Lecture 22
Segmentation: Basic Display Concepts

MP574: Applications

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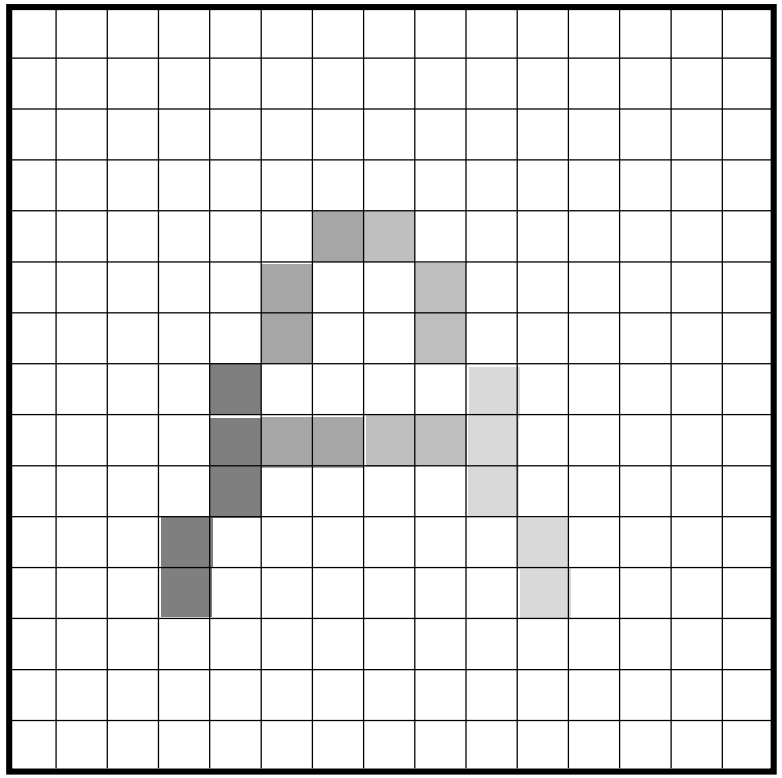
Learning Objectives

- Learn digital image display and signal intensity mapping concepts.
- Introduce basic segmentation concepts

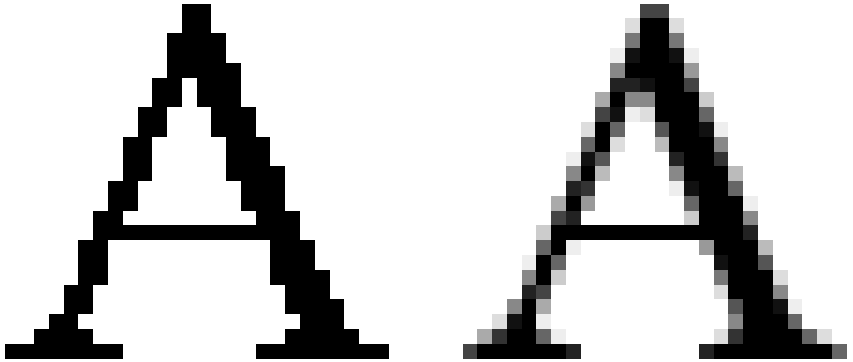
Digital Image Representation

- 2D matrix
  - Each pixel:
    - Scalar (gray value)
    - Triplet (RGB, BGR, HSV)
    - Quadruplet (ARGB, CMYK)
- Image quality properties
  - Image resolution: number of pixels
  - Blurring (point response)
  - Noise (signal to noise ratio)
- Alternative repre-sentation: vector graphic



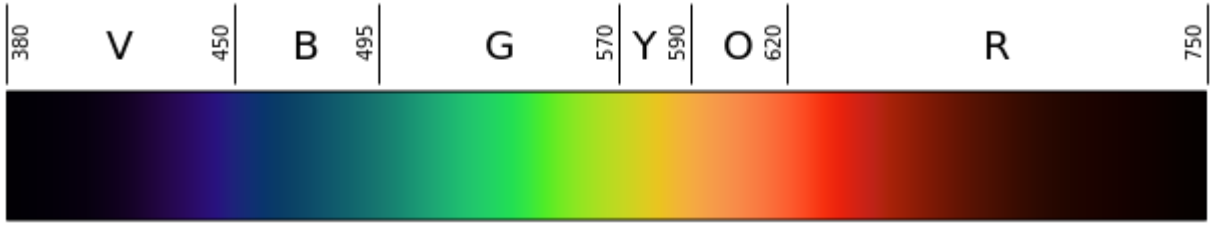
Spatial Aliasing

- Occurs when object border does not align with pixel boundary
- Anti-aliasing
  - Low-pass filter before sampling
  - Can improve visualization
  - Reduces sharpness



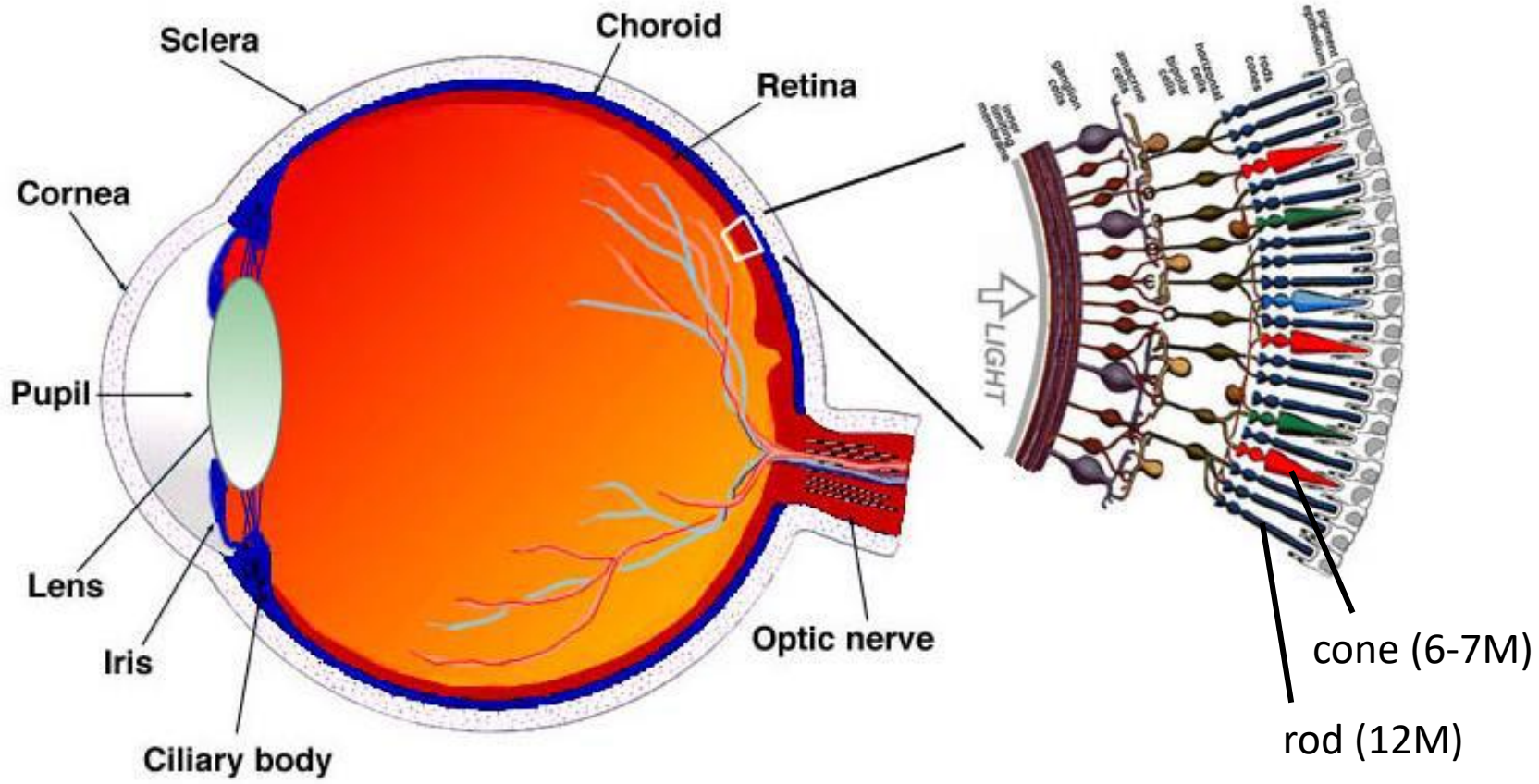
What is Color?

- Frequency / Wavelength



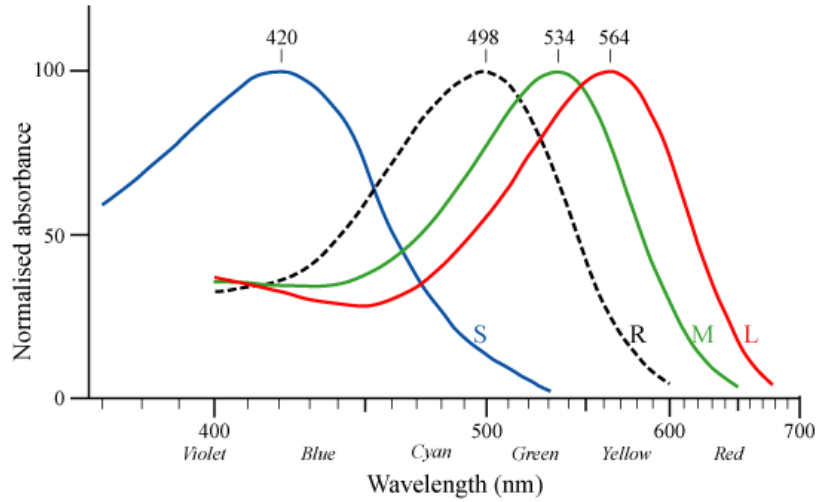
- “White light” is a combination of different wavelength
- Light Intensity

Our First Imaging System: Retina of the Human Eye



Simple Anatomy of the Retina by Helga Kolb

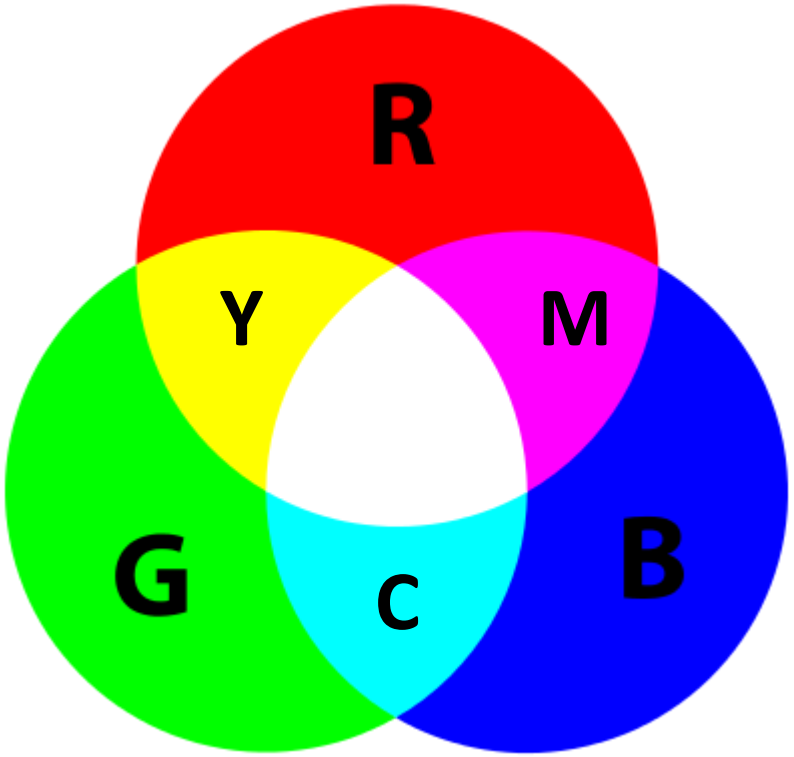
Image Perception



Spectral Frequency Sensitivity of Cones and Rods

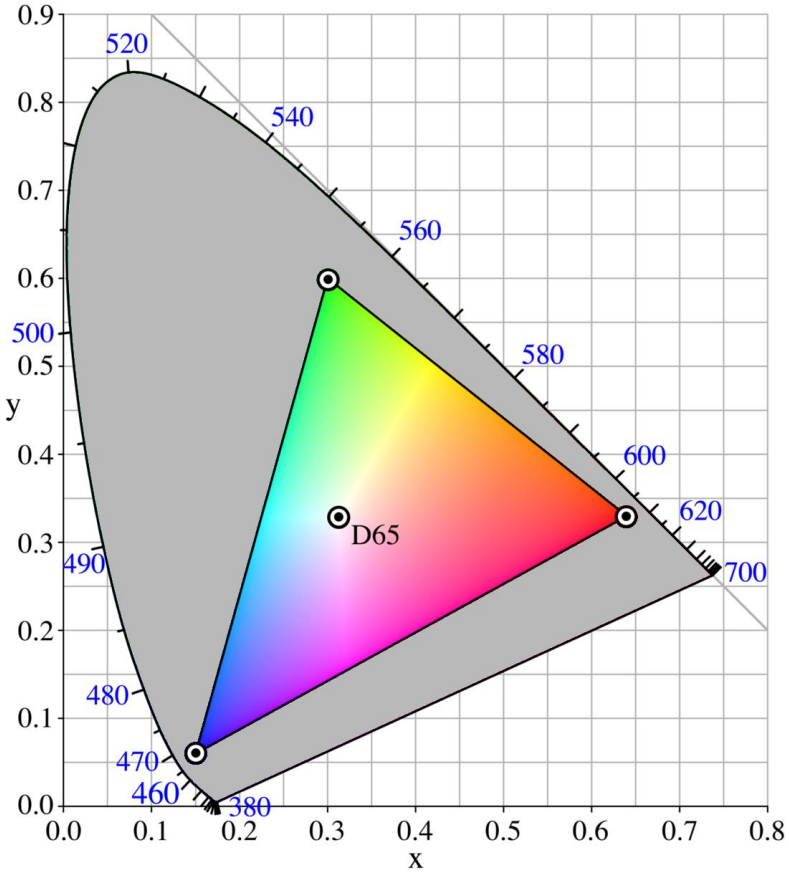
- Rods: intensity sensitive
- Cones: color sensitive.
  - Cones are further classified by their color spectral sensitivity into L(64%), M(32%) and S(2%) types.

RGB Color Model



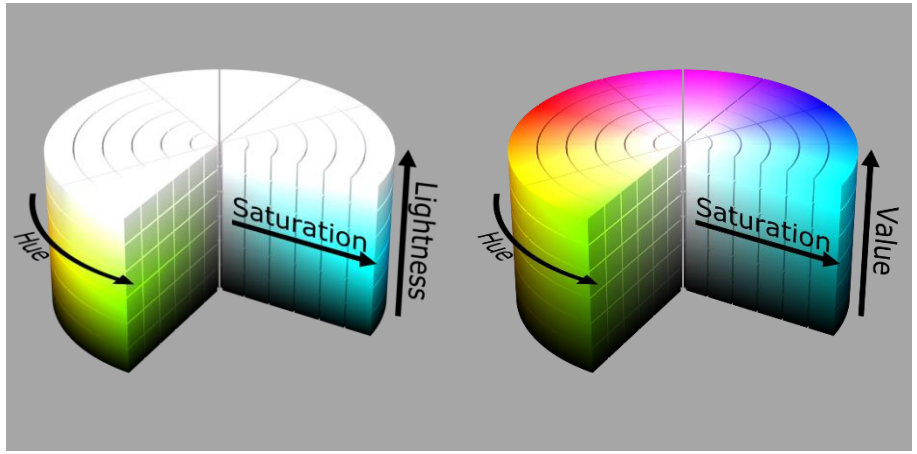
BT.709 primaries

Simulate part of visible spectrum by linear combination of primary colors (sRGB, Adobe RGB, …):



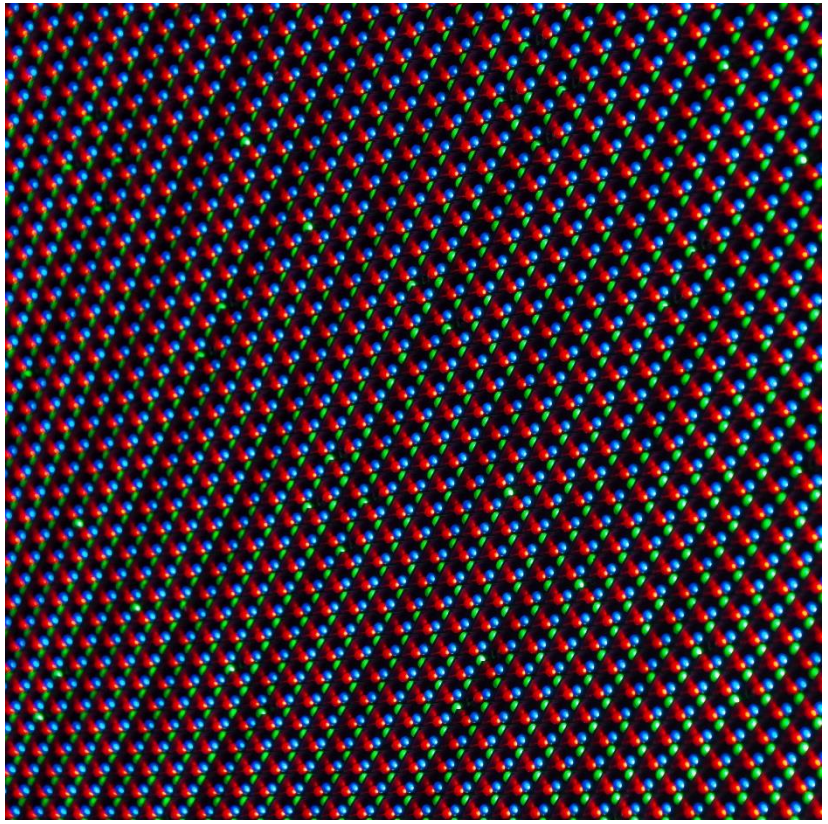
Alternative Color Models

- ARGB: Same as RGB but with additional alpha channel representing opacity
- HSV / HSL



- CMYK
  - 4 color channels
    - Cyan (C)
    - Magenta (M)
    - Yellow (Y)
    - Black (K)
  - Subtractive model
  - Mostly for print media
  - Additional black channel increases quality and saves ink

Displays



- Technologies:
  - Cathode ray tube (CRT)
  - LCD (LED-Backlit)
  - LED
  - OLED
- Each pixel is comprised of red, green and blue

Look-Up Tables

- Recall our electron beams for the CRT presented in Lecture 1

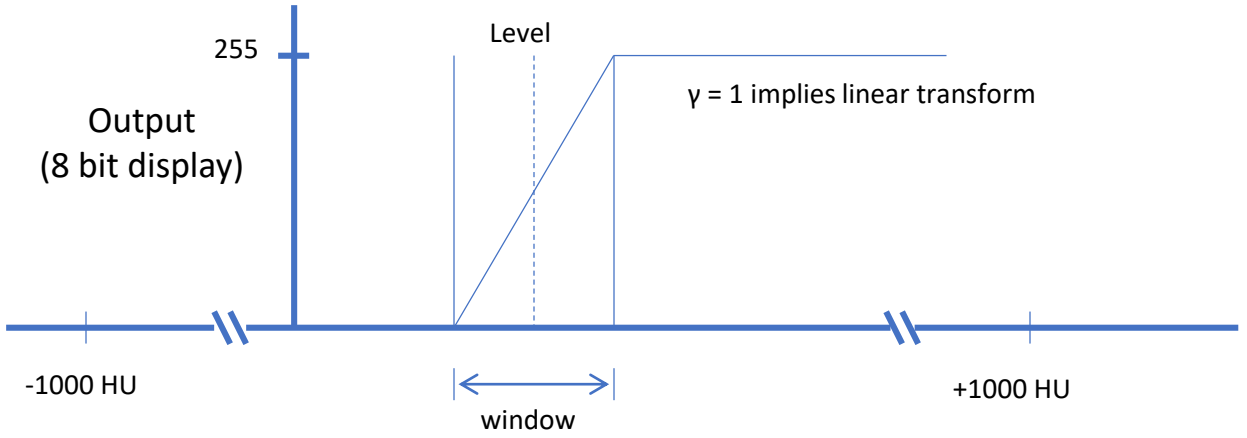
- Intensities correspond to what is called a “Look-Up Table”
  - Defines the intensity of color scale of the displayed image:
    - 8 bit Monochrome [1 1 1 1 1 1 1] = 255 => white
    - 8 bit Monochrome [0 0 0 0 0 0 0] = 0 => black

- The W/L maps the input values to displayed intensity via the Look-Up Table

Window and Level in digital display

- Example Hounsfield Unit or CT Number:

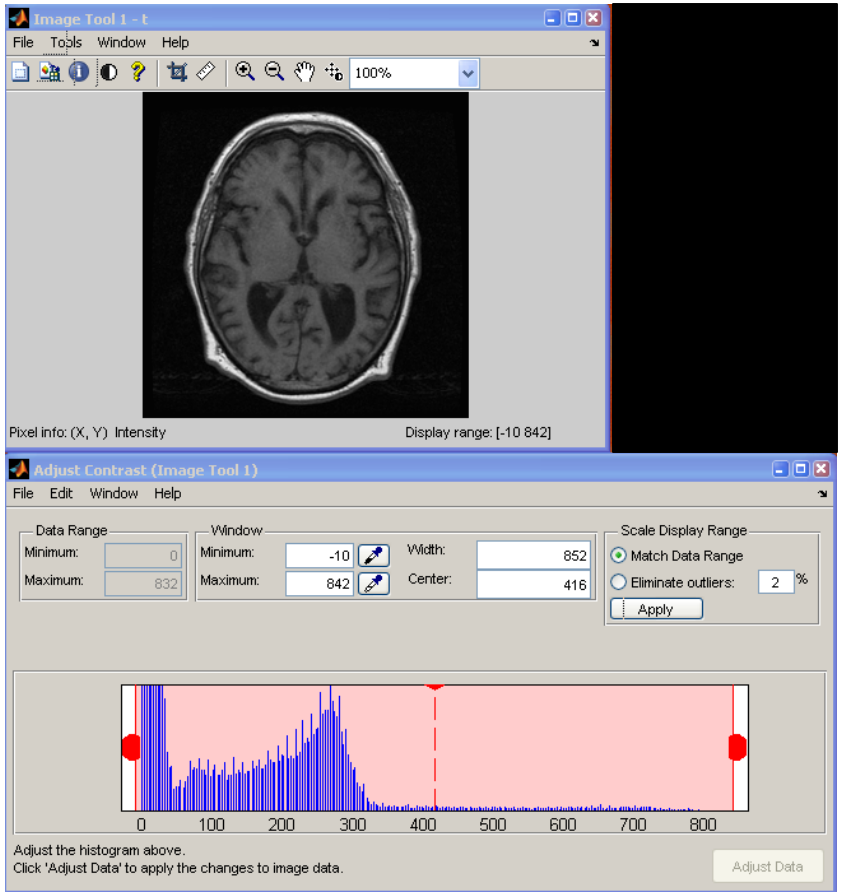
$$HU = \frac{\mu - \mu_{water}}{\mu_{water}} \times 1000$$

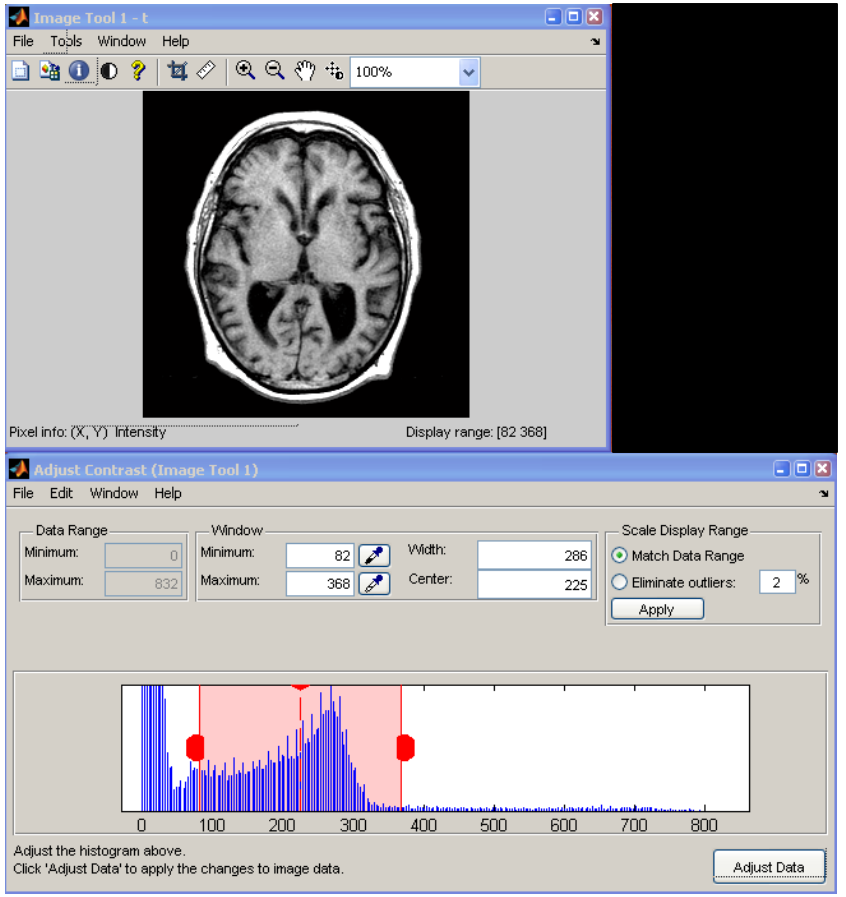


Input CT Image
(2000 HU dynamic range)

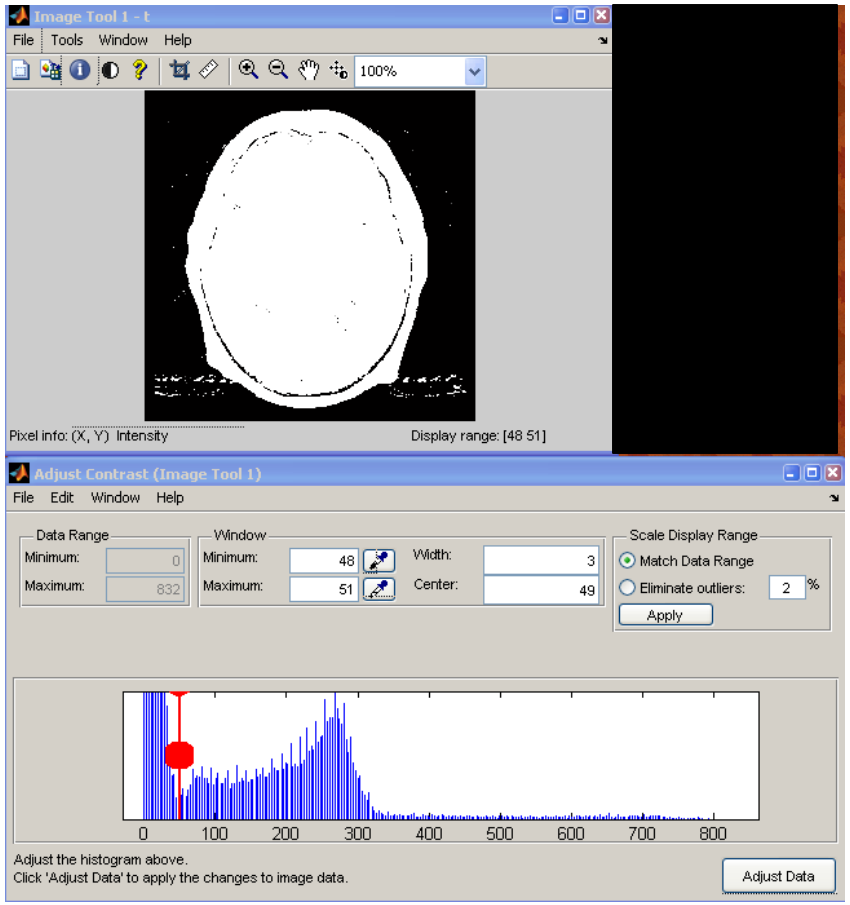
- The dynamic range of the image is much greater than the dynamic range of the display – 8 bit monitors up to 10 and 12 bit professional.

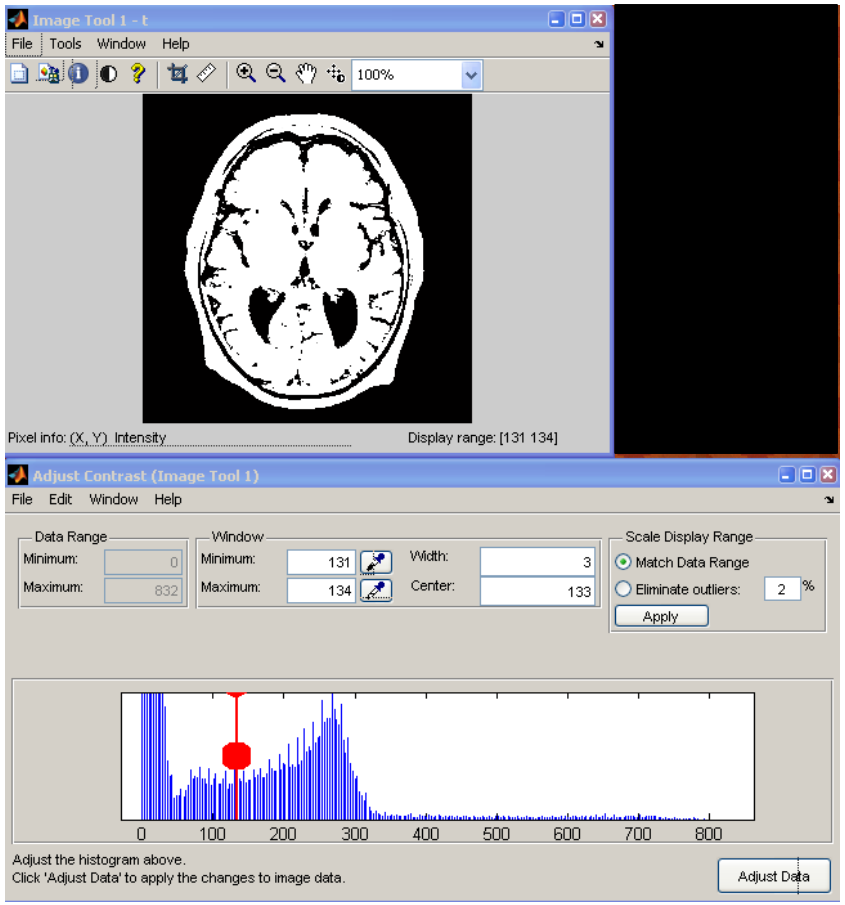
Window and Level Examples



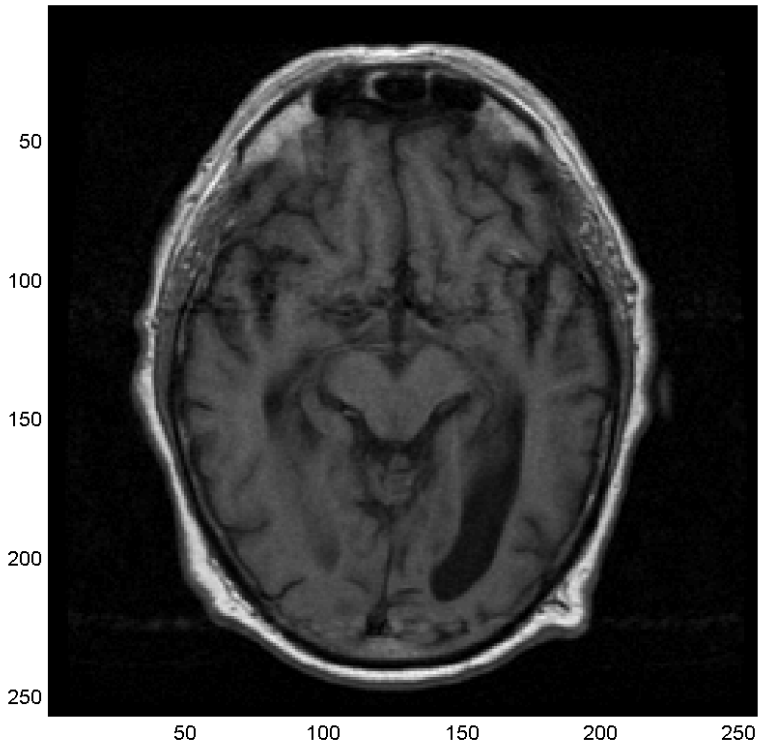


Bimodal Image Histogram

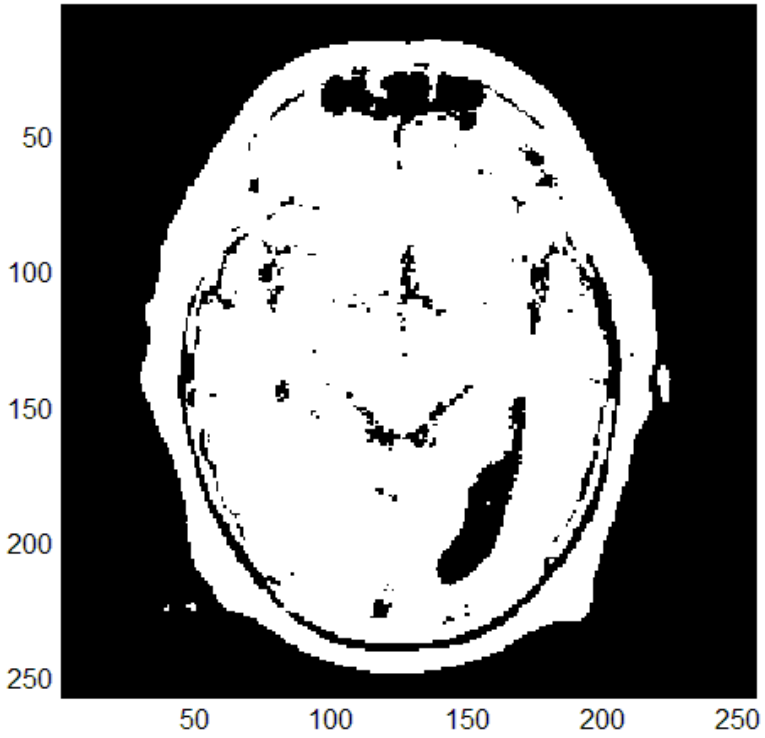




Monochrome Images: Bit Depth



8 bit depth monochrome implies 256 levels of gray



1 bit depth => 2 levels, black “0” and white “1”

Window and Level (W/L) in digital display

- Linear Transform within the window, maps input x to output T[x]:

$$T[x] = \begin{cases} x \le l_{in} = l_{out} \\ (x - l_{in}) \frac{h_{out} - l_{out}}{h_{in} - l_{in}} + l_{out} \\ x > h_{in} = h_{out} \end{cases}$$

Non-linear transforms in digital display

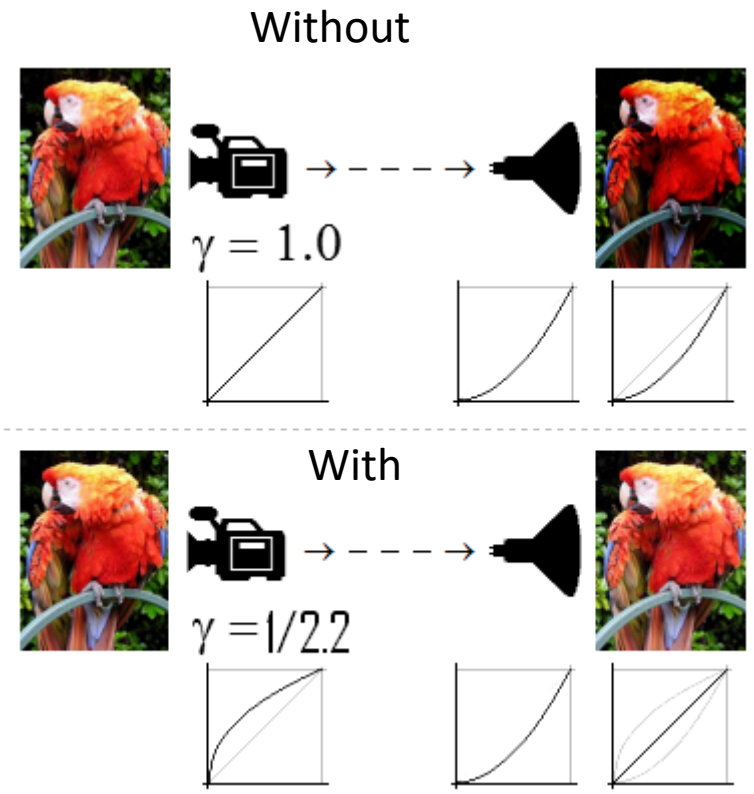
- Generalized transform, with γ, maps input x to output T[x]:

$$T[x] = \begin{cases} x \le l_{in} = l_{out} \\ (x - l_{in})^{\gamma} \frac{h_{out} - l_{out}}{(h_{in} - l_{in})^{\gamma}} + l_{out} \\ x > h_{in} = h_{out} \end{cases}$$

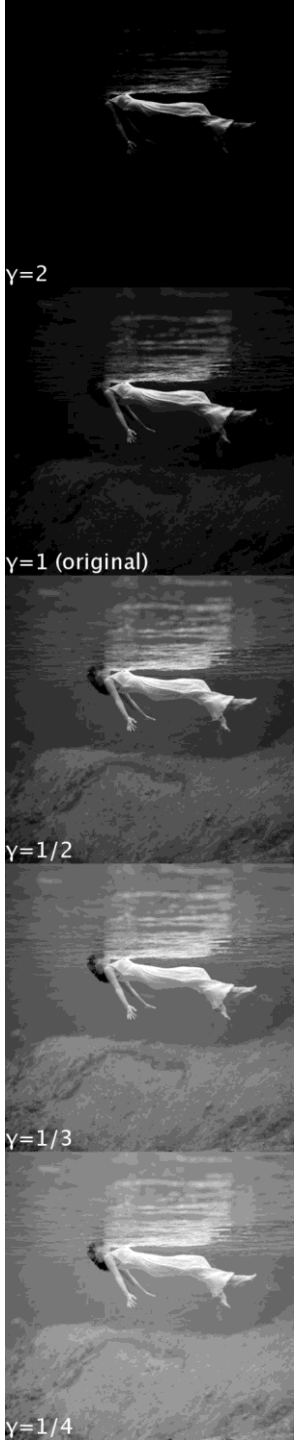
- γ>1, then concave within the window
- γ<1, then convex within the window

Gamma Correction

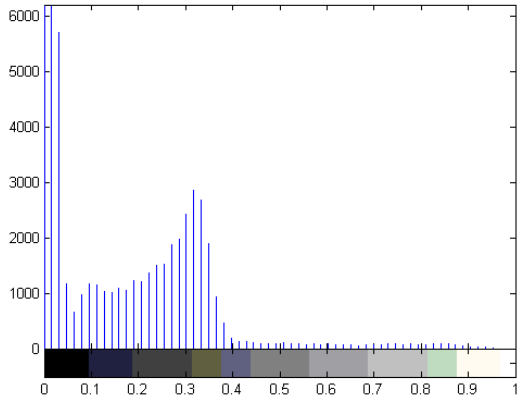
- Systems with linear and gamma-corrected cameras. The dashes in the middle represent the storage and transmission of image signals or data files. The three curves represent input–output functions of:
  1. The camera,
  2. The display, and
  3. The overall system.

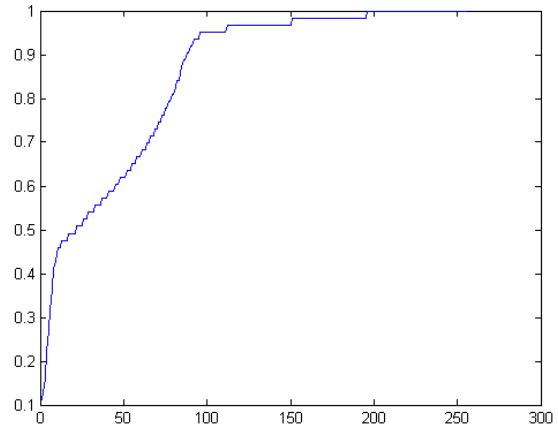


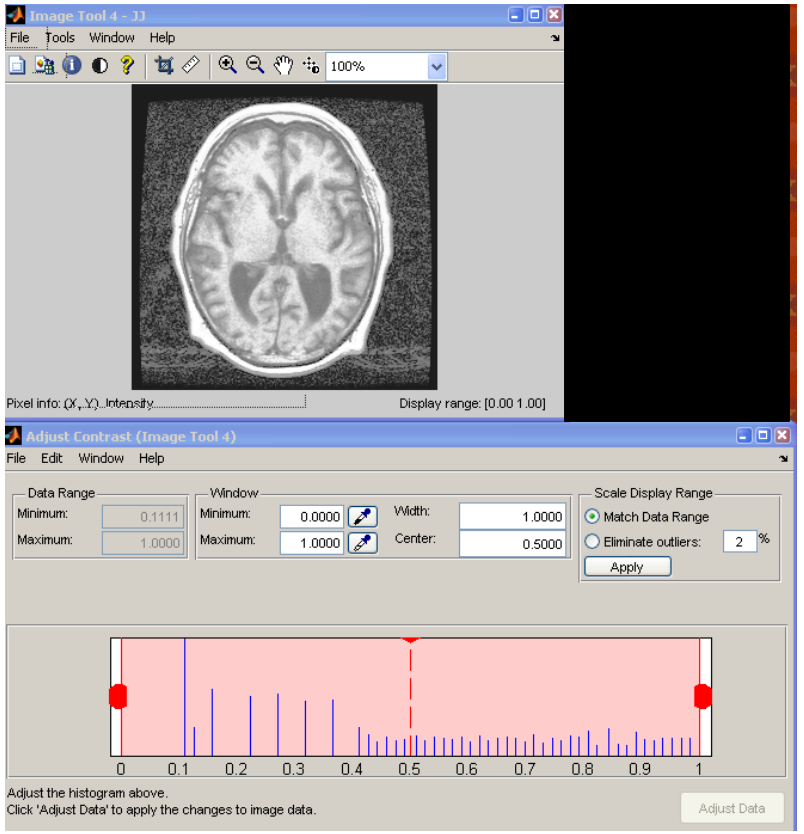
http://en.wikipedia.org/wiki/Gamma_correction#Monitor_gamma_tools



Empirical Image Transforms: Histogram Equalization



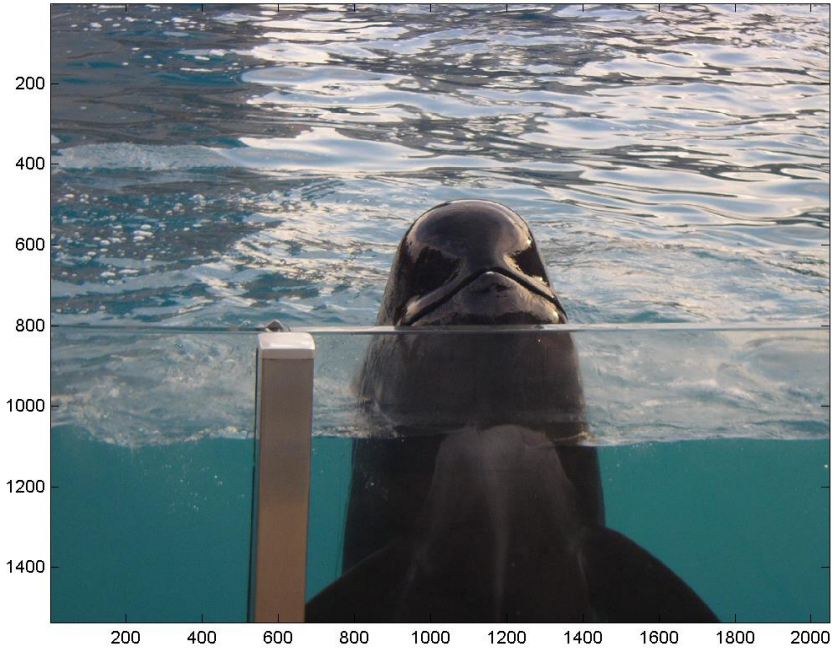




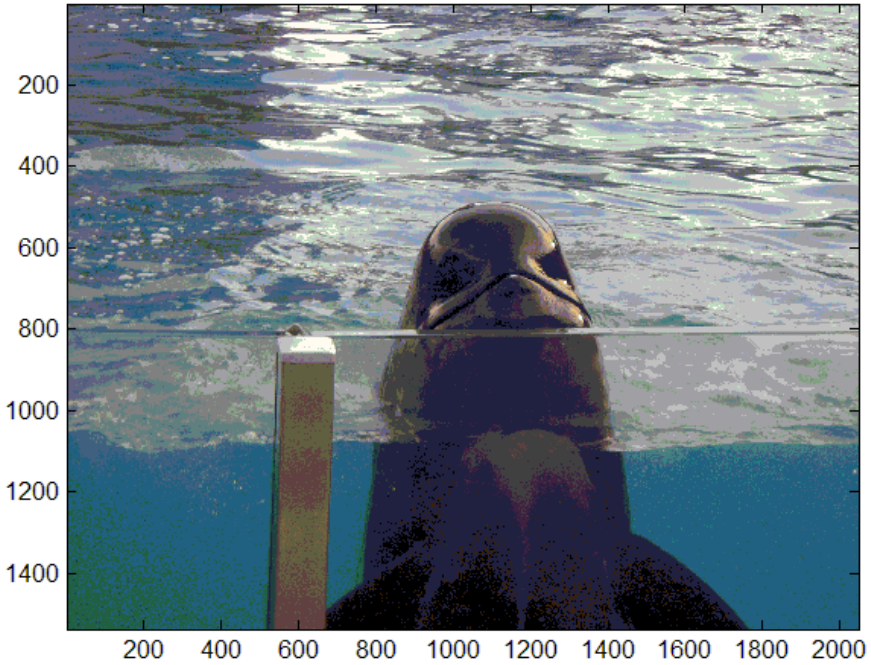
Dynamic Range vs. Bit Depth

- Note difference between dynamic range and bit depth
  - E.g. a binary image is just 0's and 1's
    - dynamic range of 2 levels
    - even if the bit depth of the encoded image is 8 bits
- Ramifications for the concepts of image compression and quantization noise
  - Information in a fraction of the bit-depth
    - Compress without loss
    - Variety of image compression (or for video COmpression/DECompression (CODEC)) algorithms

Color Images



24bit RGB, Size ~9 MB



8 bit Color Indexed Image
(256 levels), Size 3.1 MB

Contrast/Color Resolution

- Contrast resolution
  - Smallest scale of intensity change that can be depicted normalized by the dynamic range
  - Assuming the full 8 bit depth is used
    - **8 bit monochrome image (without noise) is 1/256**

- Color resolution for RGB image
  - 8 bits per color channel
  - **Note that 1/(256×256×256) = 1/16.8 million color levels**
  - RGB color images have exquisite color resolution

- Indexed color image
  - a color look up table with a finite bit-depth (e.g. 8 bit) is used to define the (e.g.
  - 256 color levels
  - **An indexed color image doesn't require any more bits to encode than a monochrome image**
  - color resolution is restricted to the bit depth or only 256 color levels

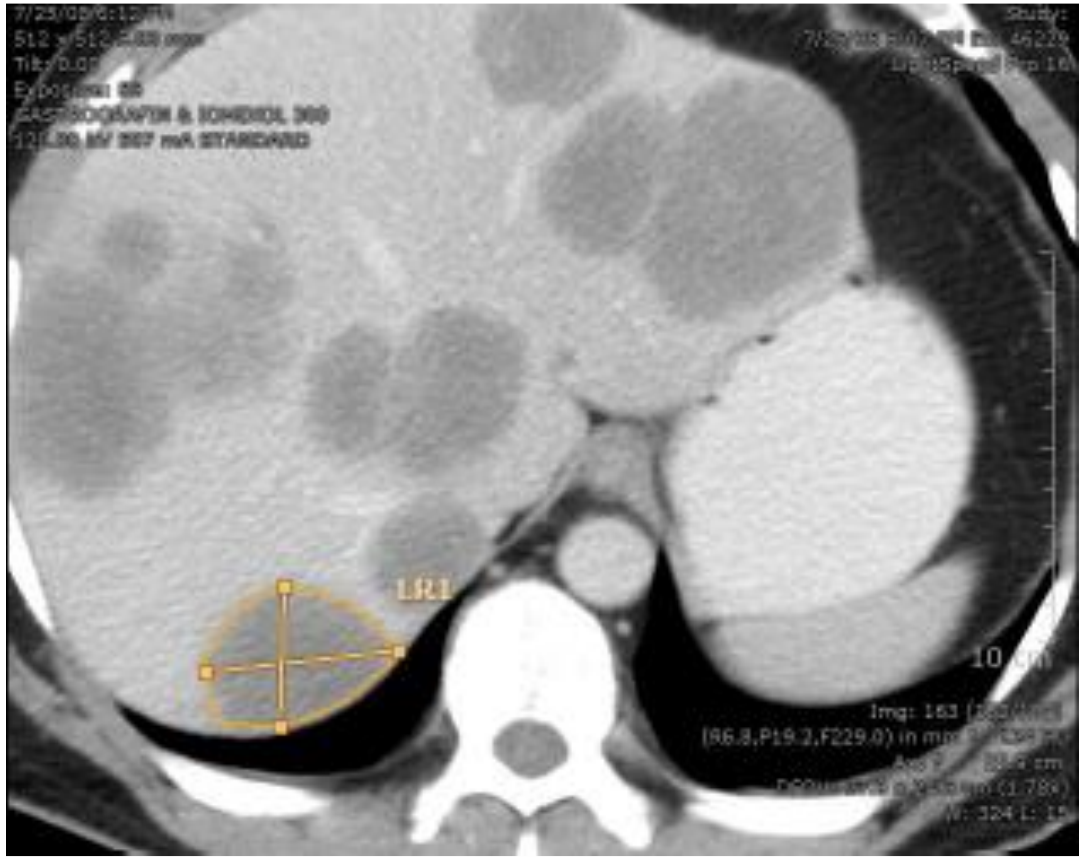
Manual Segmentation

- Manually draw region of interest (ROI)
- Most basic and most common approach
- Common examples
  - Evaluation of treatment progress for tumors (RECIST)
    - Complete Response (CR): Disappearance of all target lesions
    - Partial Response (PR): >30% decrease in the sum of diameters
    - Progressive Disease (PD): >20% increase in the sum of diameters
    - Stable Disease (SD): Neither PR nor PD
  - Penumbra segmentation for ischemic stroke evaluation

Tumor Segmentation

Lung

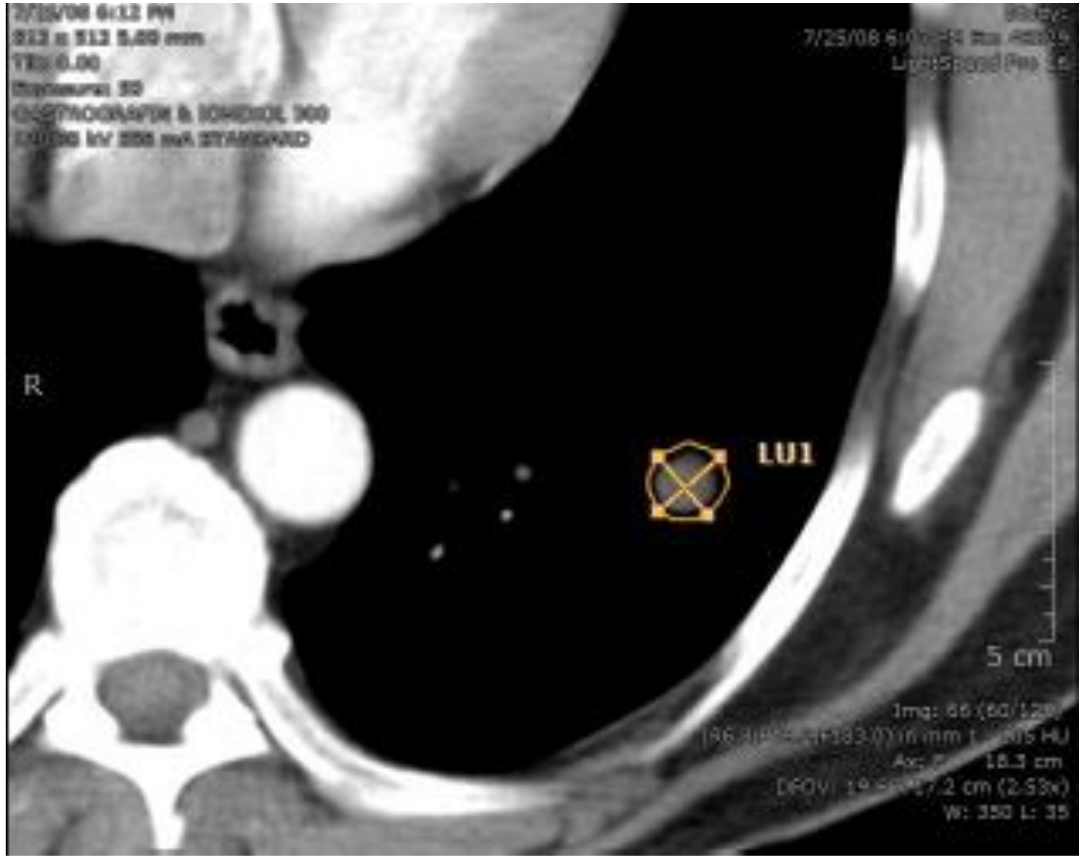
Liver



Window / Level

Lung [L: -600, W: 1500]

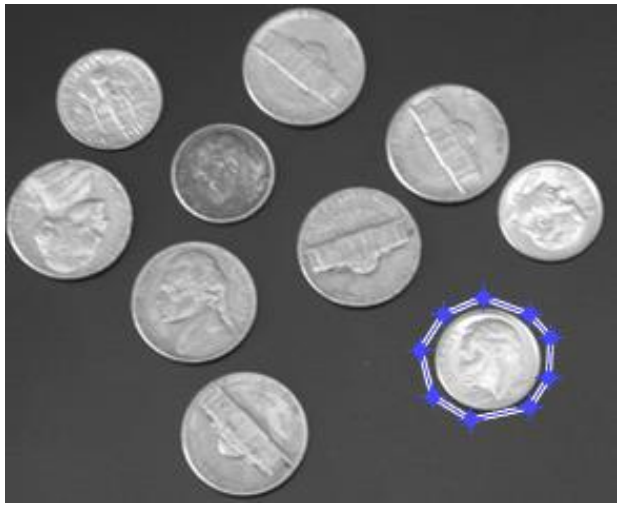
Soft tissue [L: 35, W: 350]



Matlab ROI tools

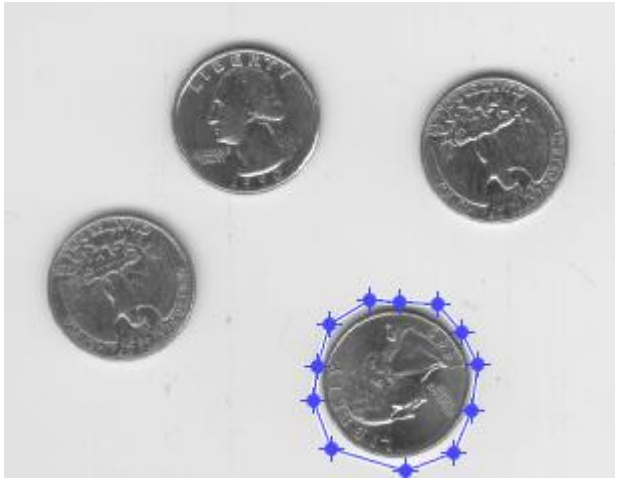
- imroi: *impoint(), imline(), imrect(), imellipse(), impoly(), imfreehand()*
  create draggable and resizable ROIs …

```
figure, imshow('coins.png');
h = impoly;
position = wait(h);
```



- *roipoly()*
  create binary mask of ROI …

```
I = imread('eight.tif');
BW = roipoly(I);
```



Segmentation Approaches: Overview

- Graylevel based methods
  - Thresholding
  - Adaptive histogram equalization
  - K-means
- Topological / morphological methods
  - Erosion / Dilation
  - Watershed
  - Region growing, splitting and merging
  - Level sets
- Gradient based methods
  - Edge detection
  - Active contour models
  - Level sets
- Iterative (optimization based) methods
  - K-Means
  - Active contour models
  - Level set
  - Graph cut / grow cut

Summary

- Digital display determined by the way image are perceived by the visual system
- Image intensity values are assigned to display based on a look up table
  - Leads to both linear and non-linear signal intensity mappings
- Color systems are used to generate a wide range of colors (RGB)
- Exploit the visual system to compress the data required to store and display information
  - Gamma correction/compression/decompression
  - Histogram equalization