EST 323 / CSE 524: CG-HCI

Graphics and Image Processing Basics

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Optical Illusion: Sidewalk Art

Julian Beever

Optical Illusion: Sidewalk Art

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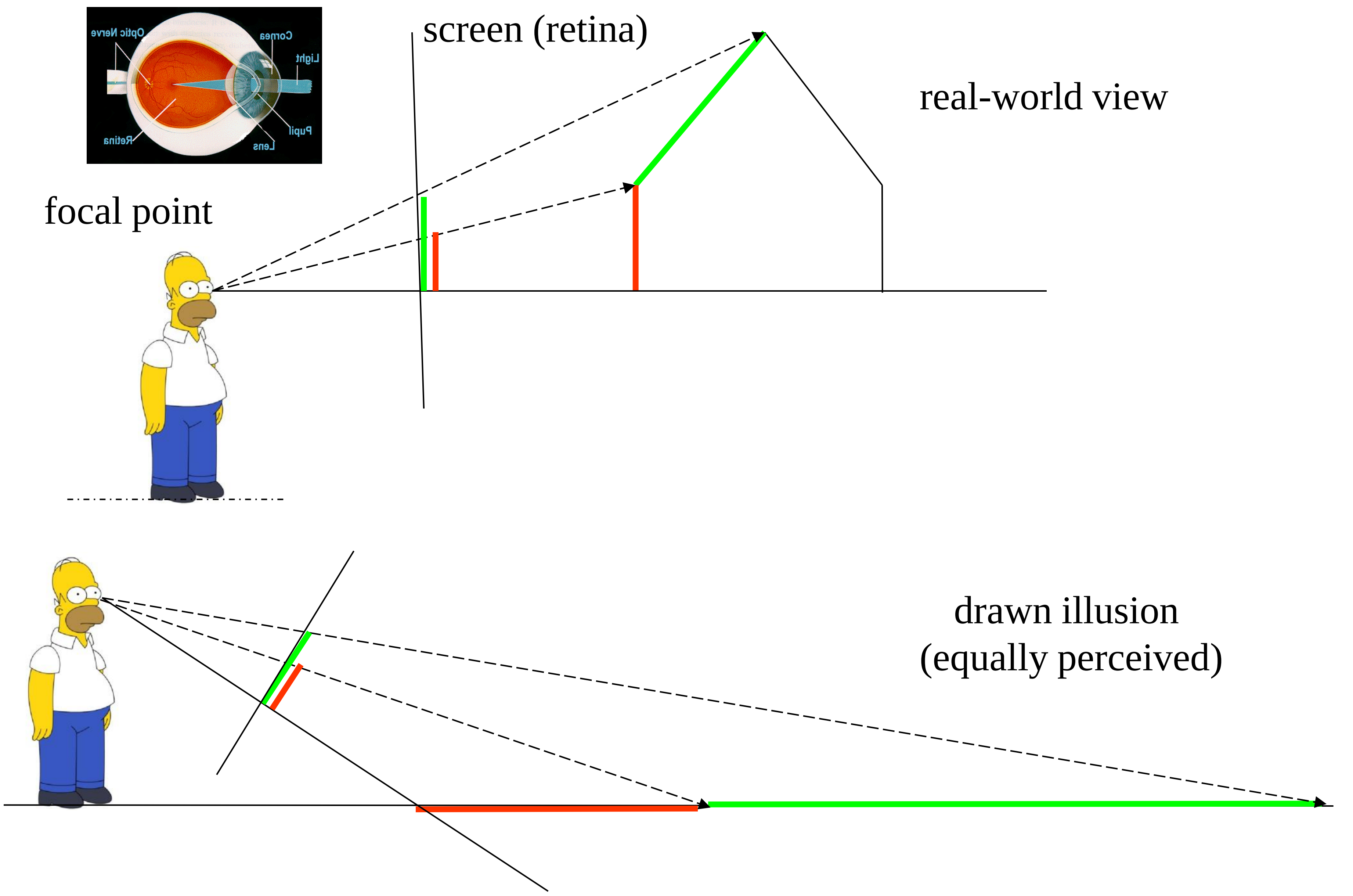
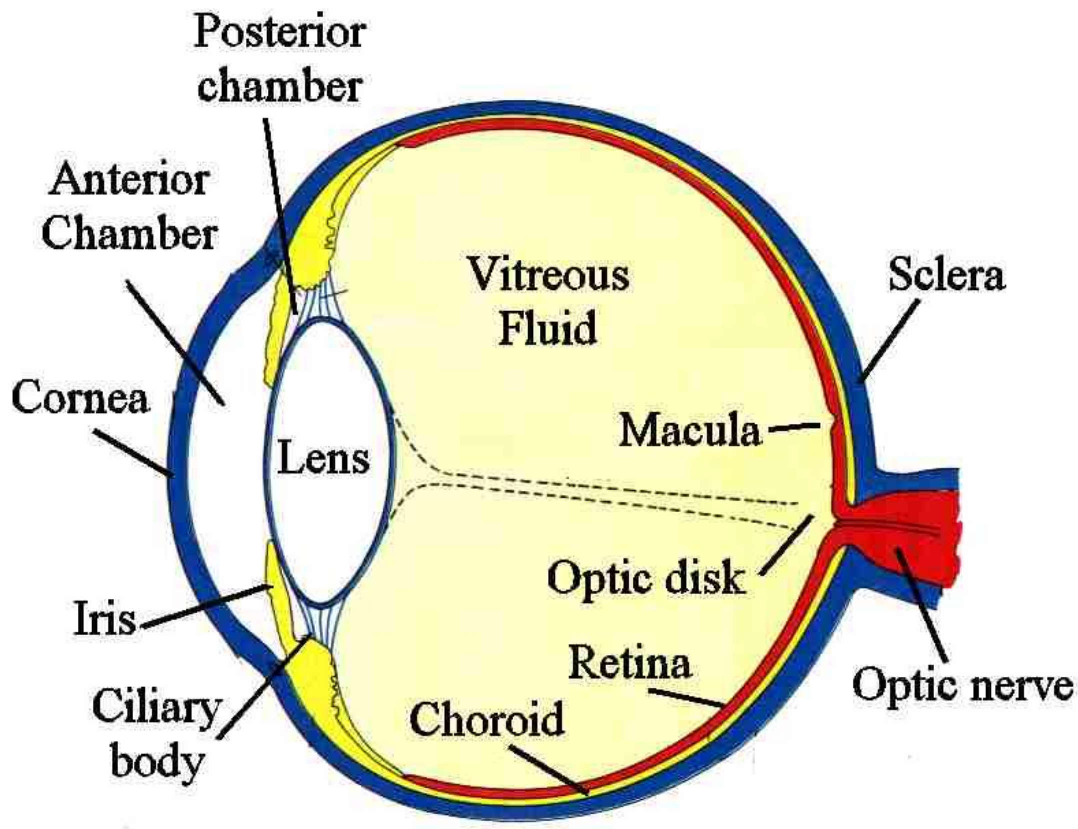
Explanation: 3D Graphics Trickery



Know The Input Device: The Eye



Kimber, D.C.; C.E. Gray, and C.E. Stackpole. (1966). *Anatomy and Physiology*. MacMillan Co., NY. pg 335.

Know The Sensors: Cones and Rods

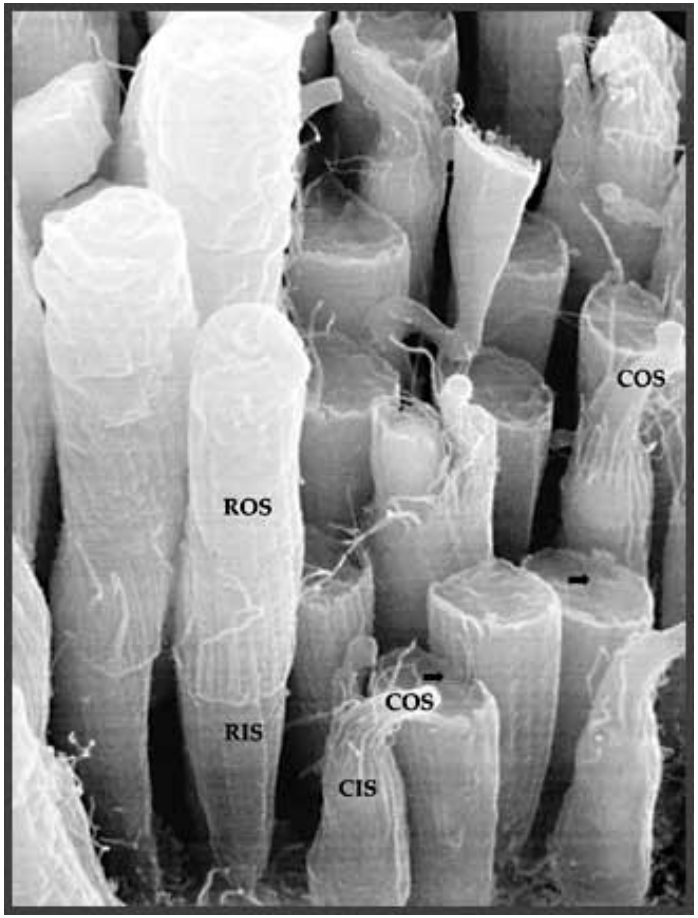
Two types of receptors on retina:
rods and *cones*

Rods:

- spread all over the retinal surface (75 - 150 million)
- low resolution, no color vision, but very sensitive to low light (*scotopic* or dim-light vision)

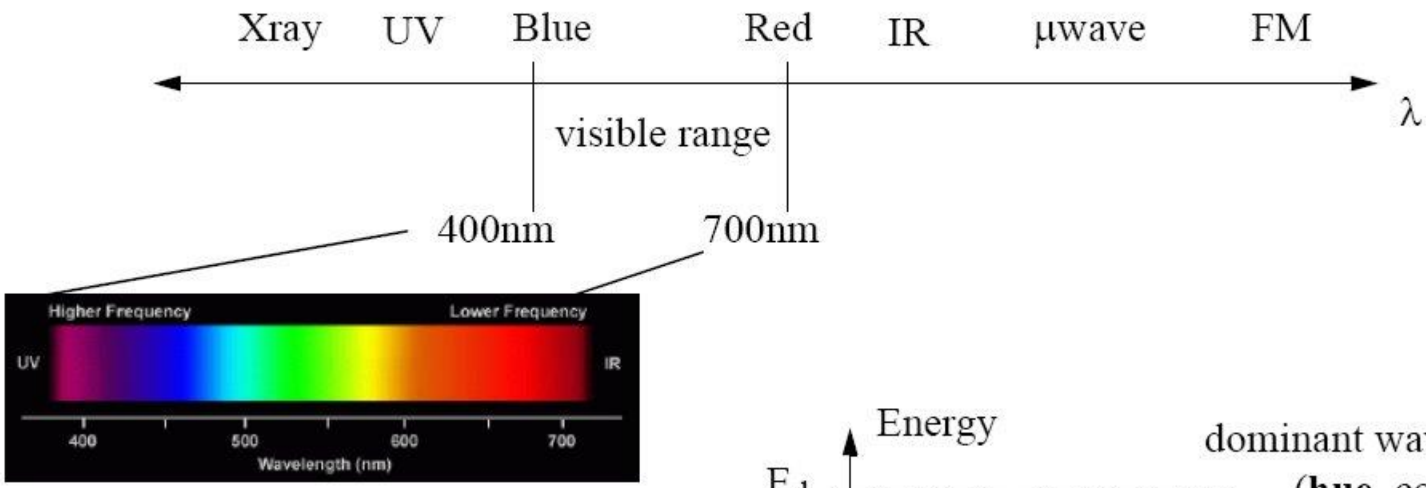
Cones:

- a dense array around the central portion of the retina, the fovea centralis (6 - 7 million)
- high-resolution, color vision, but require brighter light (*photopic* or bright-light vision)

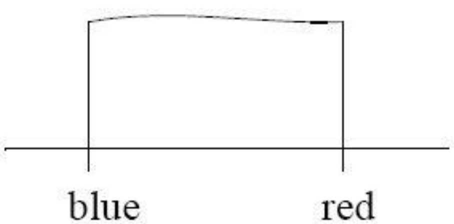


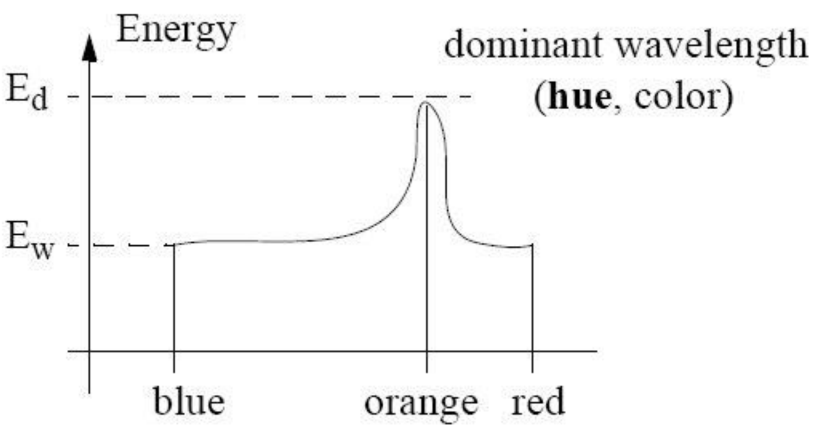
Color: Spectrum of Wavelengths

Spectrum:



white light: all wavelengths





$E(\lambda)$: overall intensity = **brightness** or **luminance**

ratio of E_d vs. E_w = **saturation**

The human eye differentiates about 300 hues and 100-150 luminance variations

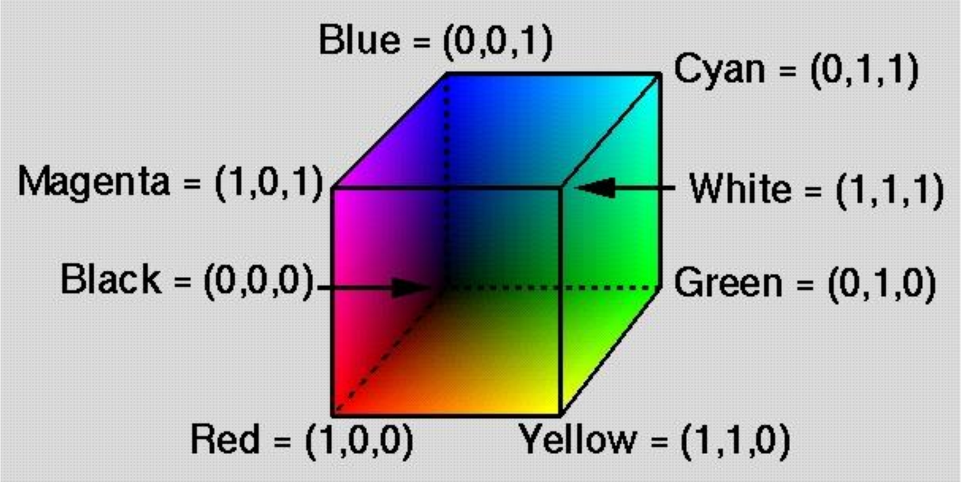
Color Perception

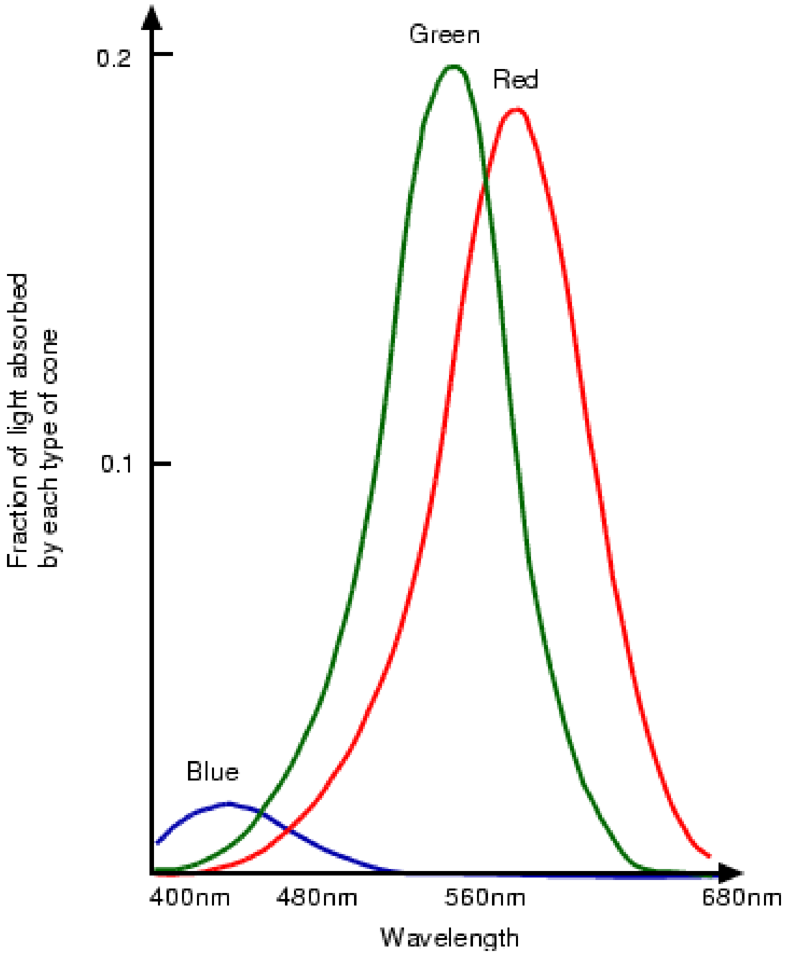
Tristimulus Theory:

- the eye has three types of color receptors: Red, Green, Blue.

Color reproduction:

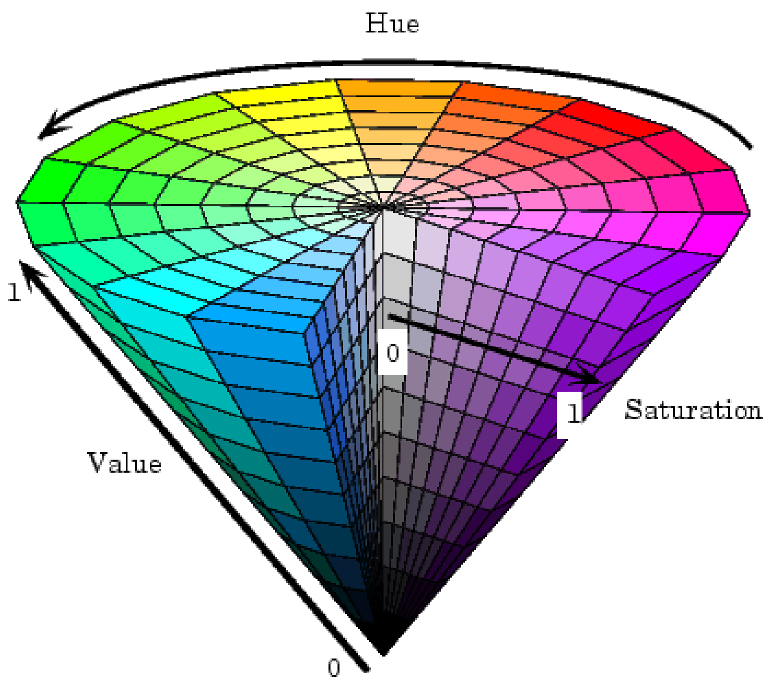
- one can generate (almost) any color on a monitor by mixing three primaries, RGB



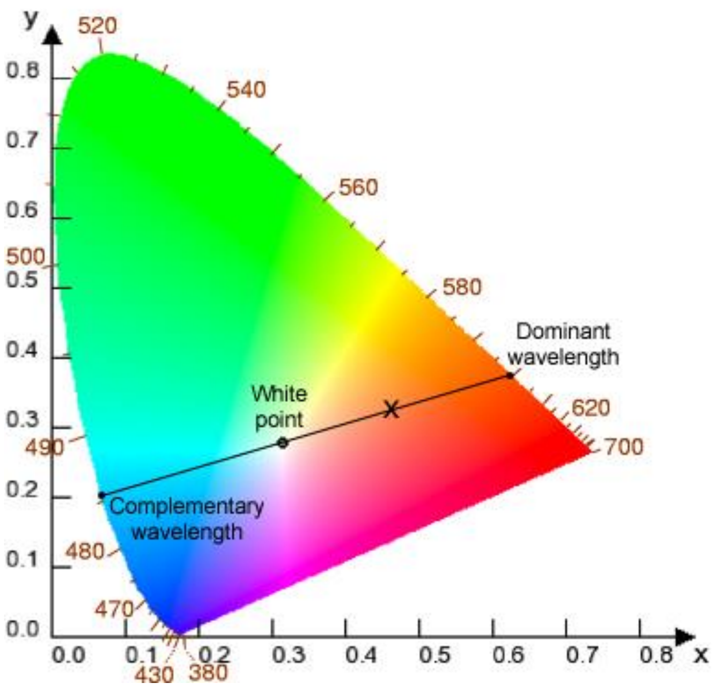


Color Spaces

HSV



CIE

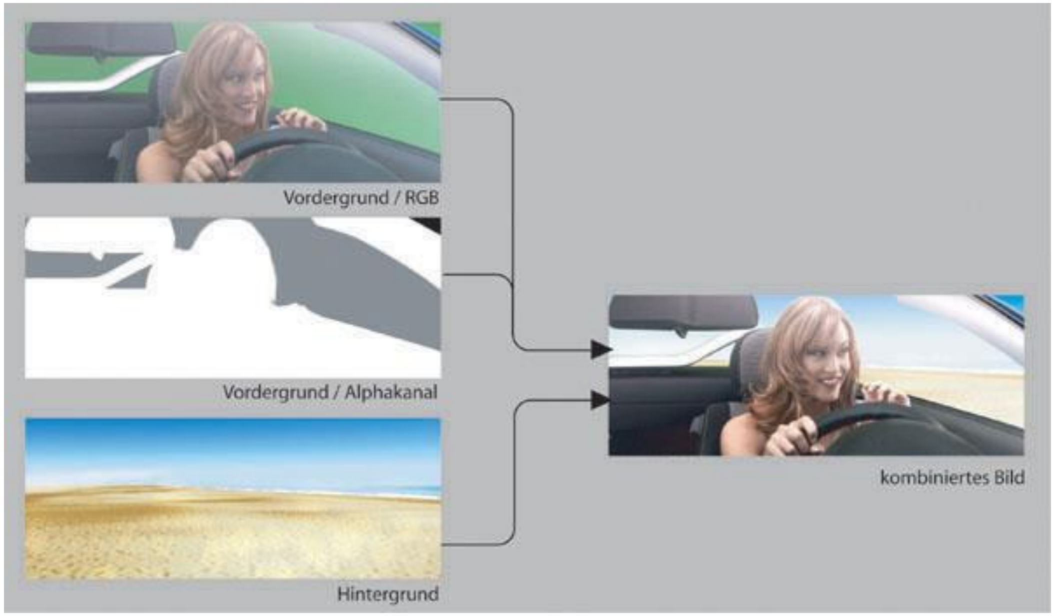


*H*ue: color
*S*aturation: peak from white light
*V*alue: overall integral across all λ

CIE Lαβ: equal distances mean equal perceptive differences

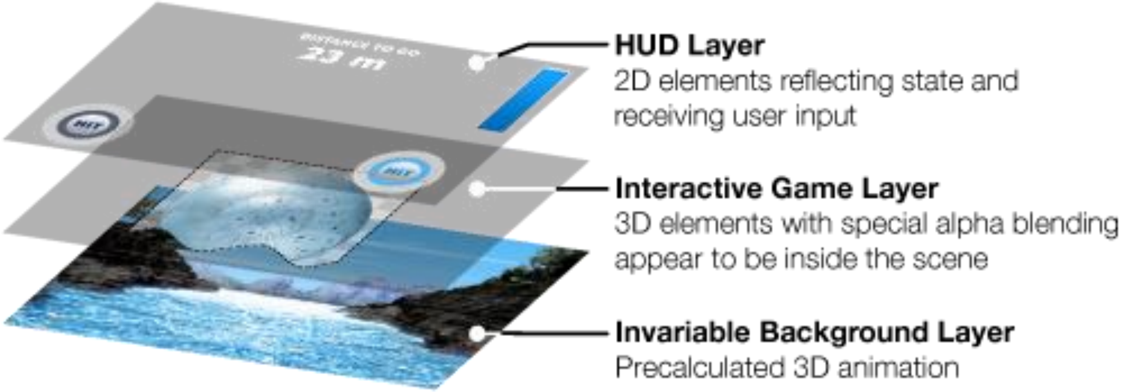
Alpha Compositing

Window manager

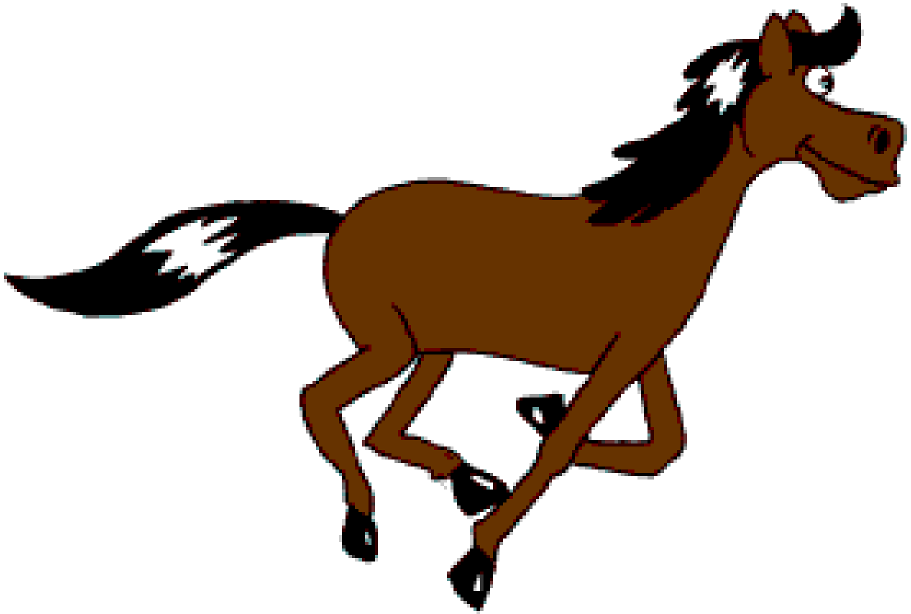


Inserting objects into scenes

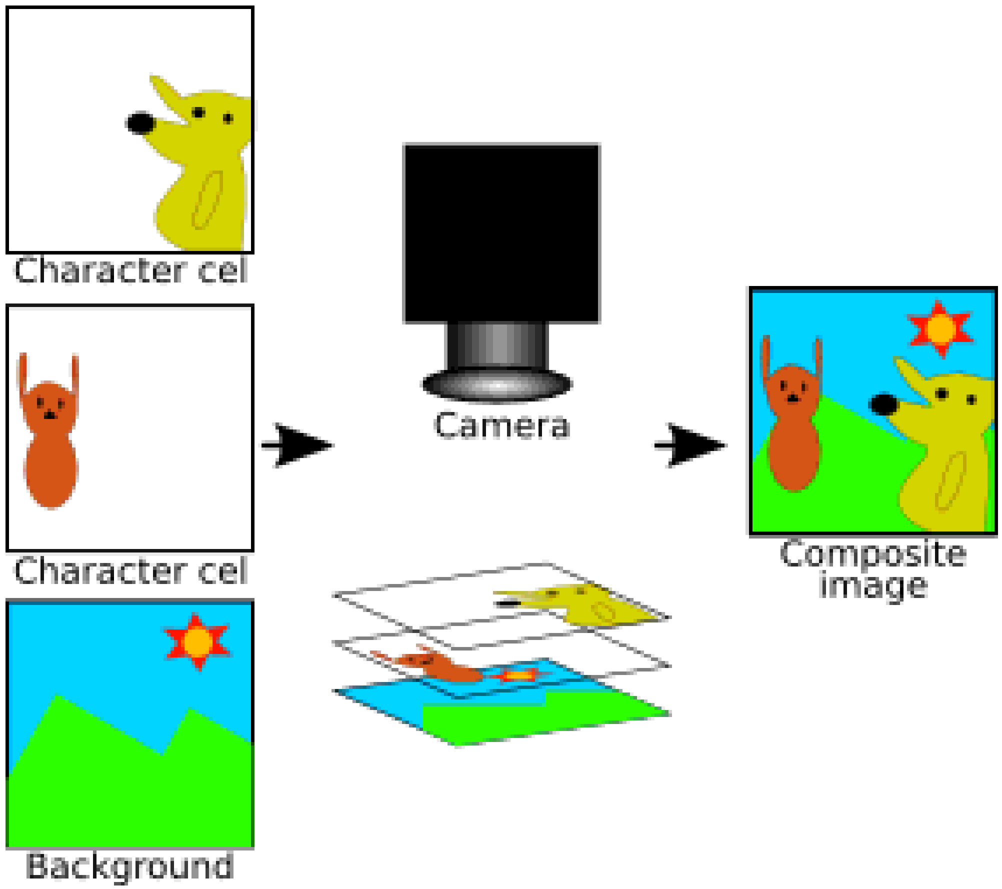
Computer games



Cel Animation



Cel Animation: Concept



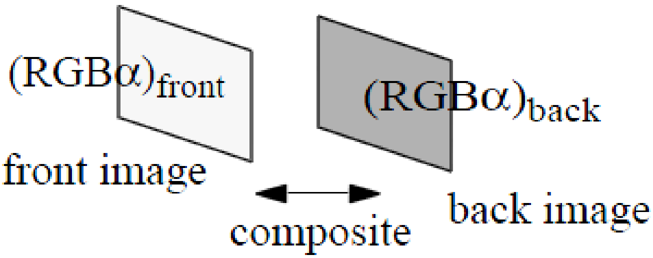
Alpha Compositing (Blending): The Math

- It is the accumulation of colors weighted by opacities
- Compositing is commonplace in cartoon animations

  - blend images of static objects with images of dynamic characters (so called *cel-animations*)
- Colors and opacities of back pixels are attenuated by opacities of front pixels:

  $rgb = RGB_{back} \cdot \alpha_{back} (1 - \alpha_{front}) + RGB_{front} \cdot \alpha_{front}$

  $\alpha = \alpha_{back} (1 - \alpha_{front}) + \alpha_{front}$



- By using:

  $rgb_{back} = RGB_{back} \cdot \alpha_{back}$

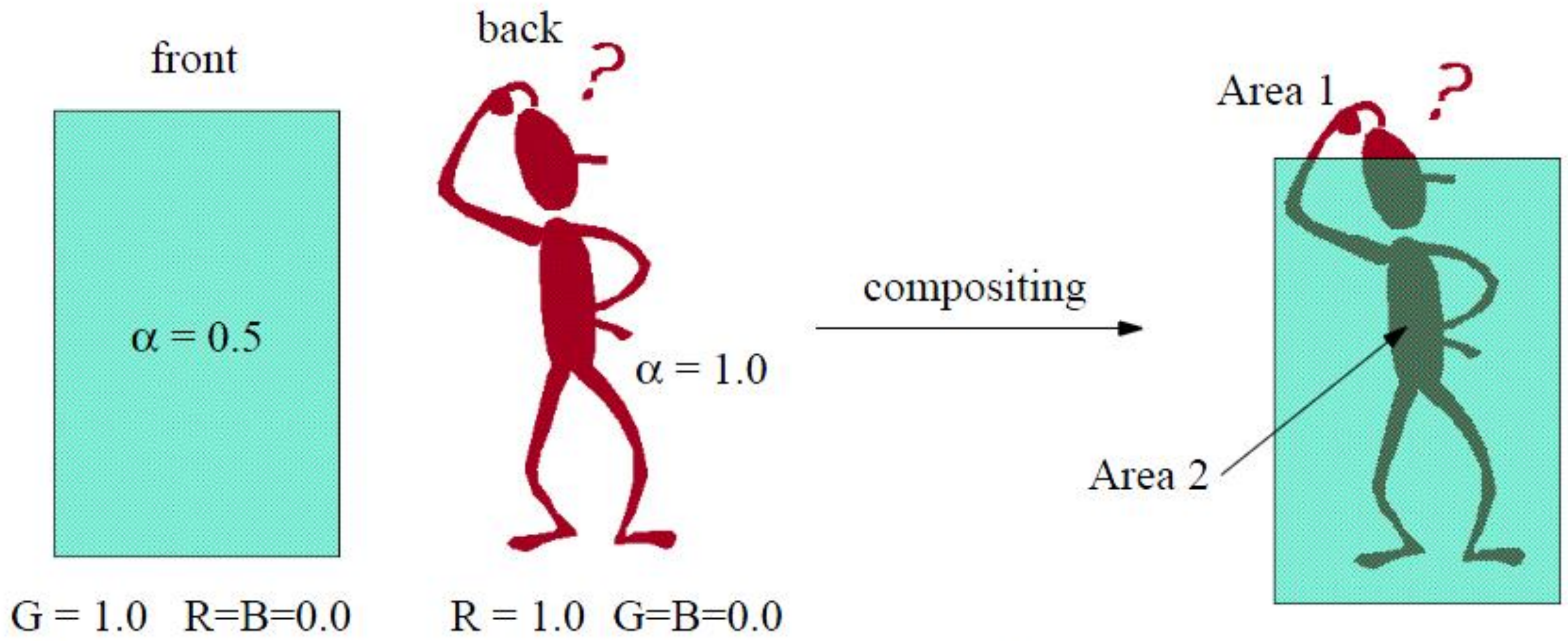
  $rgb_{front} = RGB_{front} \cdot \alpha_{front}$

  we get 2 recursive equations that can be used to composite any number of objects front-to-back:

  $rgb_{front} = rgb_{back} (1 - \alpha_{front}) + rgb_{front}$

  $\alpha_{front} = \alpha_{back} (1 - \alpha_{front}) + \alpha_{front}$
- Volume rendering uses this recursive expression to combine (=composite) the samples taken along the ray

Alpha Compositing (Blending): Numerical Example



Relax: Let's See Some Videos

[The Difference Between 2D and 3D animation]

[How To Make an Animated Movie]

Digital Image

Image:

- 2D matrix of pixels

Image resolution:

- number of pixels along each matrix dimension

300 150 75 37

resolution

Each pixel has a value:

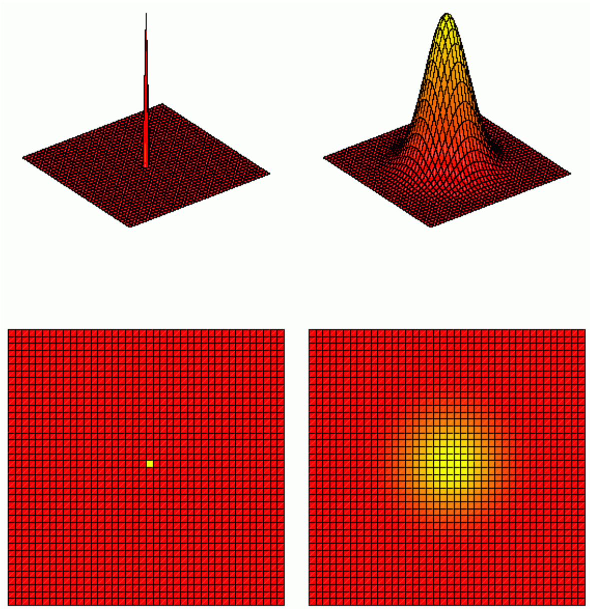
- a single value if greylevel image
- a triple RGB if color image

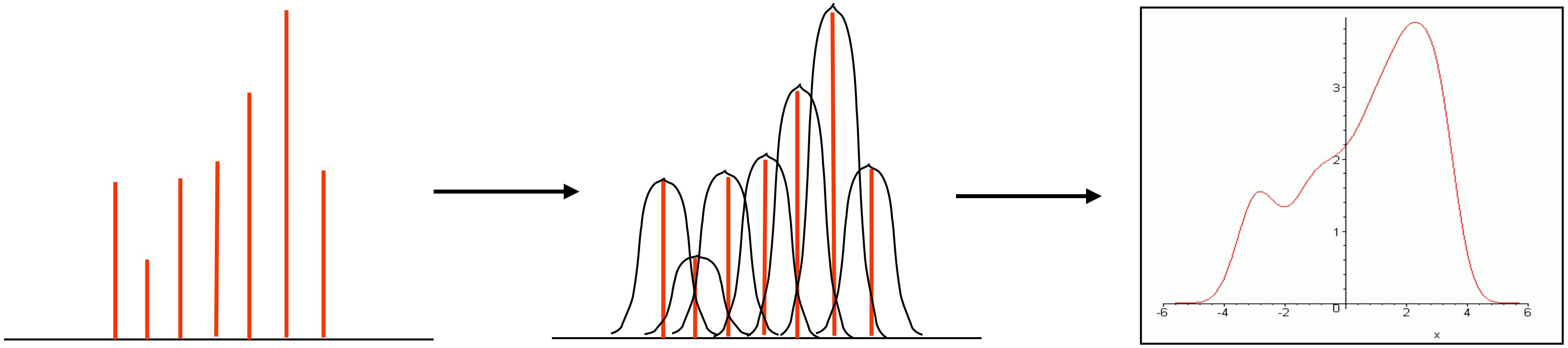
Point Spread Function

Each pixel is not a sharp spike, but represented by a point spread function (PSF)

The PSFs overlap and form a continuous function (for the eye)

Smaller PSFs give sharper images





Dynamic Range

Each pixel is represented by a number of bits

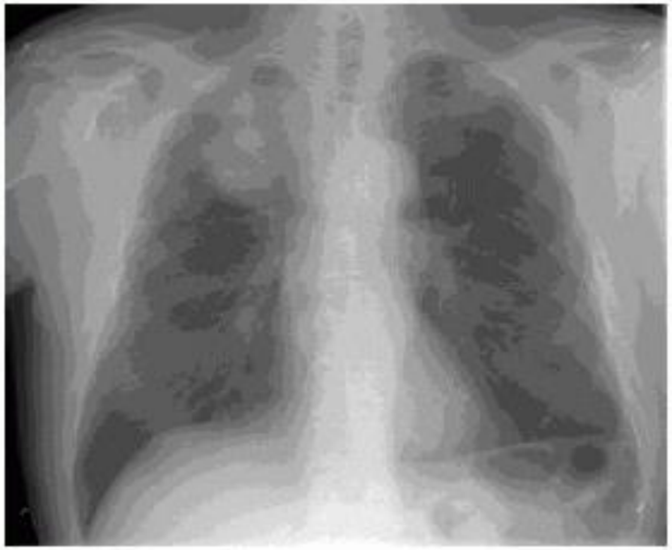
Quantization:

- process of discretizing a continuous value into bits

Minimal number of bits = 6 (64 greylevels or 4 levels for R,G,B)

- most medical digital images have 12 bits (4096 grey levels)

8 bits



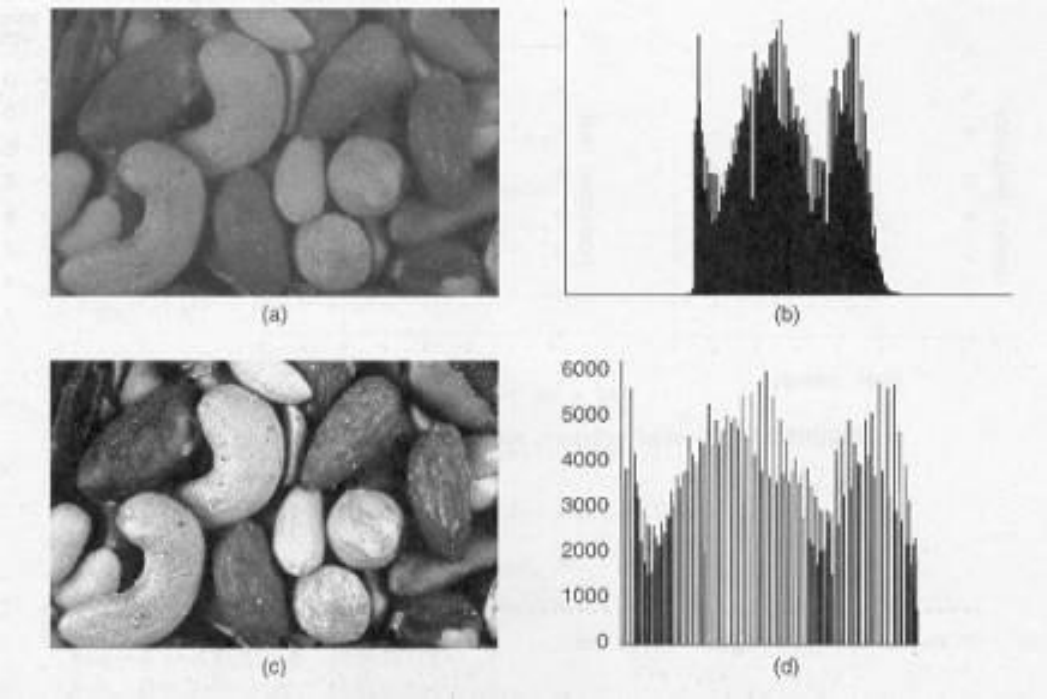
4 bits

- not enough bits leads to quantization artifacts and loss of resolution

Histogram

A histogram counts the number of pixels at each greylevel

- $h(v)$ = number of pixels having grey value v / total number of pixels



partial bandwidth

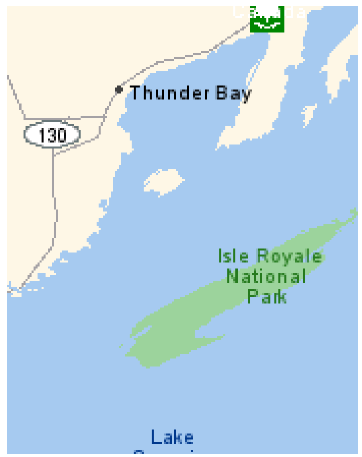
full bandwidth

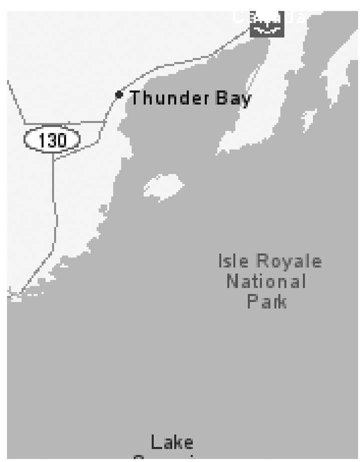
Good contrast requires a histogram with full bandwidth

Contrast

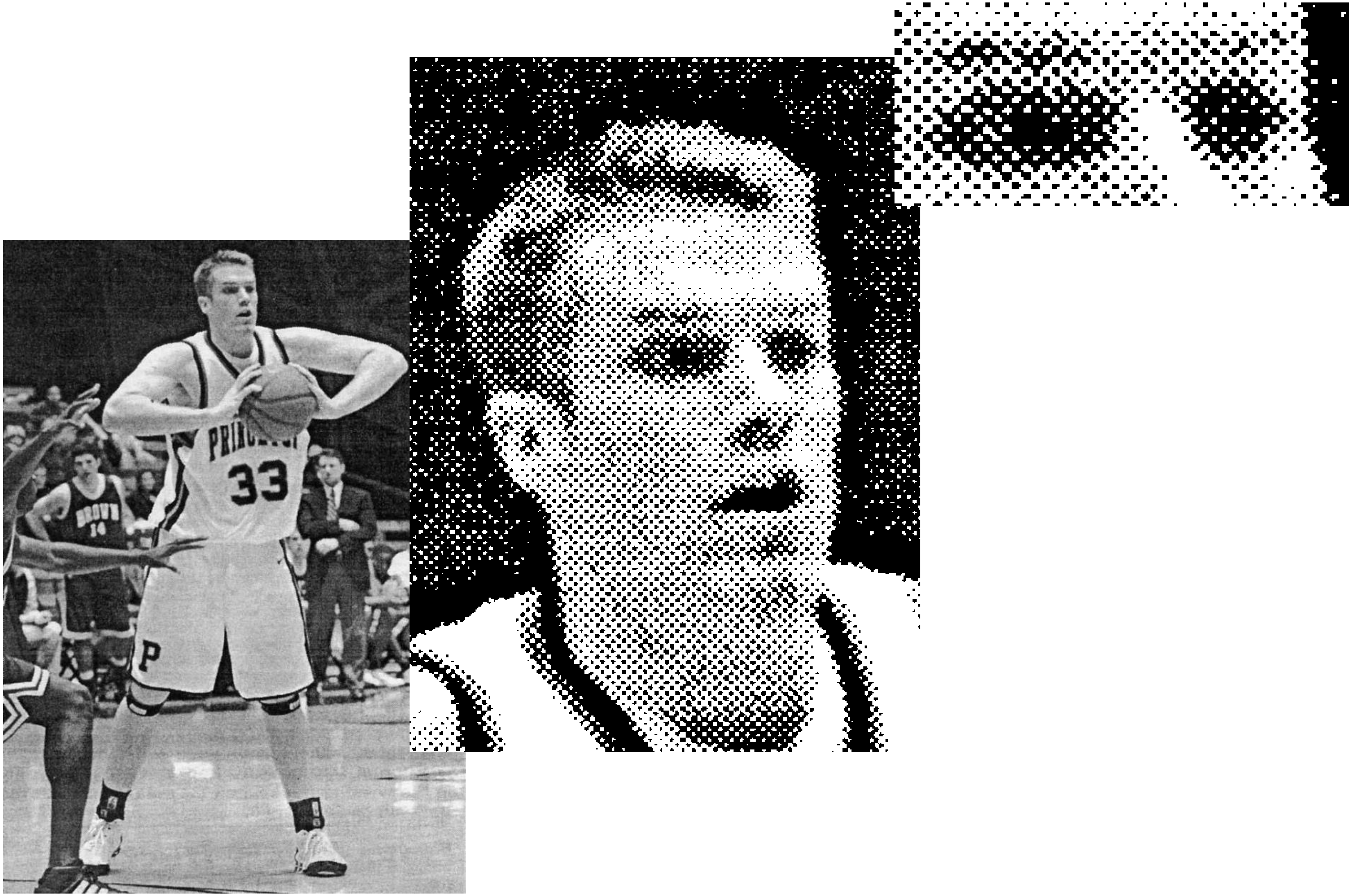
Difference of brightness in adjacent regions of the image

- grey-level (luminance) contrast
- color contrast





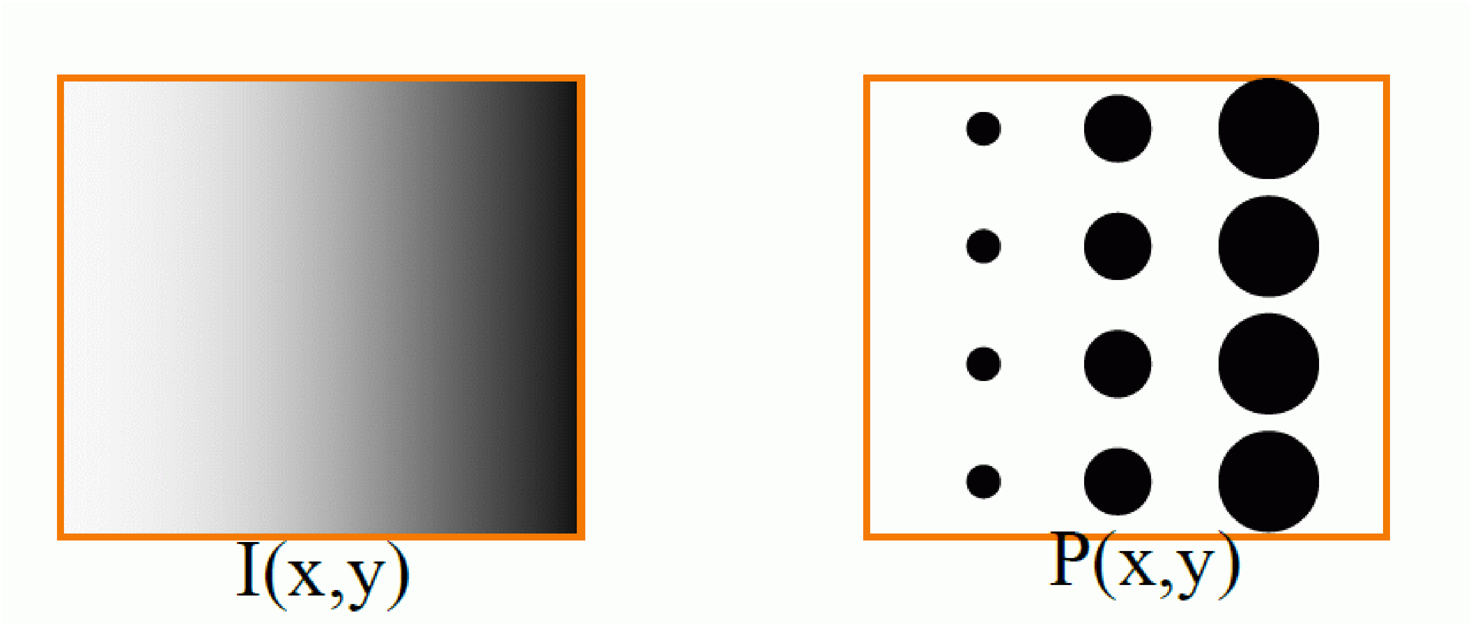
Classical Half Toning



Classical Half Toning

Use dots of varying size to represent intensities

- Area of dots proportional to intensity in image



Dithering

Distribute errors among pixels

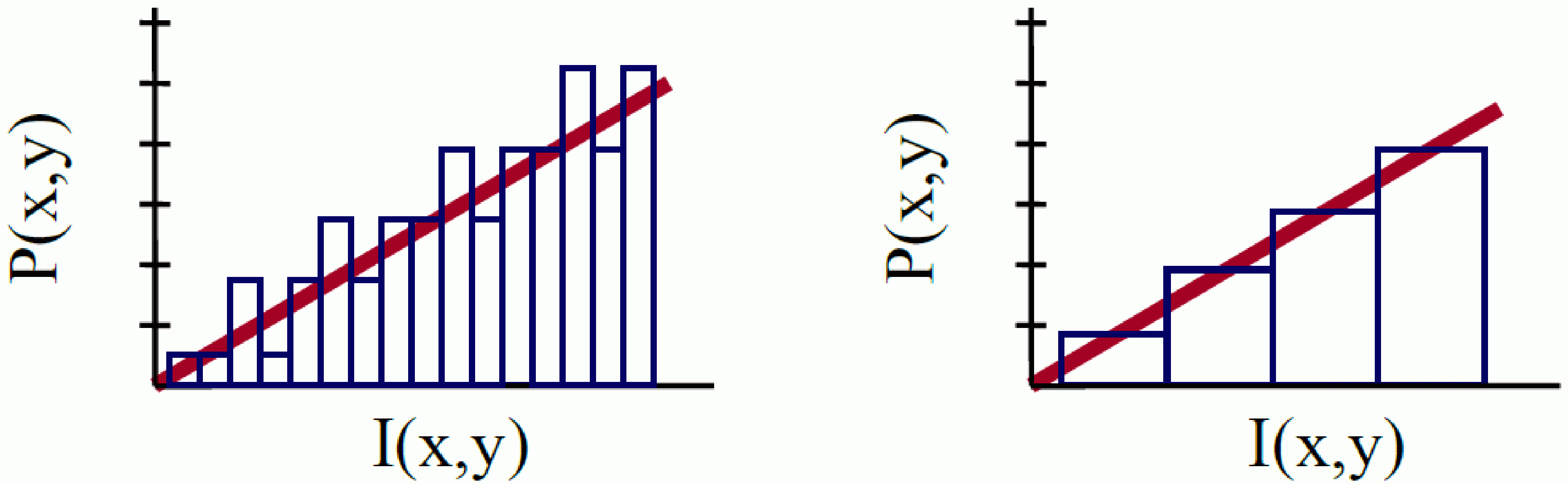
- exploit spatial integration in our eye
- display greater range of perceptible intensities

Original (8 bits) | Uniform Quantization (1 bit) | Floyd-Steinberg Dither (1 bit)

Random Dither

Randomize quantization errors

- errors appear as noise

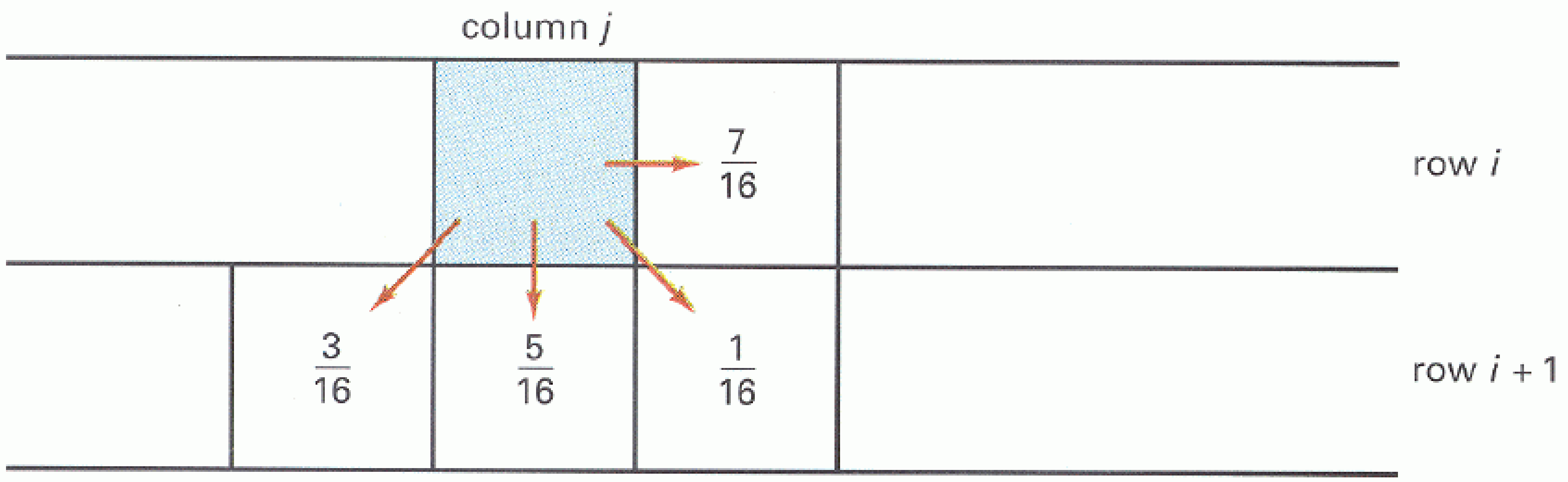


$$P(x, y) = \text{round}(\ I(x, y) + \text{noise}(x,y)\ )$$

Floyd-Steinberg Dithering

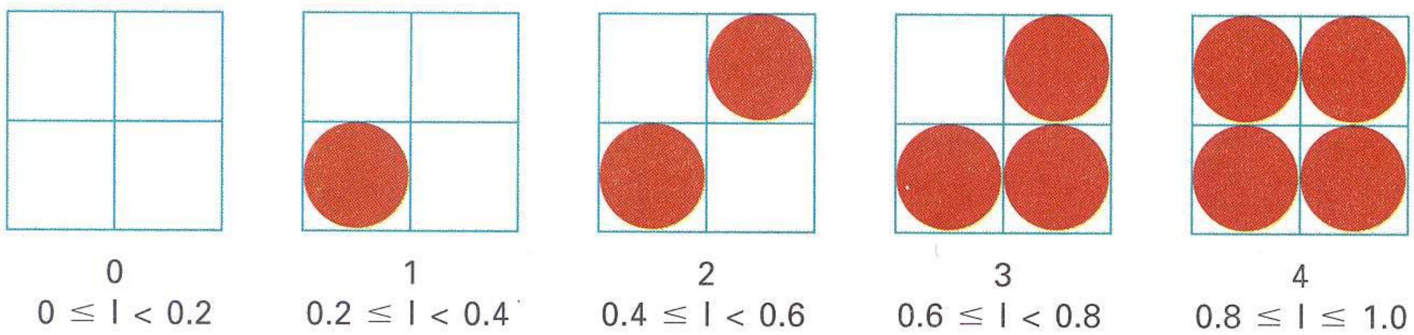
Spread quantization error over neighbor pixels

- error dispersed to pixels right and below
- Floyd-Steinberg weights



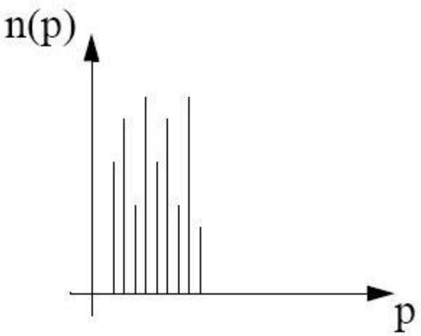
$$3/16 + 5/16 + 1/16 + 7/16 = 1.0$$

Digital Halftone Patterns



Back to The Image Histogram

dark image



bright image

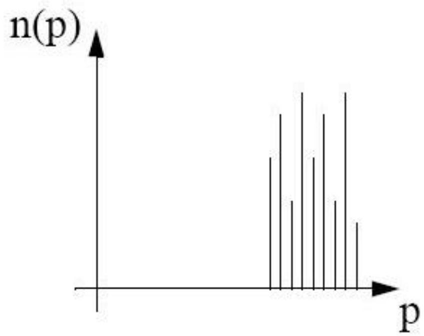
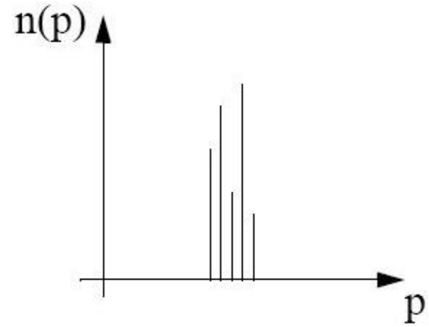


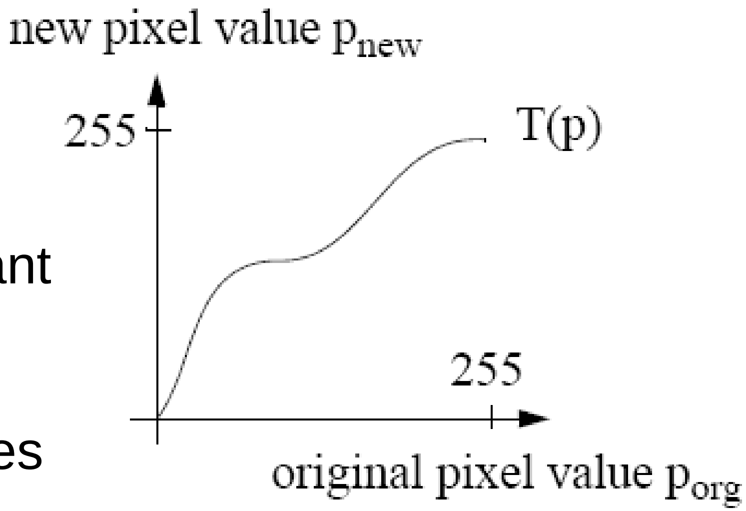
image with low contrast



Grey Level Transformation: Basics

Problem: We only have a fixed number of grey levels (256) that can be displayed or perceived

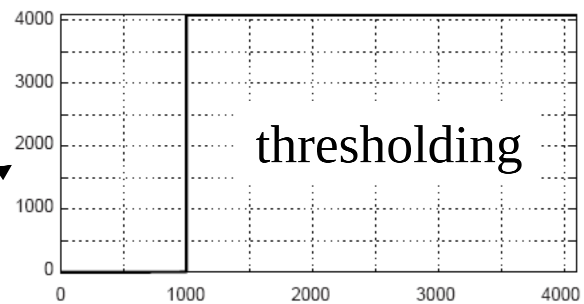
- need to use this ‘real estate’ wisely to bring out the image features that we want

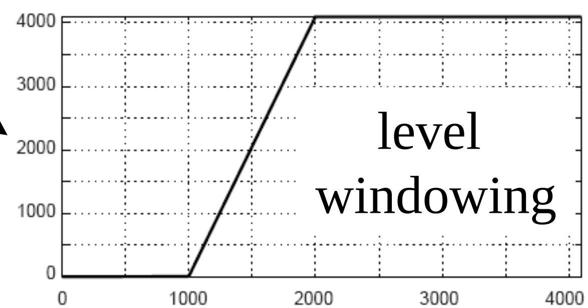


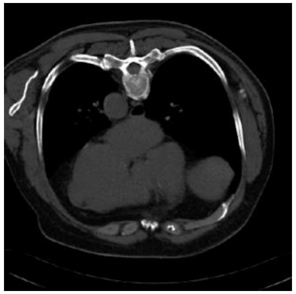
Use *intensity transformations* T_p

- enhance (remap) certain intensity ranges at the cost of compressing others

lung CT





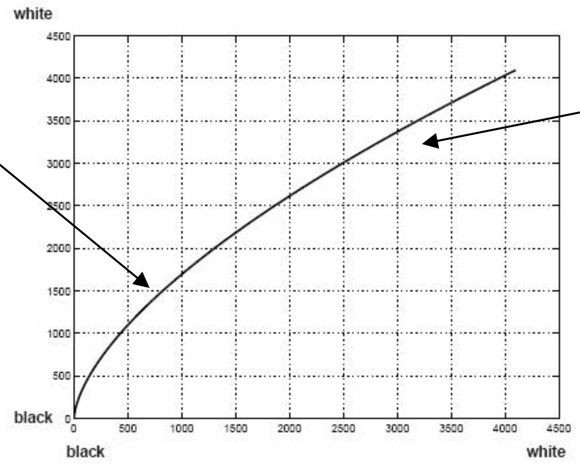


Grey Level Transformation: Enhancements

enhance the dark areas
(slope > 1)

suppress the white areas
(slope < 1)

transfer function



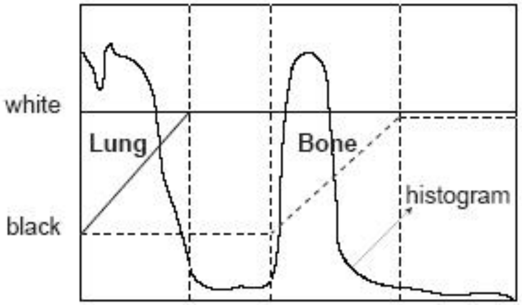
original

enhanced

Grey Level Transformation: Windowing

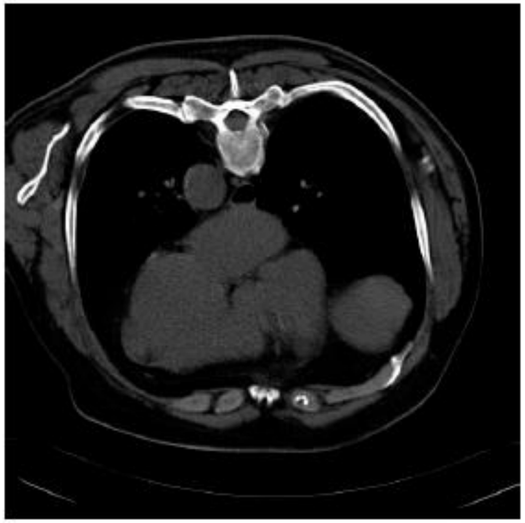
Dedicate full contrast to either bone or lungs

original lung CT image



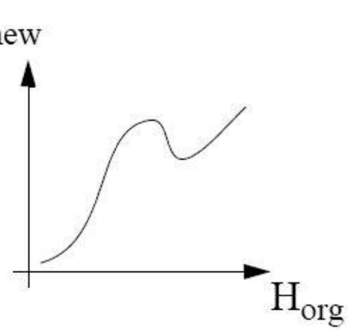
bi-modal histogram

bone window



lung window

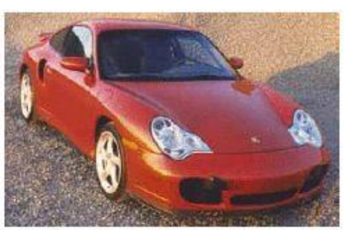
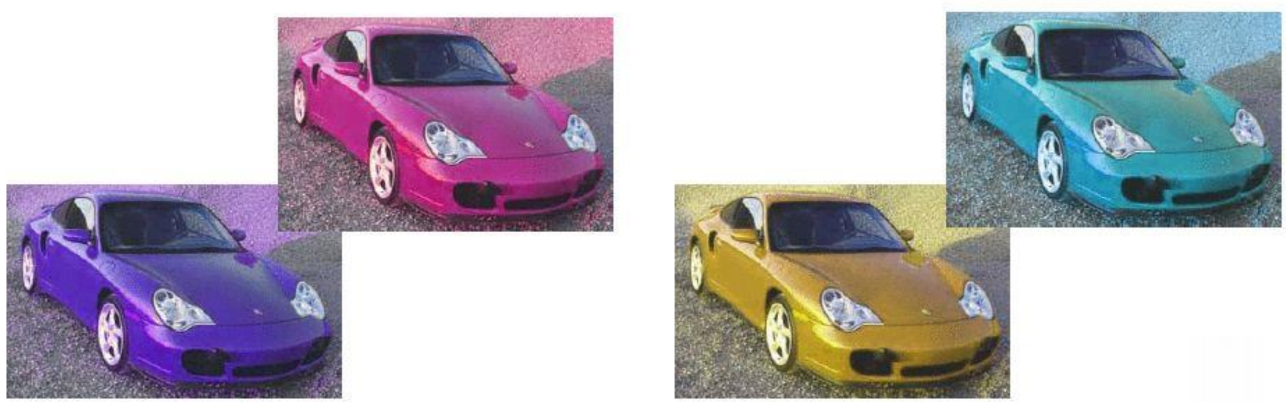
Color Image Processing



- Convert the image from RGB to HSV space
- Perform transformations of pixel H, S, V values via transfer functions
- Convert the transformed HSV image back into RGB space and display

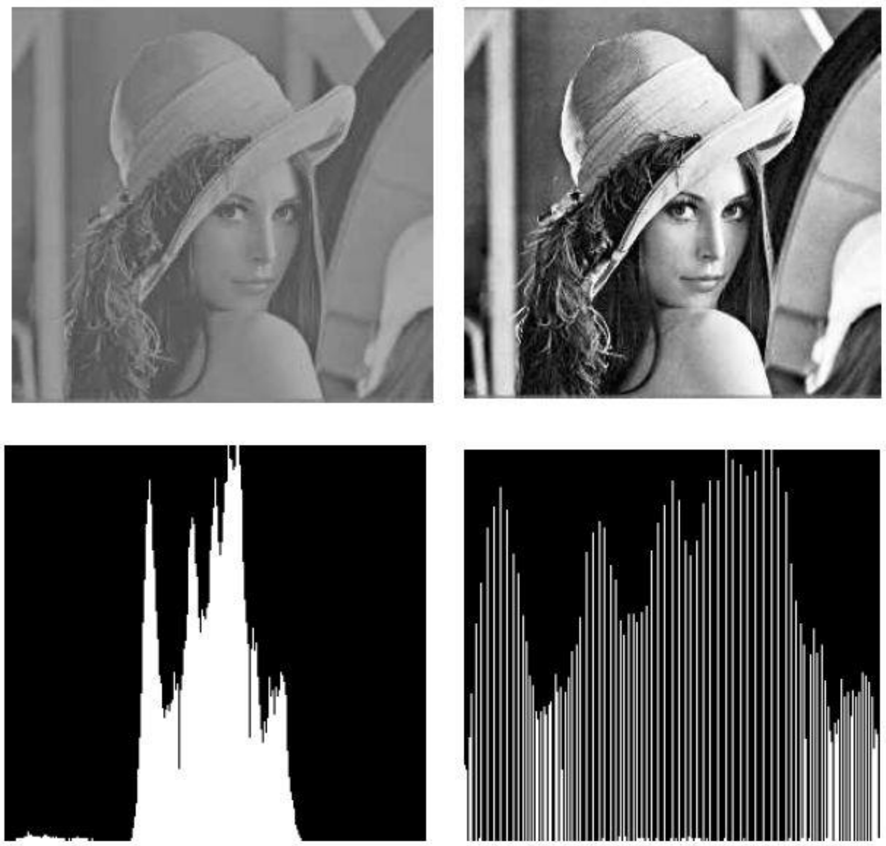

Original

Hue transformed

Histogram Equalization

Equalize the V channel, and then convert back to RGB



before equalization after equalization

grey level

color

before and after - guess which

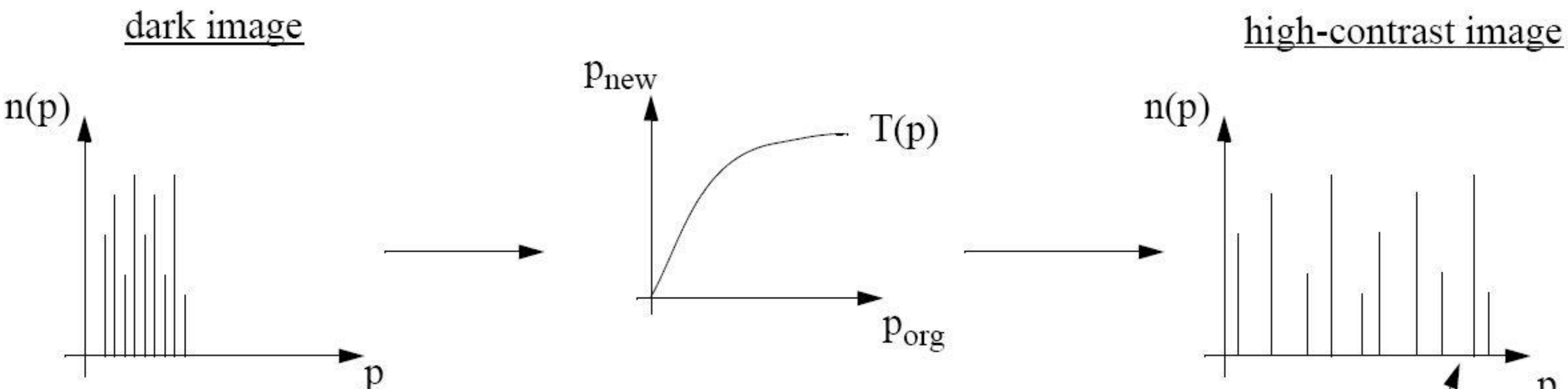
Histogram Equalization

- Image contrast and brightness may be improved by modifying the histogram
- The 'contrast stretching' operation requires the user to manipulate the image's histogram
- *Histogram equalization* is an automatic procedure to spread out the value distribution

The discrete histogram equalization equation is: $$p_{new}(k) = \sum_{j=0}^{k} \frac{n(p_{org}(j))}{n_{total}} \cdot p_{max}$$

255

- For example, the equalization transformation for a dark image would be:



Note: the bars do not change in height, they are just shifted to different positions