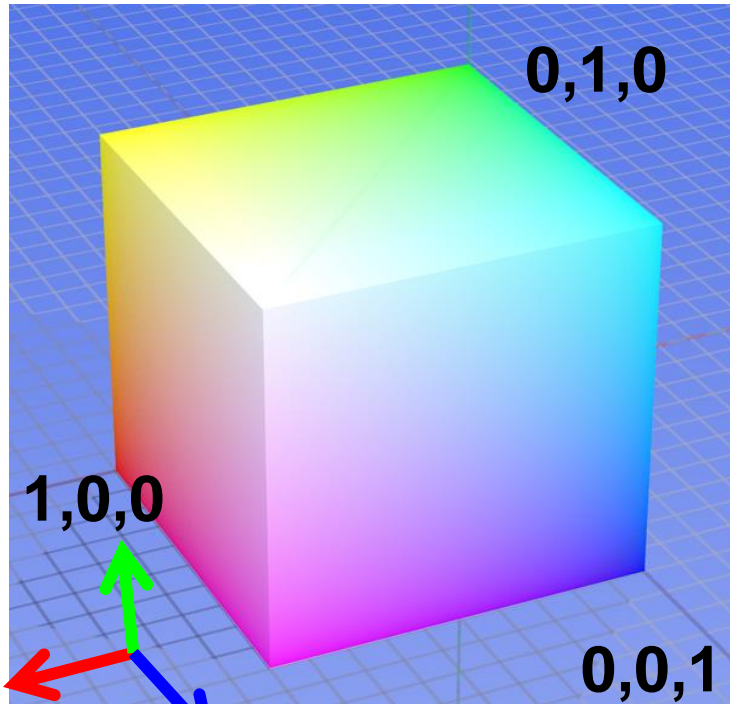
RGB cube

- Easy for devices
- But not perceptual
- Where do the grays live?
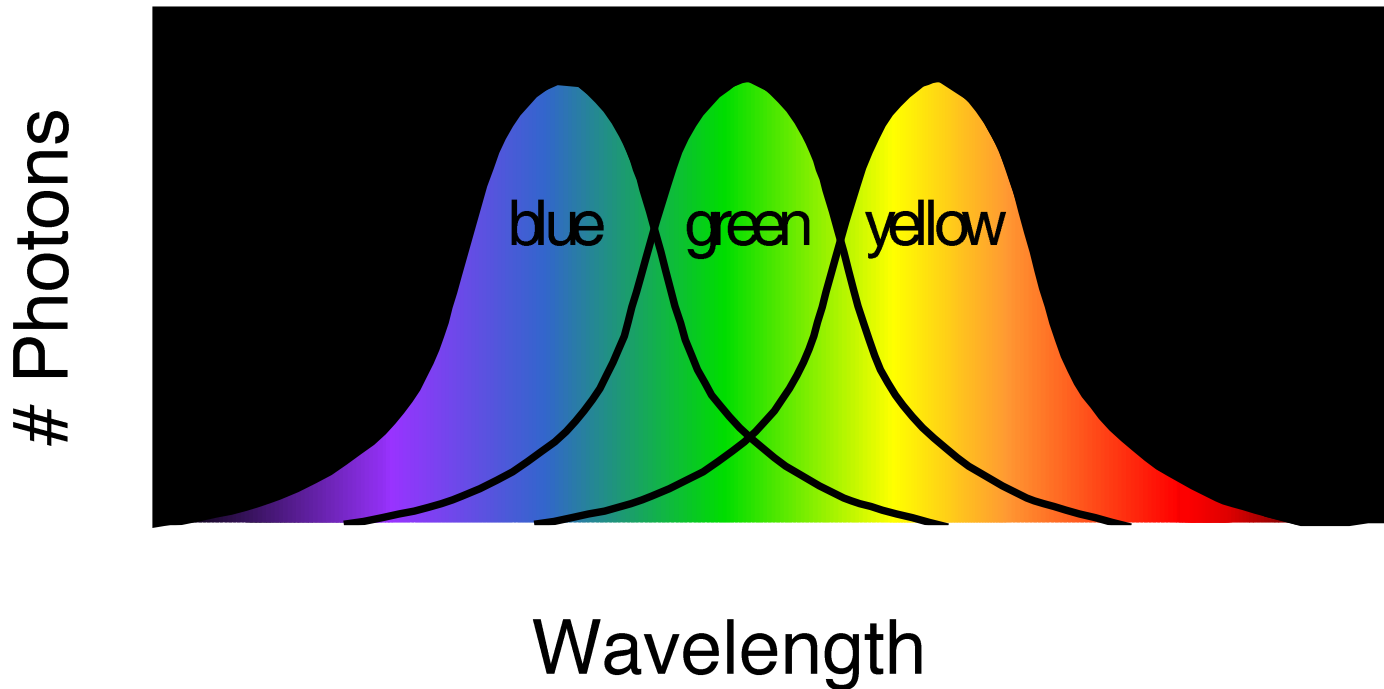- Where is hue and saturation?

R
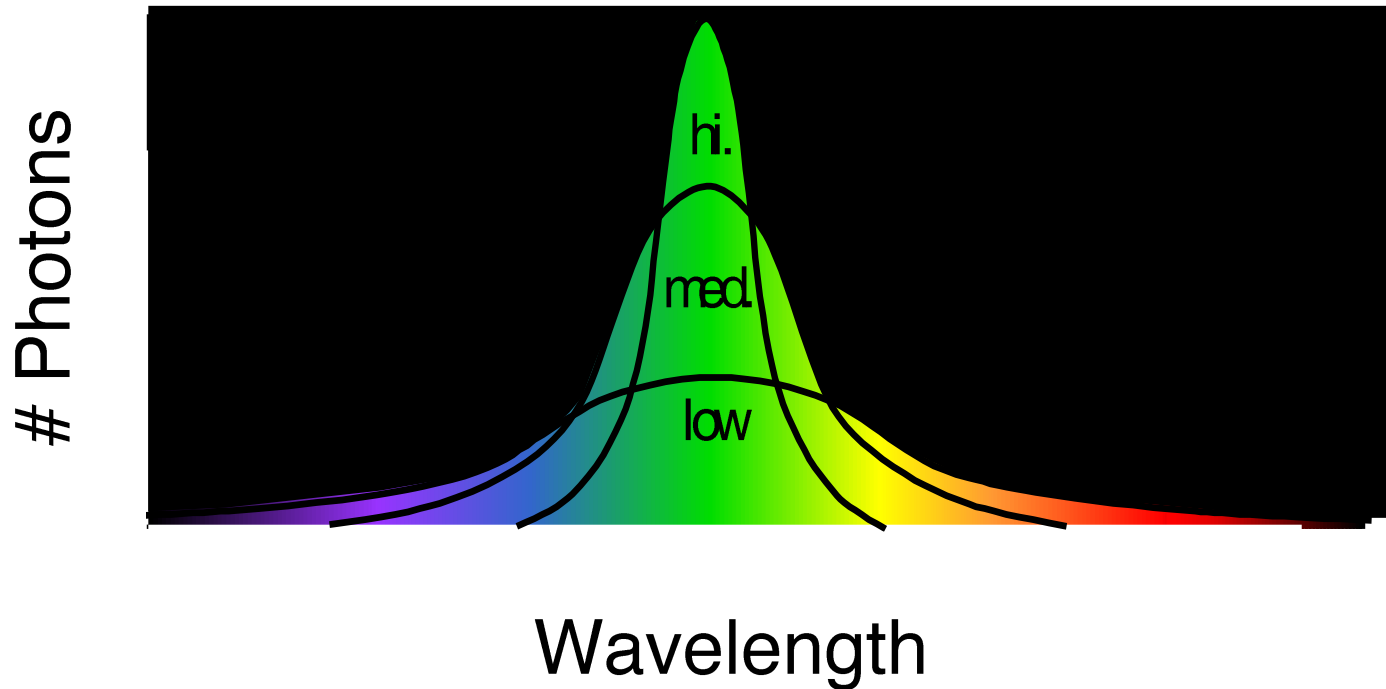(G=0,B=0)

G
(R=0,B=0)

B
(R=0,G=0)

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Image from: http://en.wikipedia.org/wiki/File:RGB_color_solid_cube.png

The Psychophysical Correspondence

Mean ⟺ **Hue**

The Psychophysical Correspondence

Variance ⟷ Saturation

The Psychophysical Correspondence

Area ⟷ Brightness

Photons

Wavelength

bright

dark
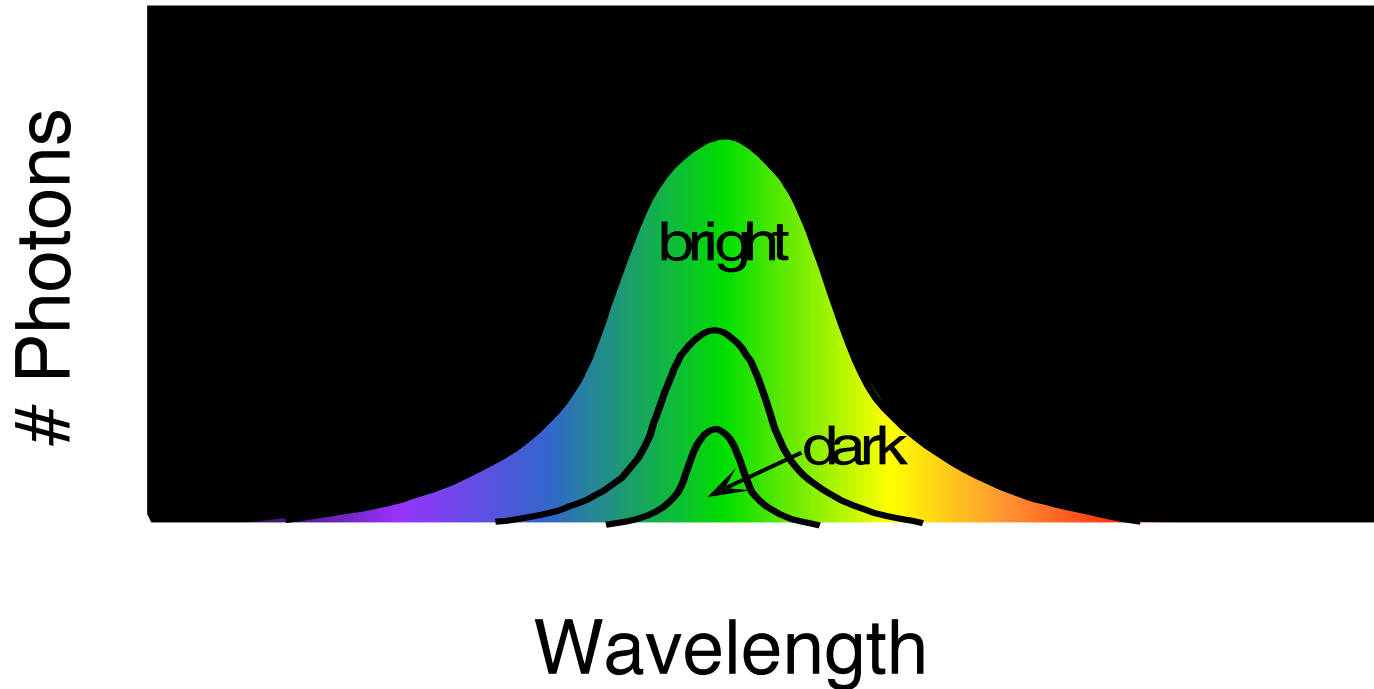
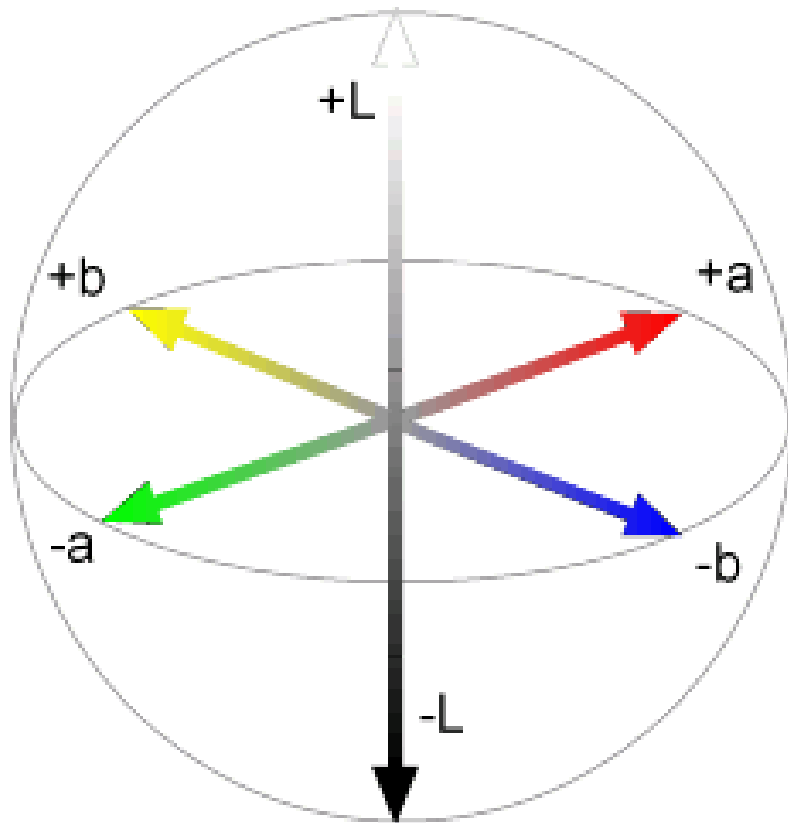# *Color spaces: HSV*

Intuitive color space
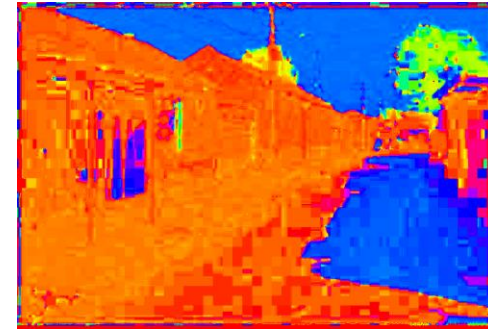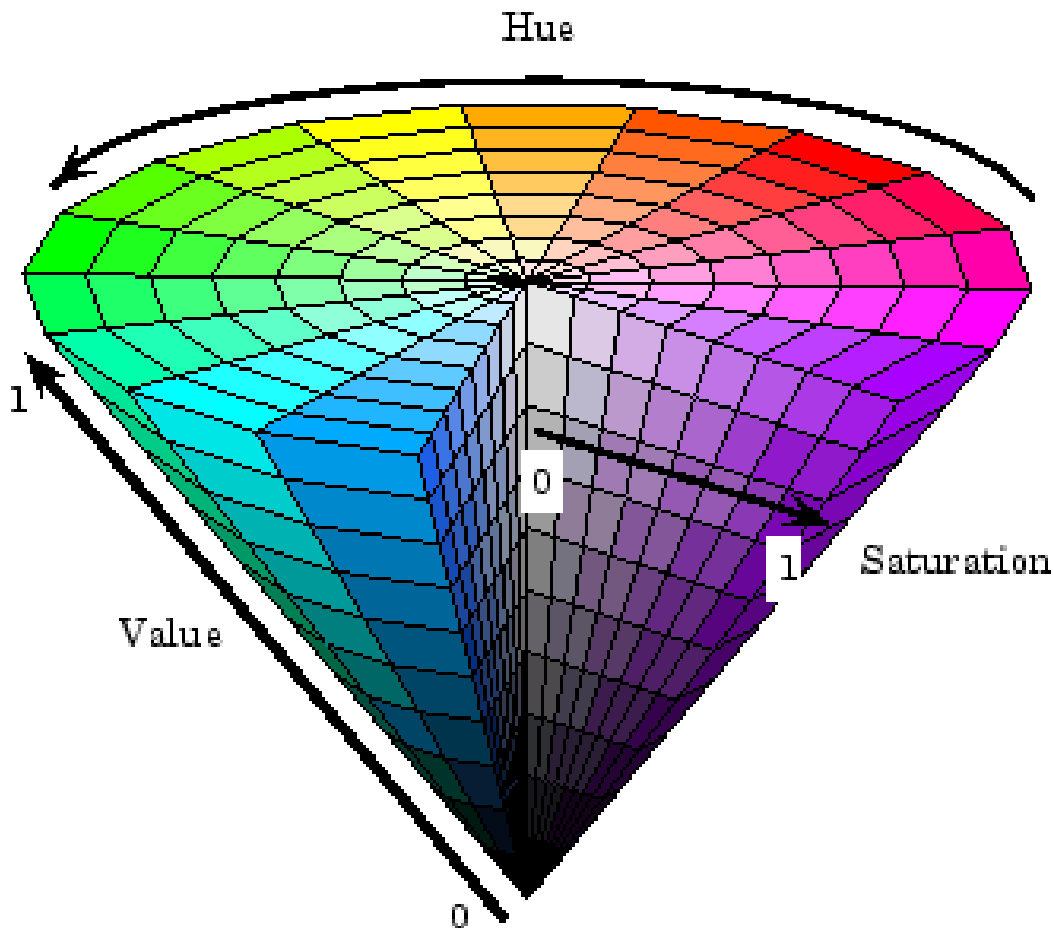
H
(S=1,V=1)

S
(H=1,V=1)

V
(H=1,S=0)

*Color spaces: L*a*b**

"Perceptually uniform"* color space

L
(a=0,b=0)

a
(L=65,b=0)

b
(L=65,a=0)

References

- Color Image Processing
Gonzalez, chapter 7
Szeliski, section 2.3.2 (and 2.2)