Digital Image Processing CS390S

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Day 2

- Image (color gray binary), dimension
- Pixel, intensity
- Pixel relationship, distance
- **Matlab, Matlab tutorial**
- https://www.tutorialspoint.com/matlab/matlab_environment.htm

- **Digital Image Processing using Matlab**: Chapter 2 2.1-2.8

- Start Basic Image Enhancement Tools (pdf)

Day 3

- Image (color gray binary), dimension
- Pixel, intensity
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- **Matlab, Matlab tutorial**
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- **Digital Image Processing using Matlab: Chapter 2 2.1-2.8**

- **Basic Image Enhancement Tools (pdf)**
- **Assigment 1**

Image Enhancement in Spatial Domain

- Image Histogram
- Image Negative
- Contrast Stretching
- Power-Law Transformation
- Histogram Equalization
- Local Enhancement
- Image Subtraction
- Image Averaging
- Image Smoothing
- Image Sharpening

Image enhancement

Enhancement Techniques

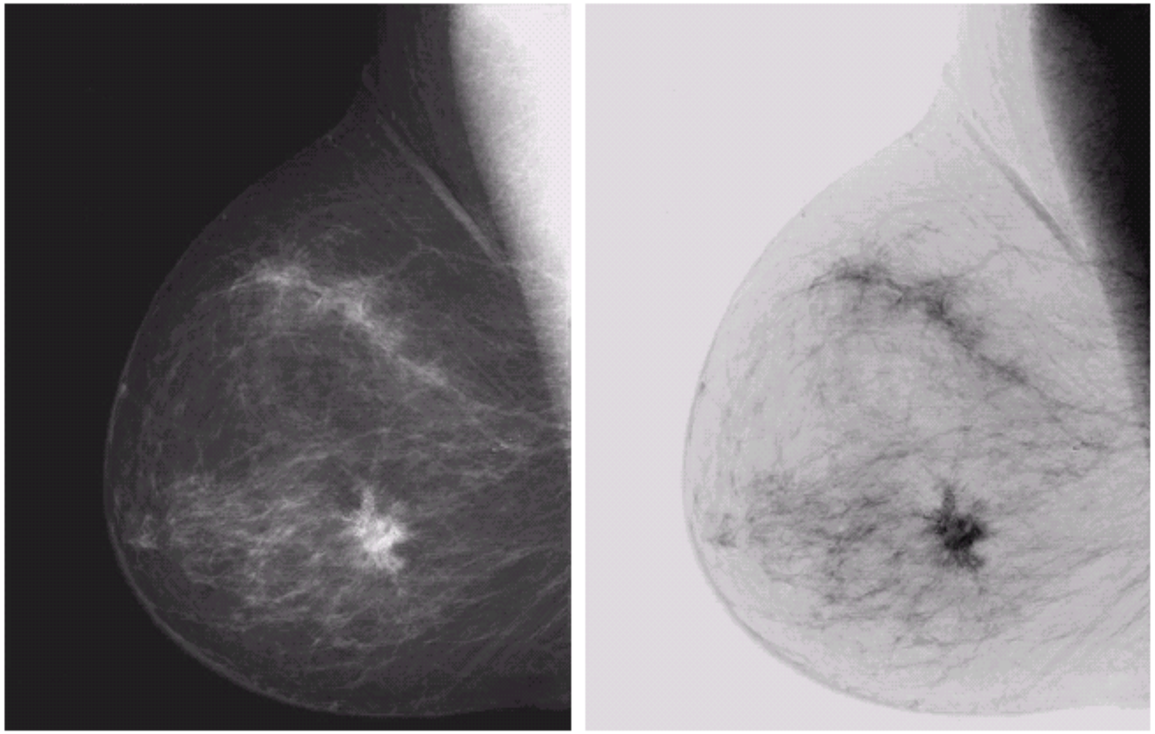
- Spatial
  Operates on pixels
- Frequency Domain
  Operates on FT of Image

Spatial Domain Methods

- In these methods a operation (linear or non-linear) is performed on the pixels in the neighborhood of coordinate (x,y) in the input image F, giving enhanced image F'
- Neighborhood can be any shape but generally it is rectangular (3x3, 5x5, 9x9 etc)

$$g(x,y) = T[f(x,y)]$$

Image negative



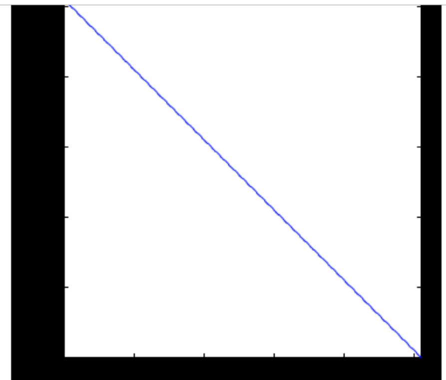
a b

FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

Image Negative: $s = L - 1 - r$

Image negative

Demo

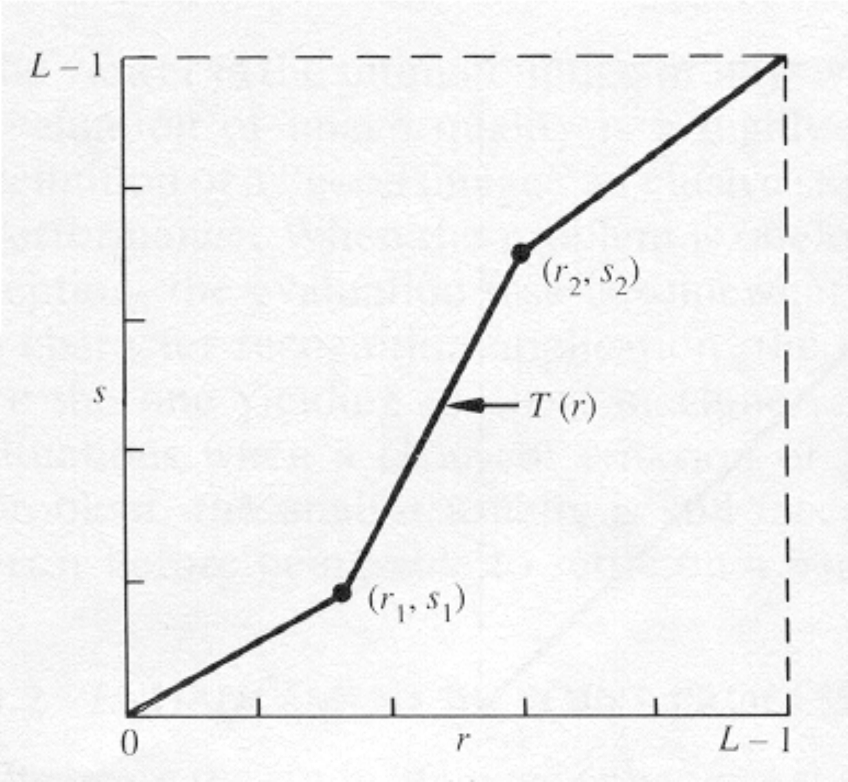


S=255-r

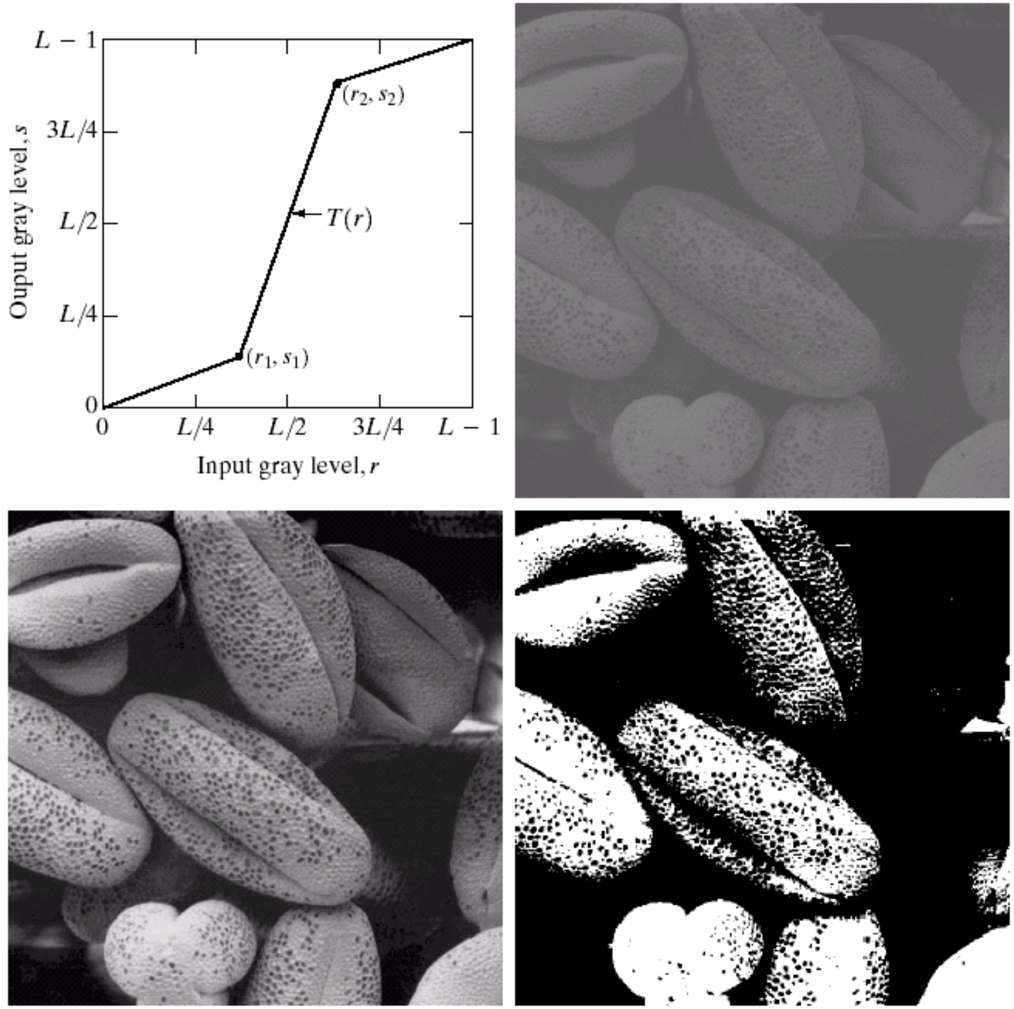
Image Negative: $s = L - 1 - r$

Contrast Stretching

- To increase the dynamic range of the gray levels in the image being processed.



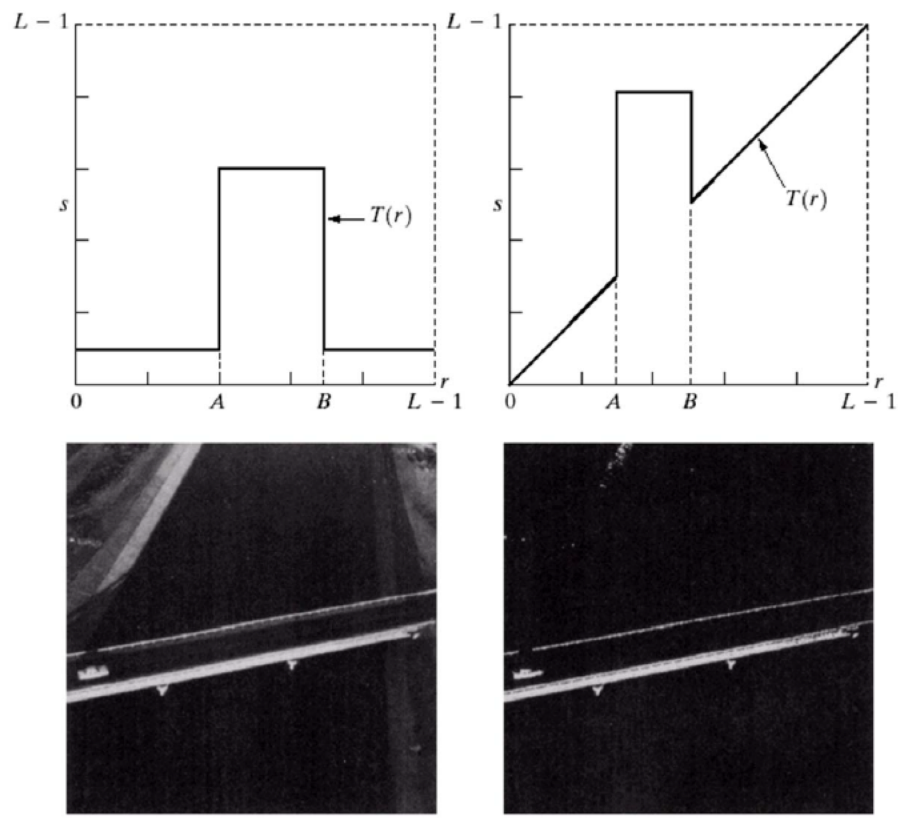
Example



a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Contrast Stretching for image highlighting



Power Law Transformation

- $s = cr^{\gamma}$
- C, γ : positive constants
- Gamma correction

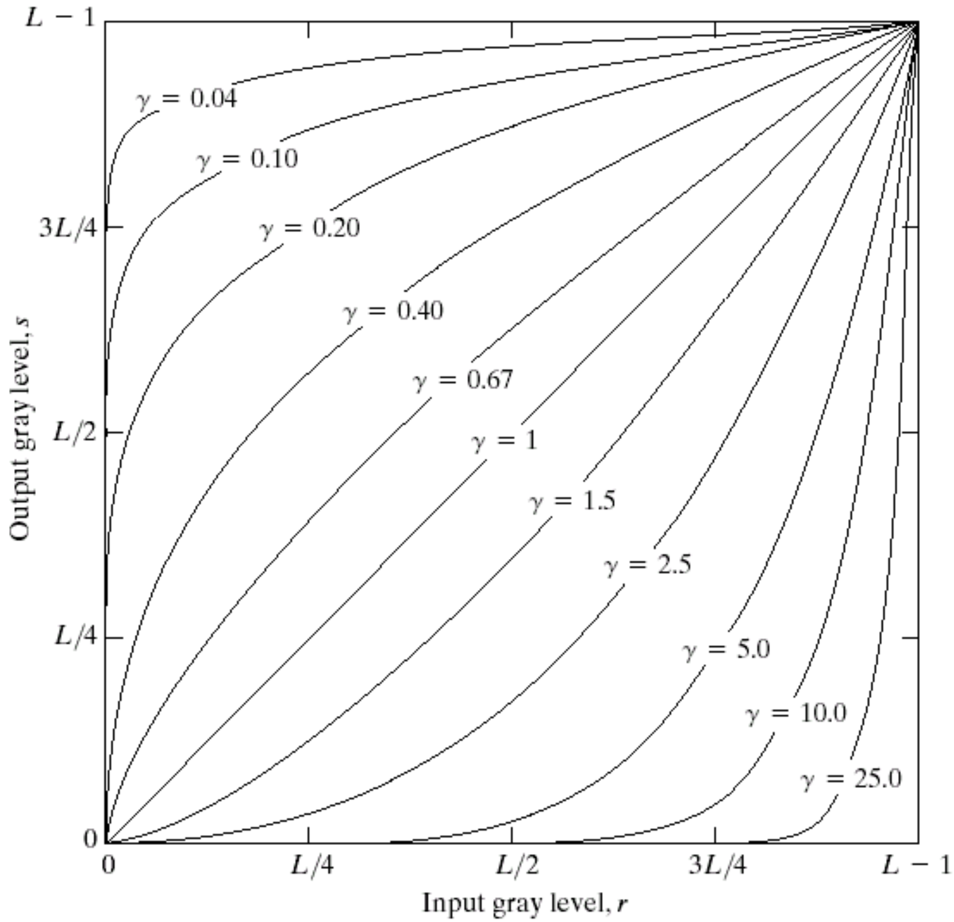
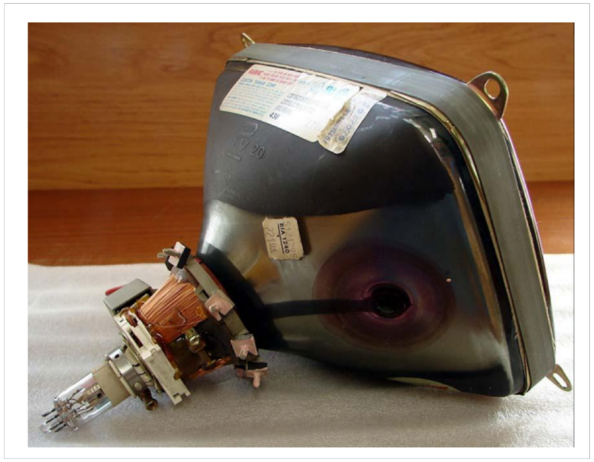
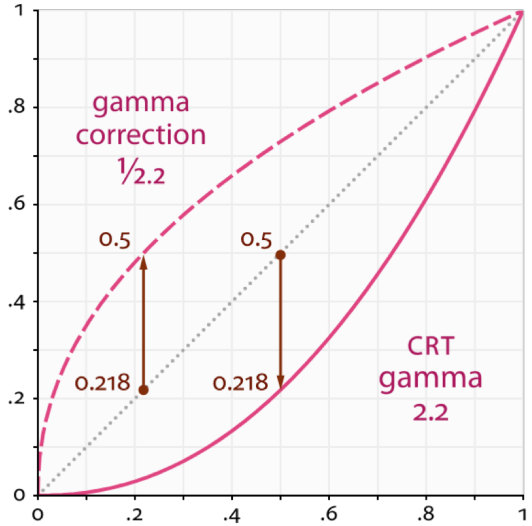


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

Power Law Transformation



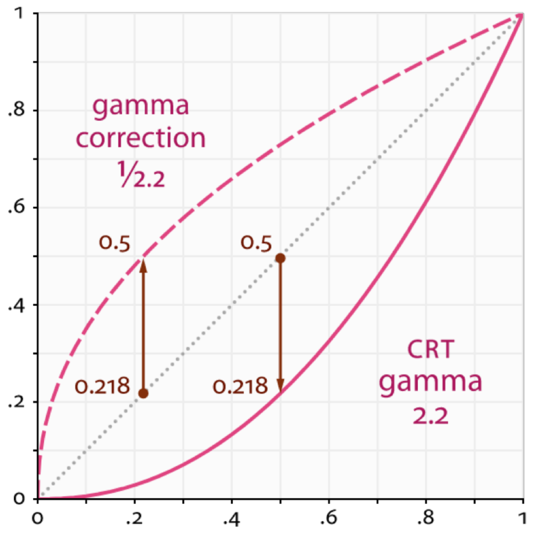
The effect can be overcome by applying an end-to-end power function whose exponent is about 1.1 or 1.2.

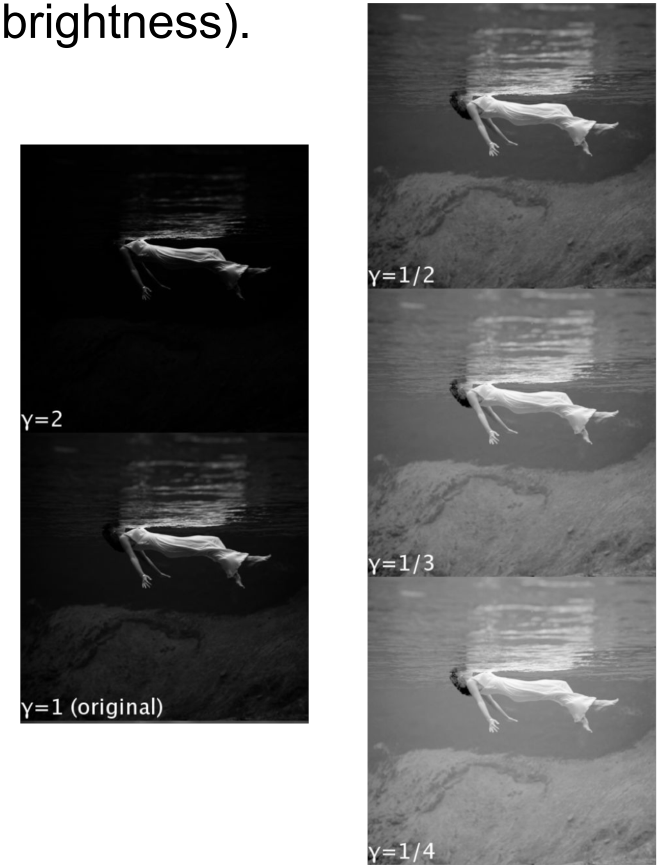


Almost every computer monitor, from whatever manufacturer, has one thing in common. They all have a intensity to voltage response curve which is roughly a 2.5 power function.

Power Law Transformation

Gamma correction function is a function that maps luminance levels to compensate the non-linear luminance effect of display devices (or sync it to human perceptive bias on brightness).





Bit-Plane Slicing

- To highlight the contribution made to the total image appearance by specific bits.
  - i.e. Assuming that each pixel is represented by 8 bits, the image is composed of 8 1-bit planes.
  - Plane 0 contains the least significant bit and plane 7 contains the most significant bit.
  - Only the higher order bits (top four) contain visually significant data. The other bit planes contribute the more subtle details.

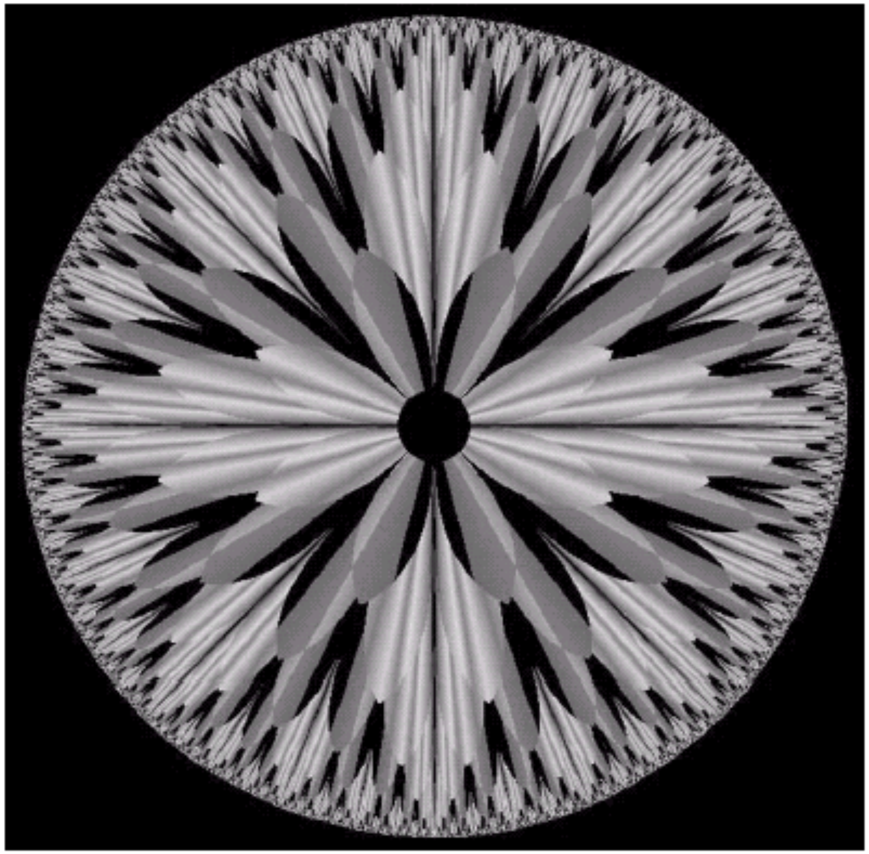


FIGURE 3.13 An 8-bit fractal image. (A fractal is an image generated from mathematical expressions). (Courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA.)

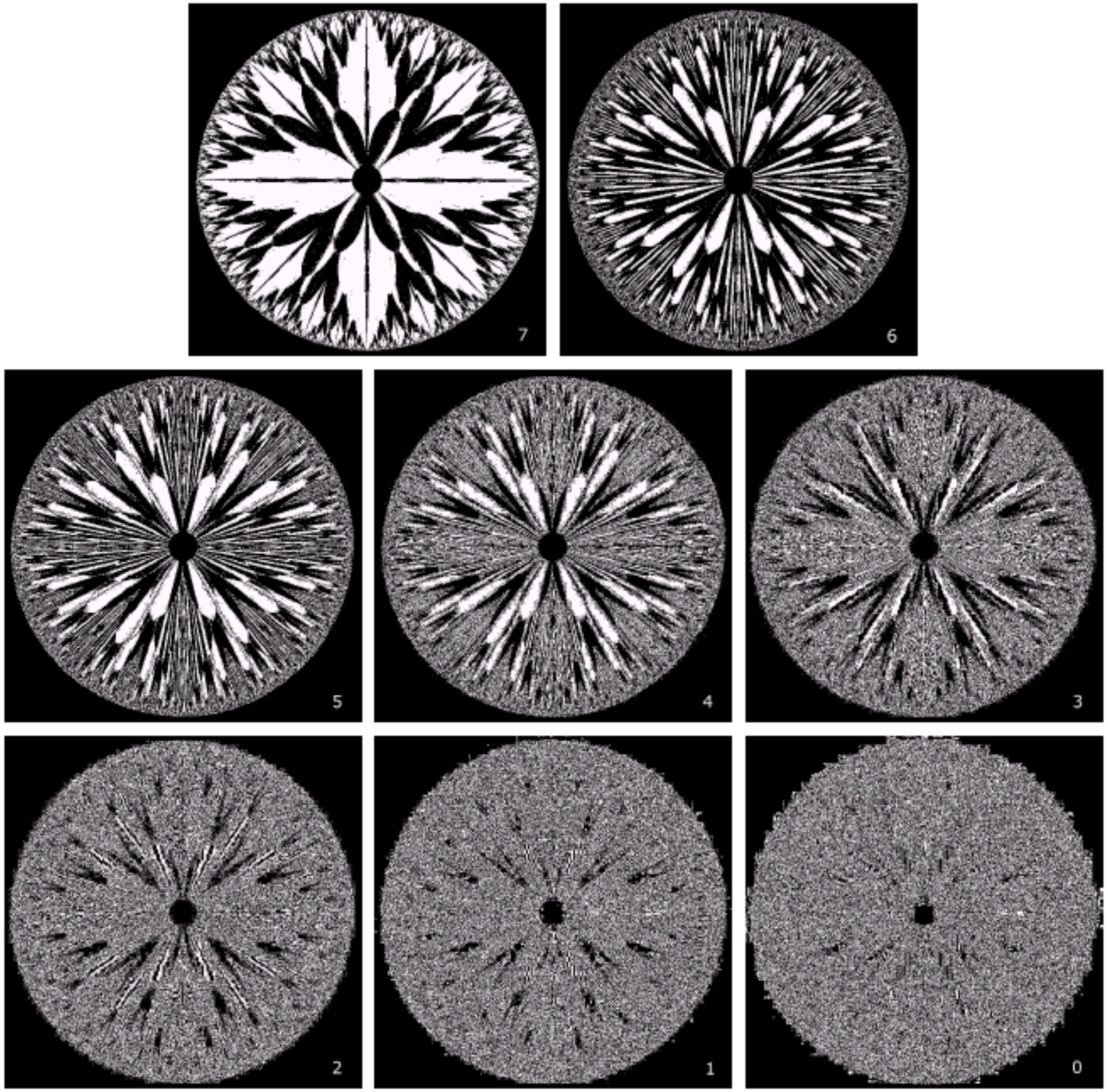
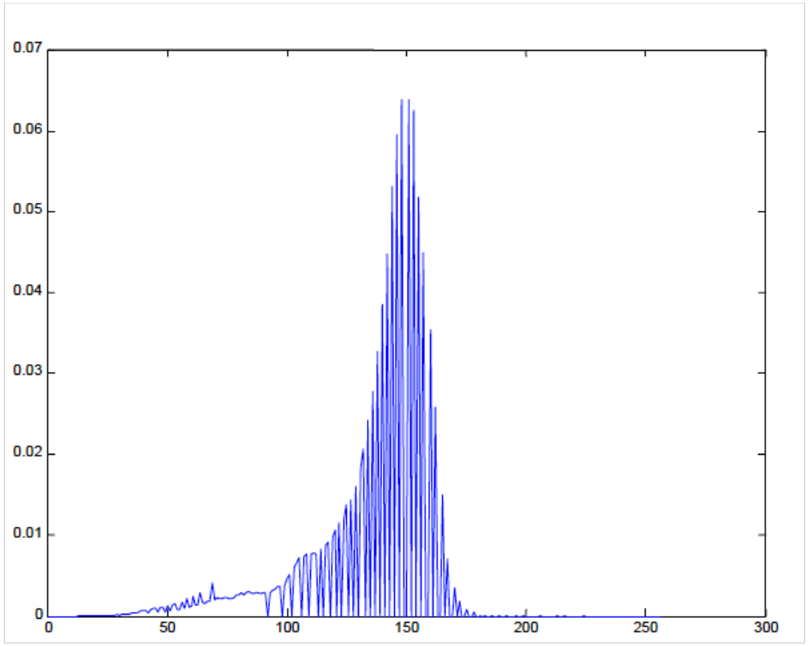


FIGURE 3.14 The eight bit planes of the image in Fig. 3.13. The number at the bottom, right of each image identifies the bit plane.

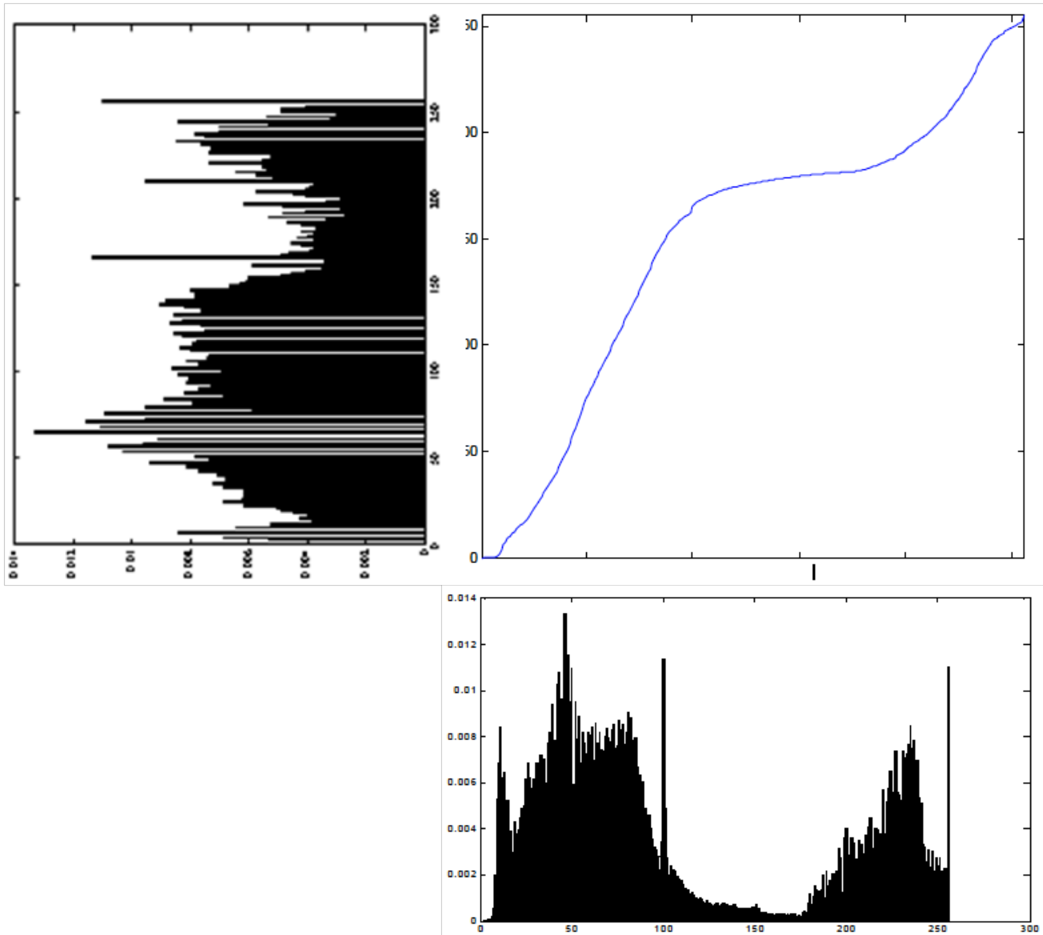
Histogram Processing

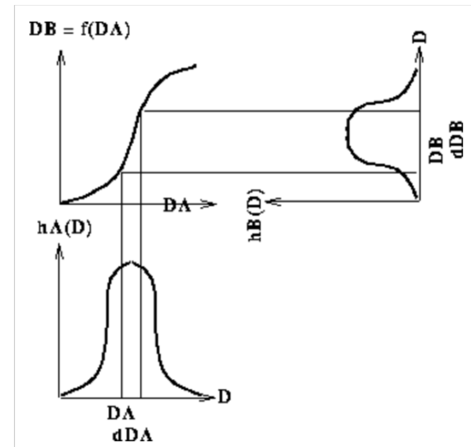
- The histogram of a digital image with gray levels from 0 to L-1 is a discrete function $h(r_k)=n_k$, where:
  - r_k is the kth gray level
  - n_k is the # pixels in the image with that gray level
  - n is the total number of pixels in the image
  - k = 0, 1, 2, …, L-1
- Normalized histogram: $p(r_k)=n_k/n$
  - sum of all components = 1

Histogram Processing



Histogram Equalization

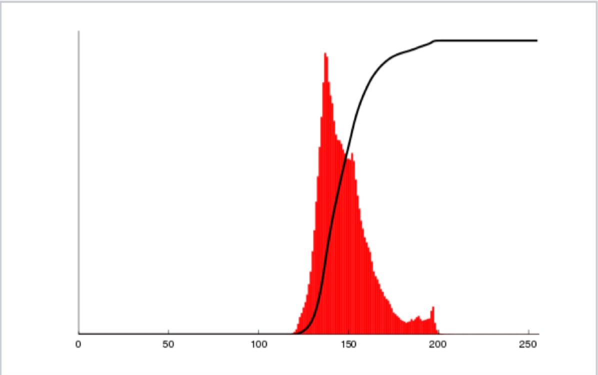




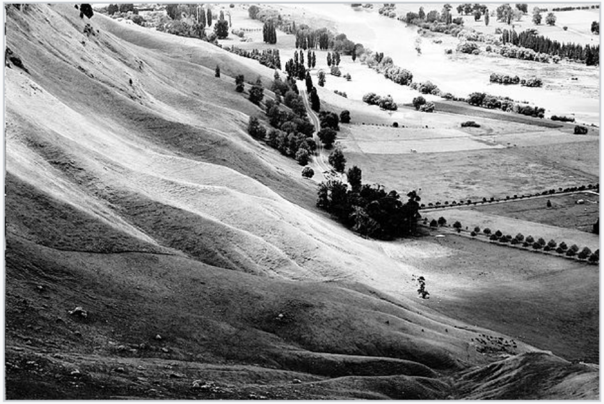
[http://homepages.inf.ed.ac.uk/rbf/HIPR2/histe](http://homepages.inf.ed.ac.uk/rbf/HIPR2/histeq.htm)
q.htm

Histogram Equalization

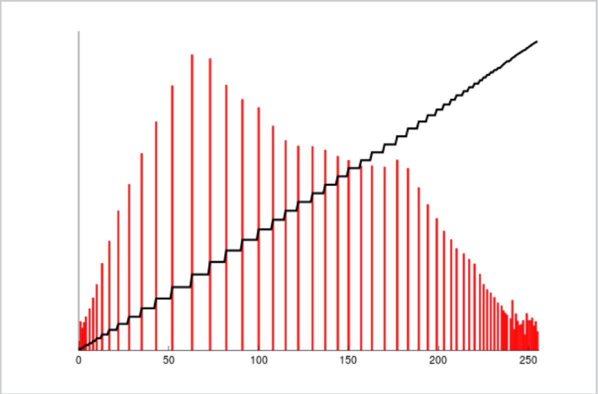
Before Histogram Equalization



Corresponding histogram (red) and cumulative histogram (black)



After Histogram Equalization



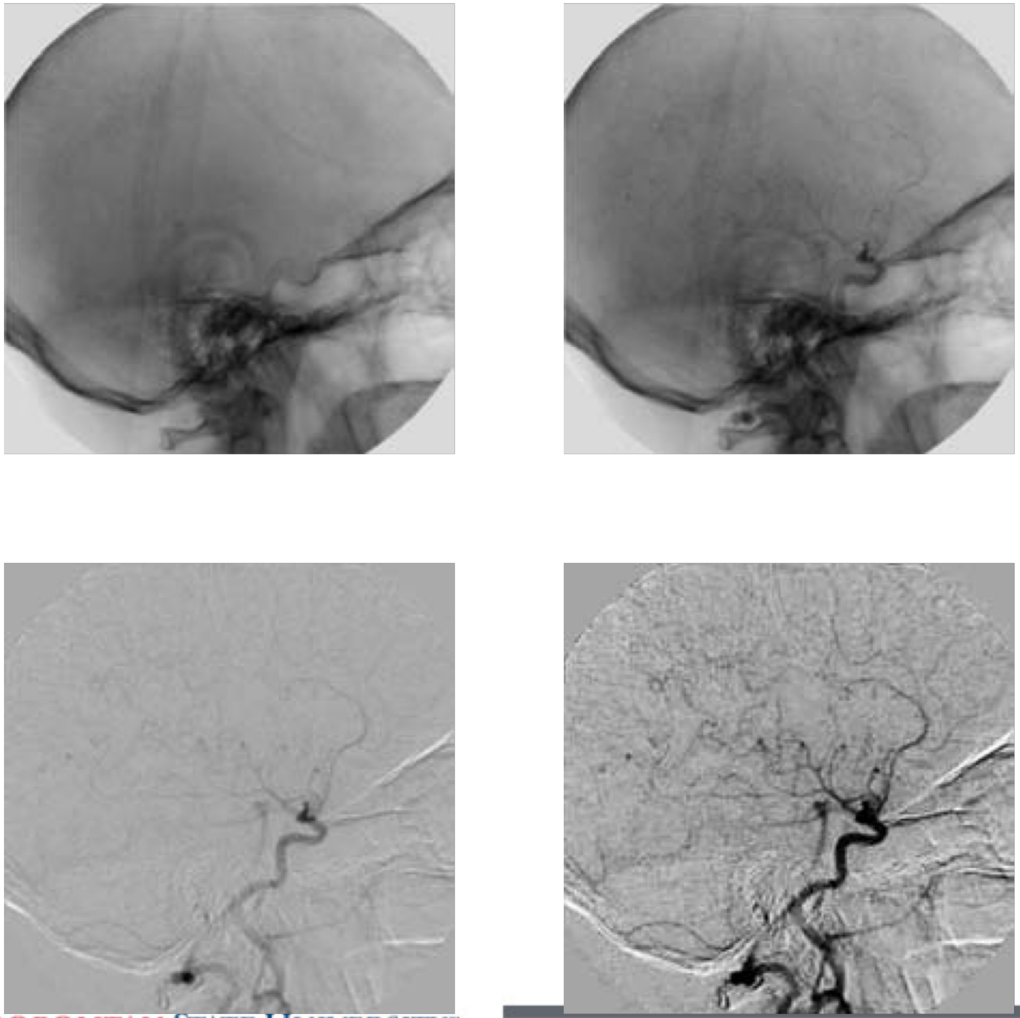
Corresponding histogram (red) and cumulative histogram (black)

Histogram Equalization

Original Image

After Histogram Equalization

Image subtraction



(a) Mask image. (b) A live image. (c) Difference between (a) and (b). (d) Enhanced difference image. (Figures (a) and (b) courtesy of The Image Sciences Institute, University Medical Center, Utrecht,The Netherlands.)

Day 4

- **Basic Image Enhancement Tools**
- **About noise, filter**
- **Common applications of image filtering**

Review

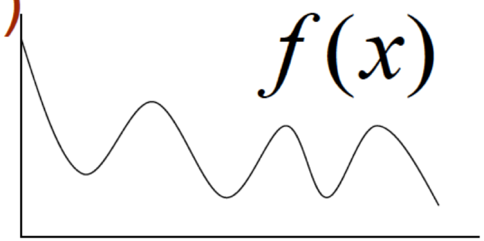
Random Variable (RV)

- Variable (number) associated with the outcome of an random experiment
- Dice
  - E.g. Assign 1-6 to the faces of dice
- Urn
  - Assign 0 to black and 1 to white (or vise versa)
- Cards
  - Lots of different schemes - depends on application
- A function of a random variable is also a random variable

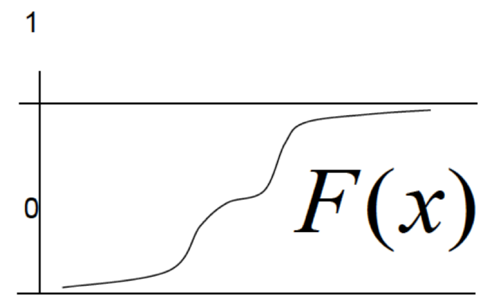
Review

Continuous Random Variables

- f(x) is pdf (normalized to 1)
- F(x) – cdf continuous
  - – –> x is a continuous RV



$$F(x) = \int_{-\infty}^{x} f(q)dq$$



$$f(x) = \left.\frac{dF(q)}{dq}\right|_{x} = F'(x)$$

Review

Probability Density Functions

- f(x) is called a probability density function (pdf)

$$\int_{-\infty}^{\infty} f(x) = 1 \quad f(x) \geq 0 \ \forall \ x$$

- A probability density is not the same as a probability
- The probability of a specific value as an outcome of continuous experiment is (generally) zero
  - To get meaningful numbers you must specify a range

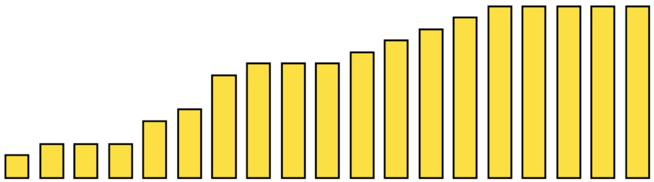
$$P(a \leq x \leq b) = \int_a^b f(q)dq = F(b) - F(a)$$

Review

Cumulative Distribution Function (cdf)

- F(x), where x is a RV
- F(-infty) = 0, F(infty) = 1
- F(x) non decreasing

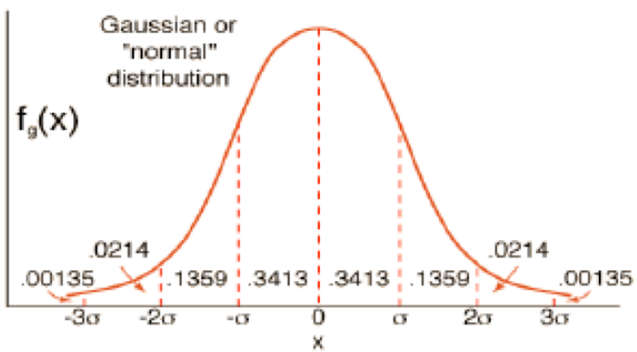
$$F(x) = \sum_{i=-\infty}^{x} P(i)$$



Review

Gaussian Distribution

- "Normal" or "bell curve"
- Two parameters: μ - mean, σ – standard deviation



$$\frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

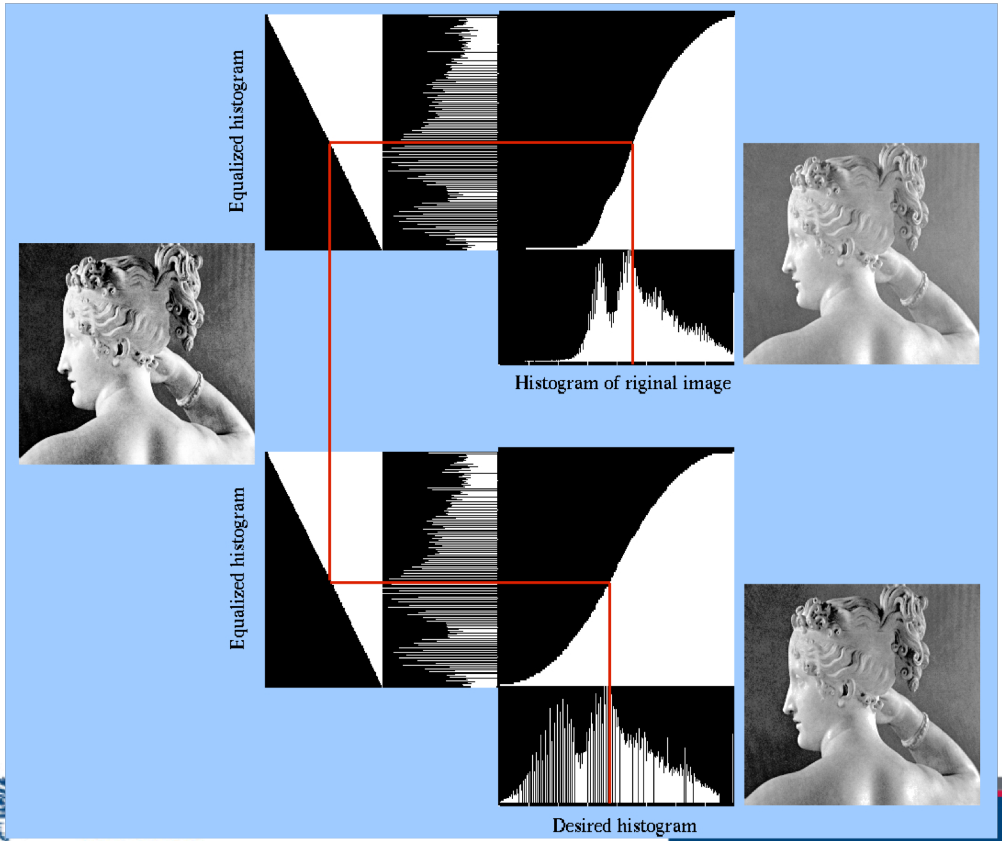
Review

Gaussian Properties

- Best fitting Guassian to some data is gotten by mean and standard deviation of the samples
- Occurrence
  - Central limit theorem: result from lots of random variables
  - Nature (approximate)
    - Measurement error, physical characteristic, physical phenomenon
    - Diffusion of heat or chemicals

Histogram

- **Histogram equalization**
- **Histogram specification**

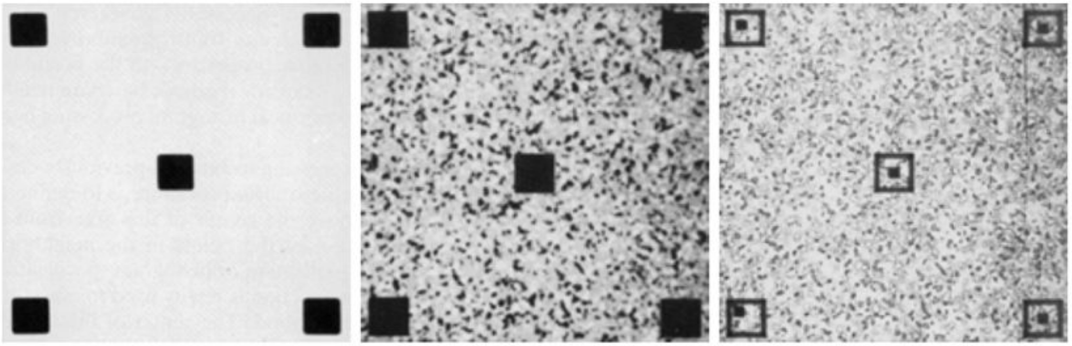


G=histeq(f,p);

Histogram

- **Histogram equalization**
- **Histogram specification**
- **Local histogram equalization**

Define a neighborhood and move its center from pixel to pixel. At each location, the histogram of the points in the neighborhood is computed and histogram equalization transformation is obtained.



a b c

FIGURE 3.23 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization using a 7×7 neighborhood about each pixel.

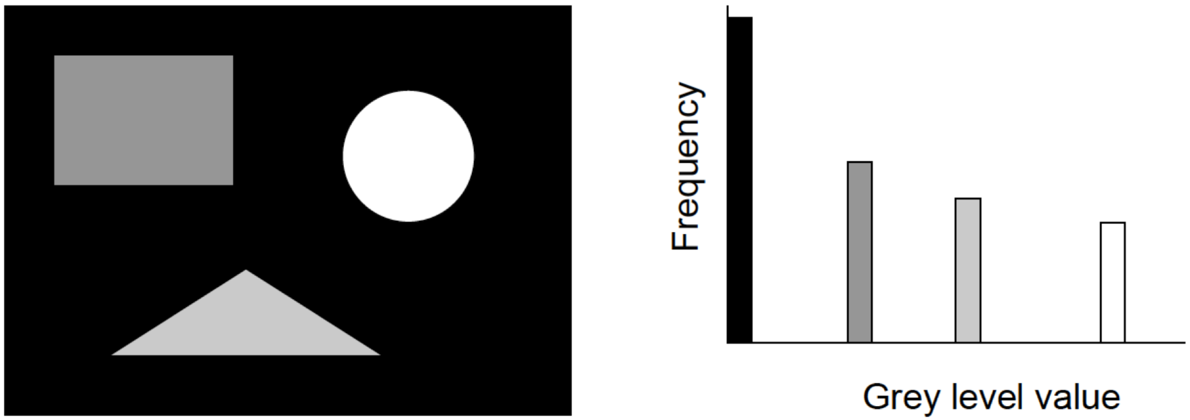
Histogram Applications

- http://www.sci.utah.edu/~gerig/CS6640-F2012/CS6640-F2012.html

Histogram Applications

Histogram of Image Intensities

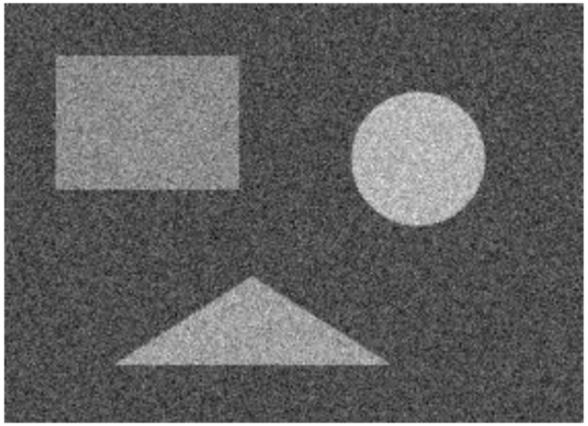
- Create bins of intensities and count number of pixels at each level
  - Normalize or not (absolute vs % frequency)

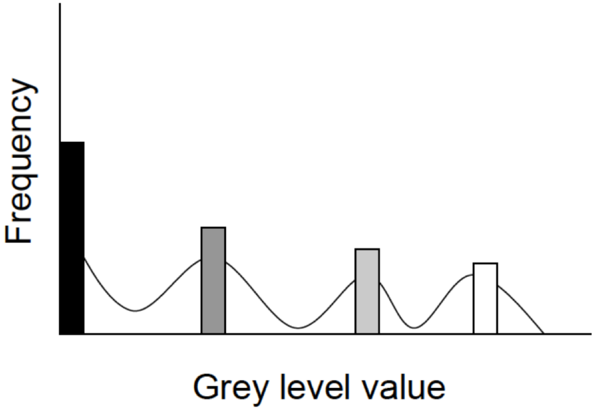


Histogram Applications

Histograms and Noise

- What happens to the histogram if we add noise?
  - $g(x, y) = f(x, y) + n(x, y)$

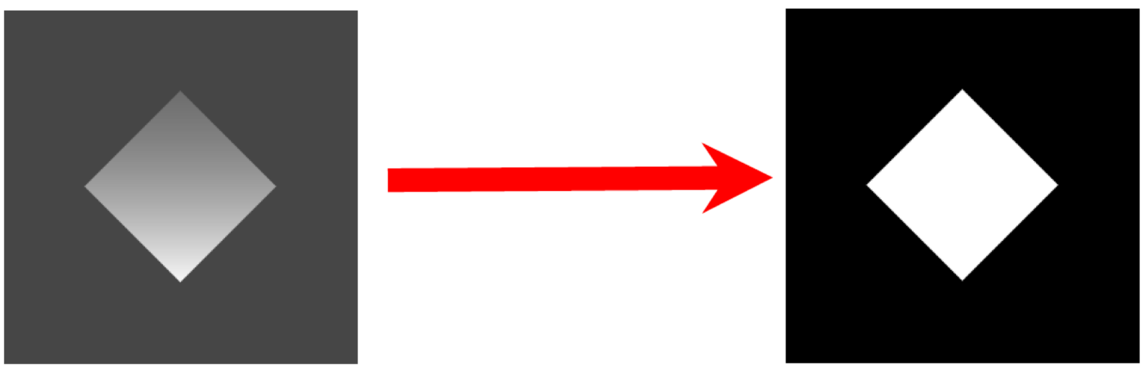




Histogram Applications

What is image segmentation?

- Image segmentation is the process of subdividing an image into its constituent regions or objects.
- Example segmentation with two regions:



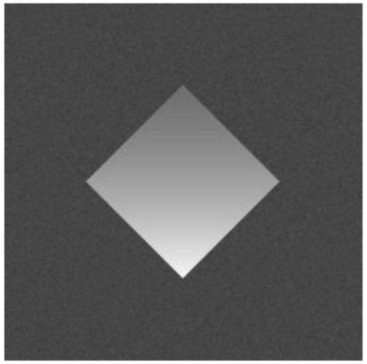
Input image
intensities 0-255

Segmentation output
0 (background)
1 (foreground)

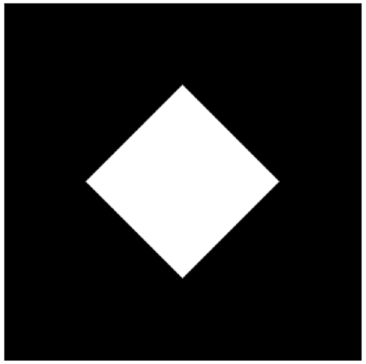
Histogram Applications

Thresholding

$$g(x,y) = \begin{cases} 1 & if \quad f(x,y) > T \\ 0 & if \quad f(x,y) \leq T \end{cases}$$



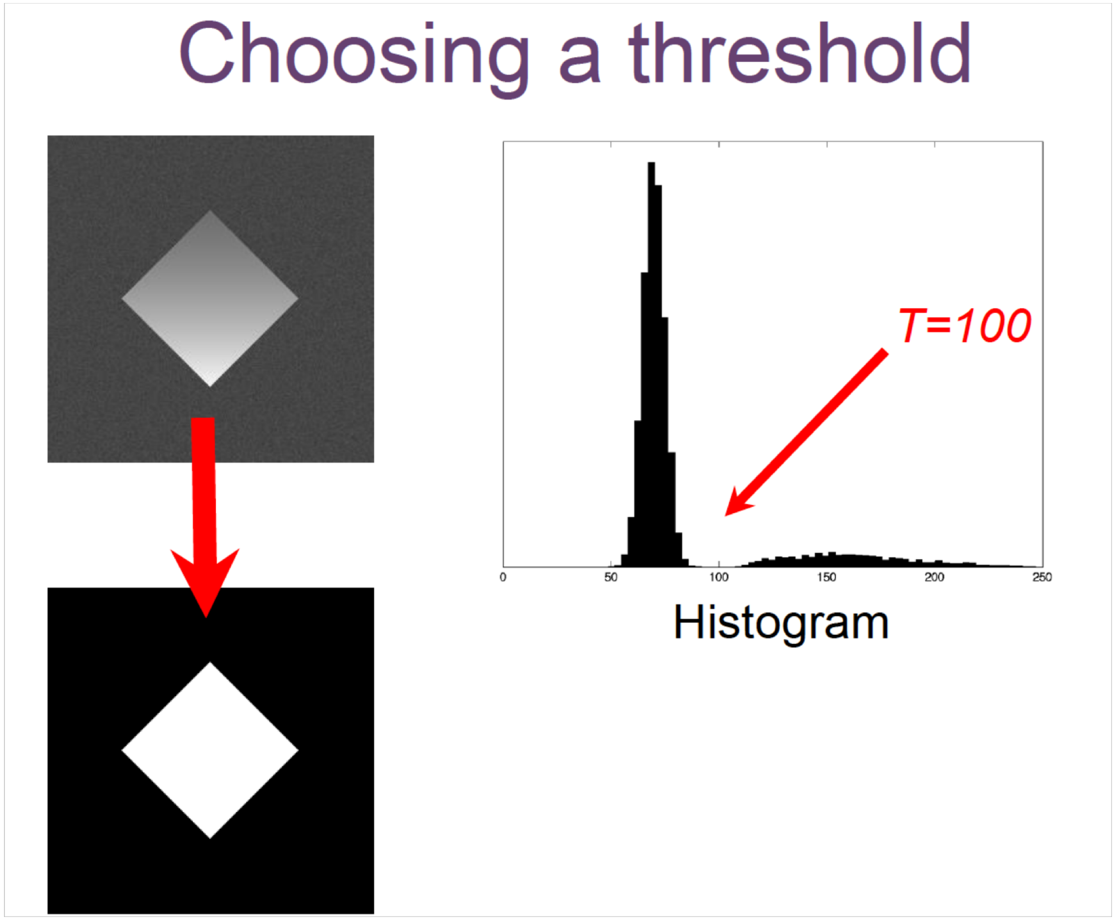
Input image f(x,y)
intensities 0-255



Segmentation output g(x,y)
0 (background)
1 (foreground)

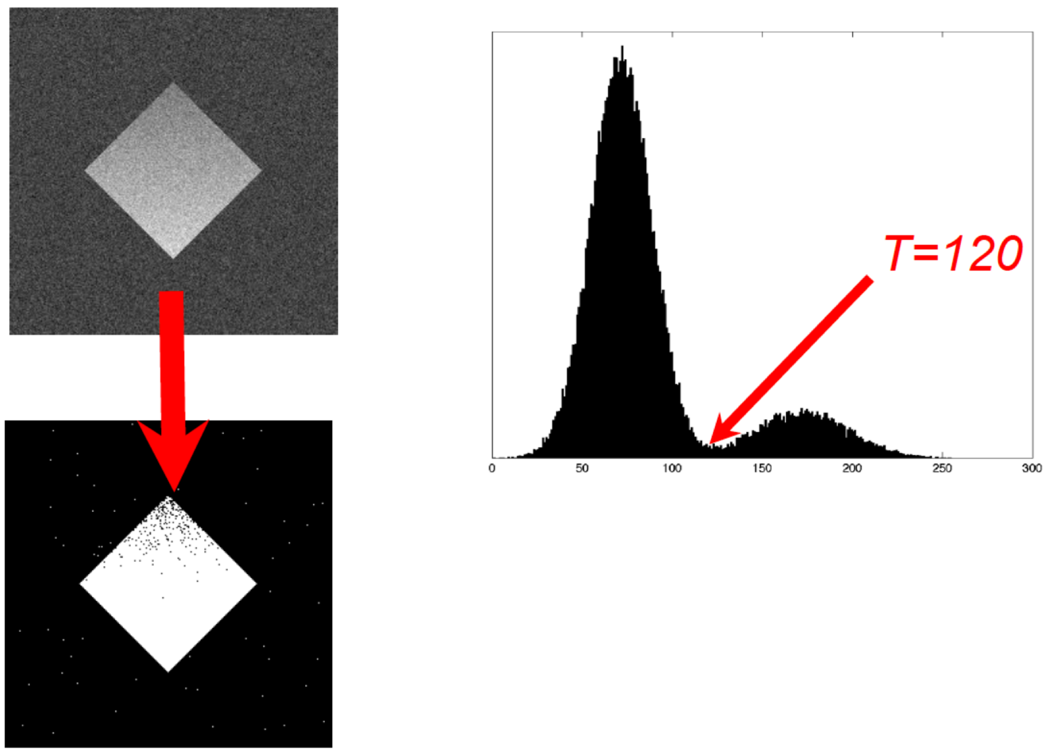
- How can we choose T?
  - Trial and error
  - Use the histogram of f(x,y)

Histogram Applications



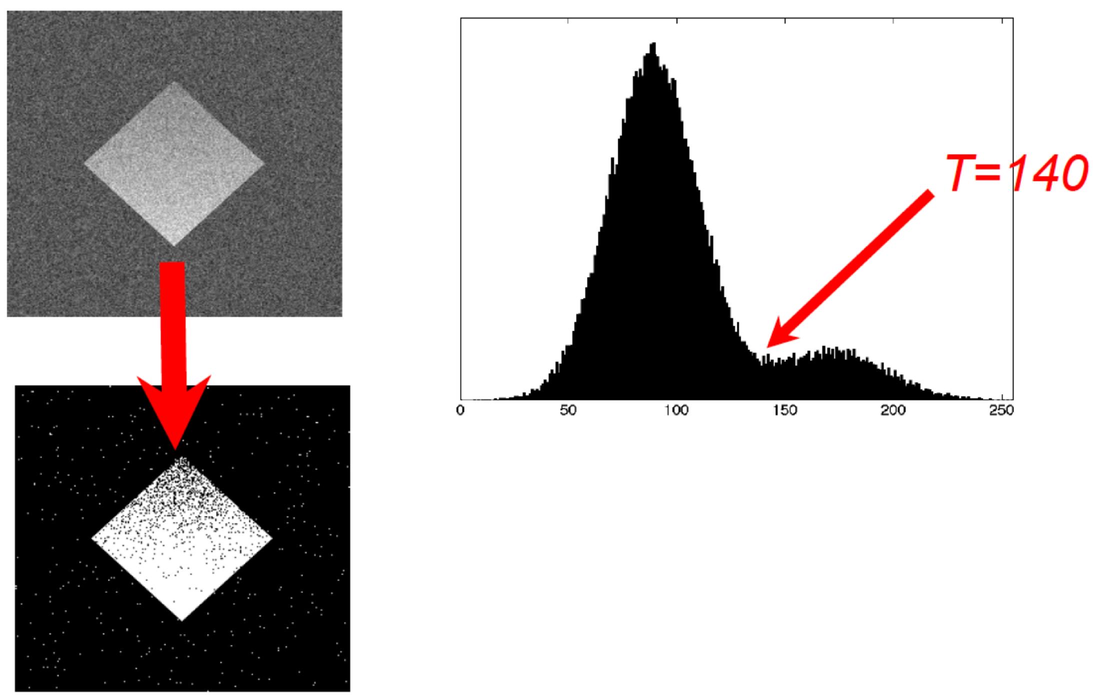
Histogram Applications

Role of noise

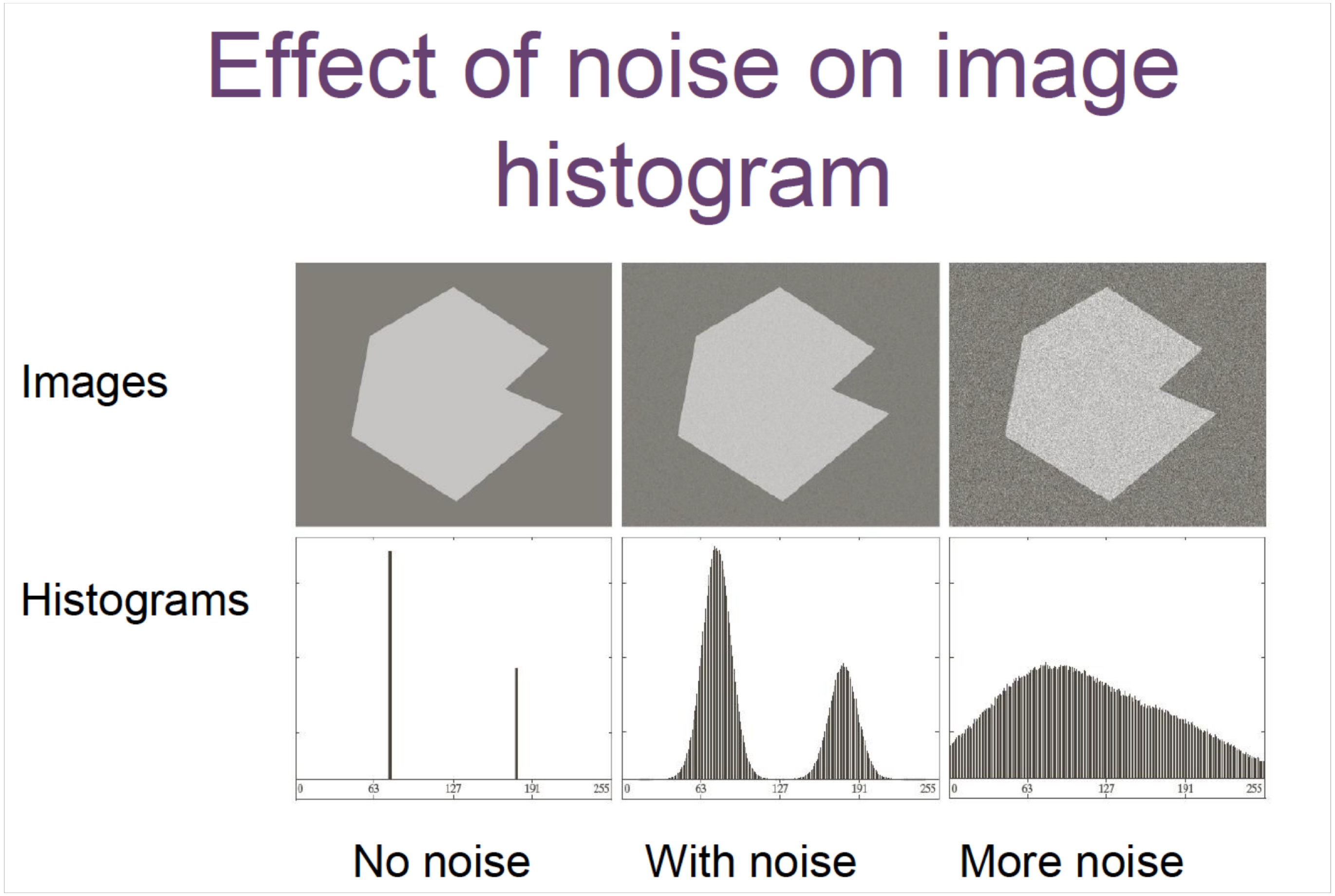


Histogram Applications

Low signal-to-noise ratio



Histogram Applications

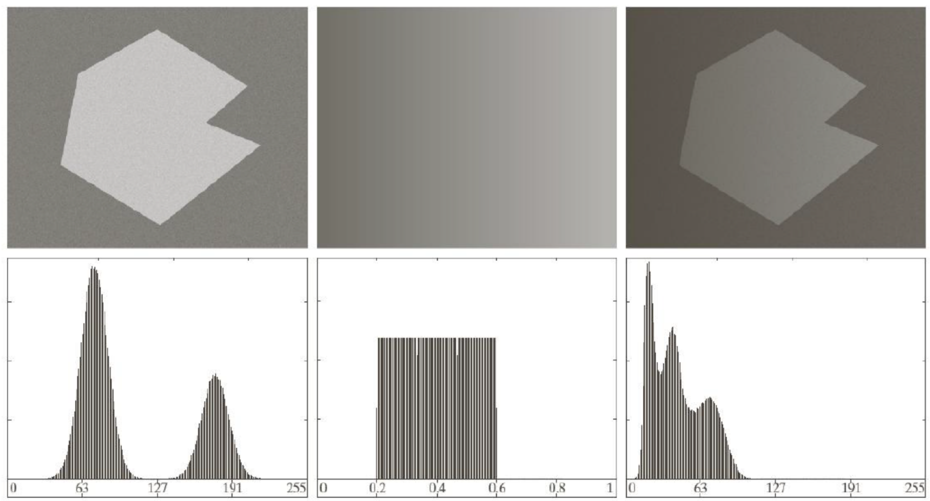


Histogram Applications

Effect of illumination on histogram

Images

Histograms



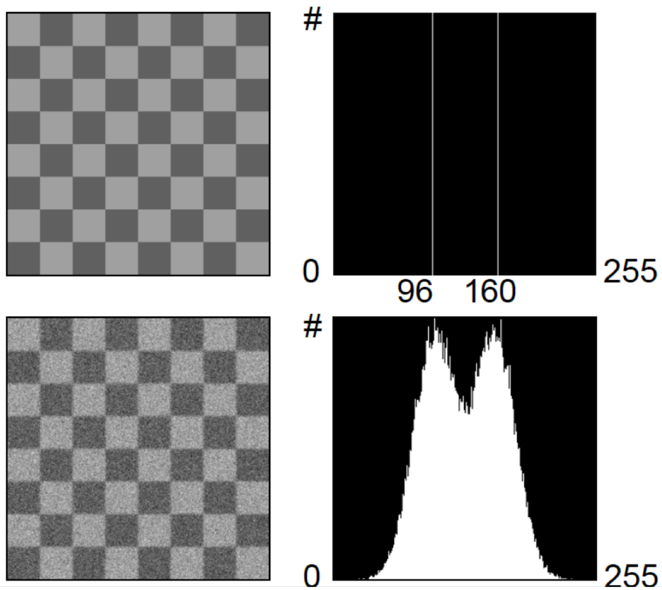
f x g = h

Original image | Illumination image | Final image

Histogram Applications

Histogram of Pixel Intensity Distribution

Histogram: Distribution of intensity values $p(v)$
(count #pixels for each intensity level)



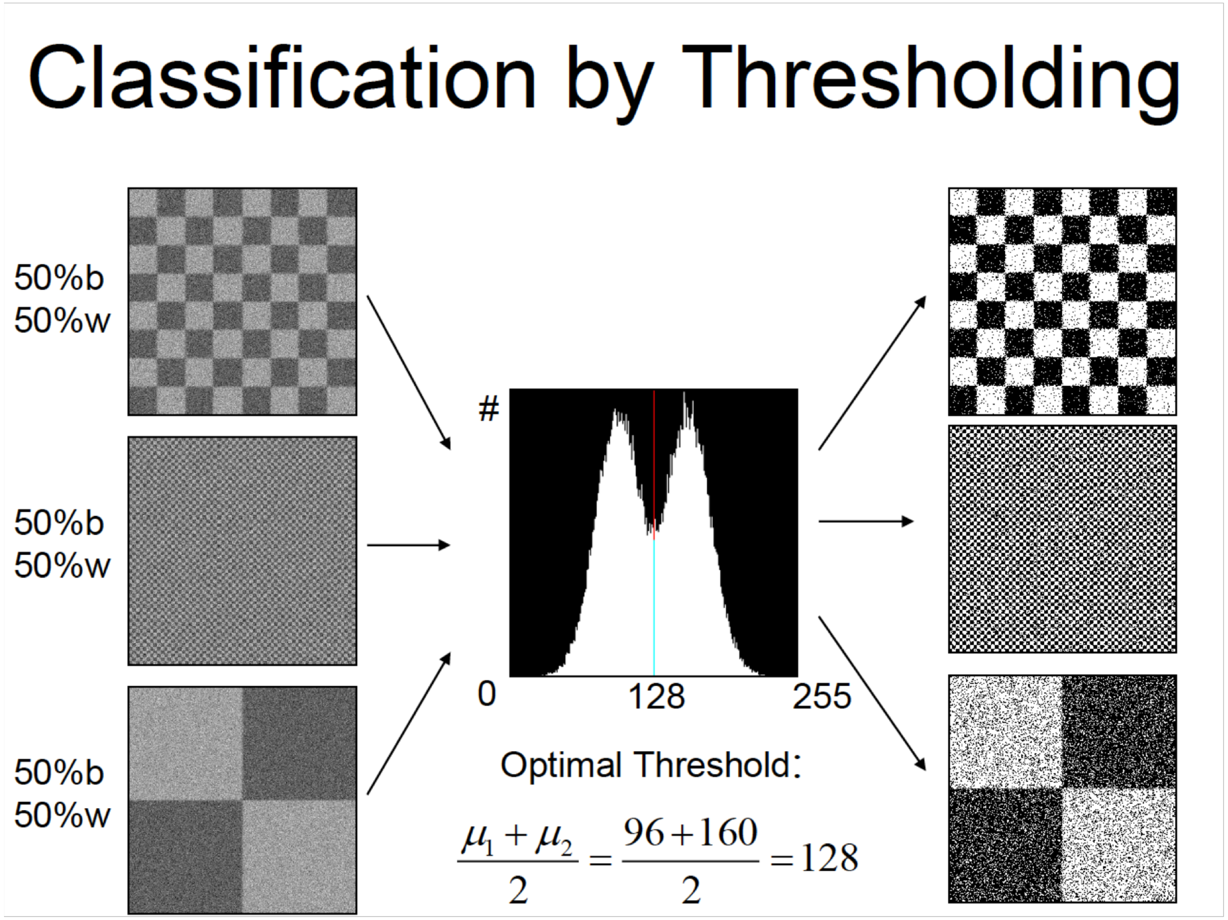
Checkerboard with values 96 and 160.

Histogram:
- horizontal: intensity
- vertical: # pixels

Checkerboard with additive Gaussian noise (sigma 20).

Regions: 50%b,50%w

Histogram Applications

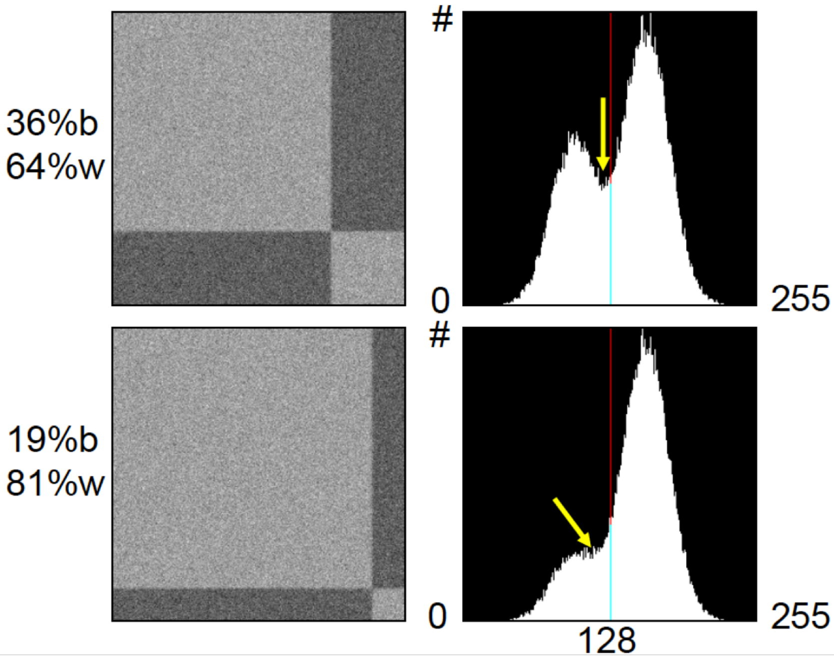


Histogram Applications

- Histogram does not represent image structure such as regions and shapes, but only distribution of intensity values
- Many images share the same histogram

Histogram Applications

Is the histogram suggesting the right threshold?

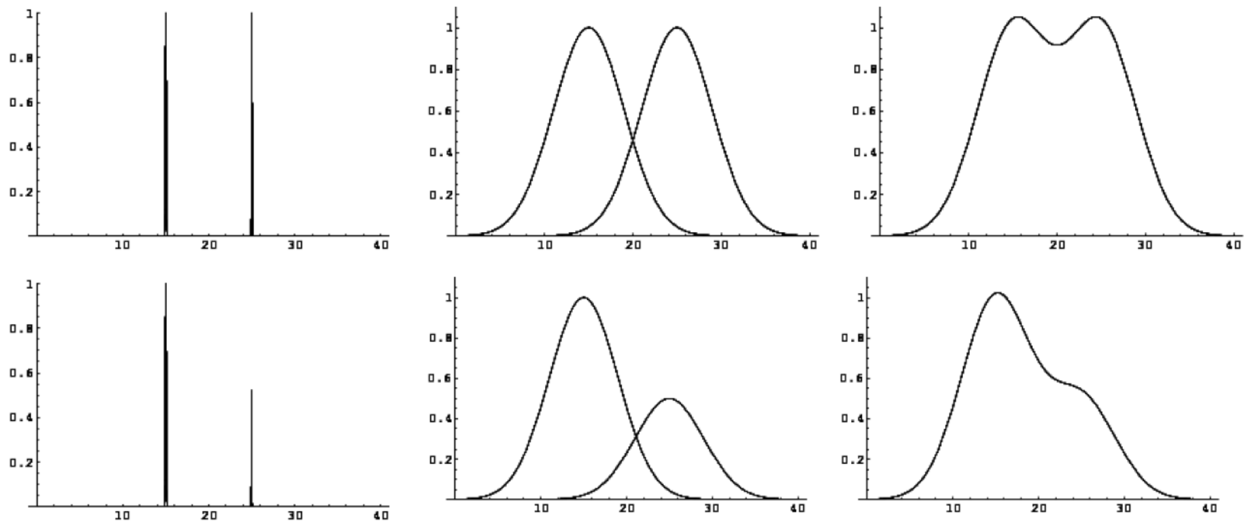


Proportions of bright and dark regions are different ⇒ Peak presenting bright regions becomes dominant.

Threshold value 128 does not match with valley in distribution.

Histogram Applications

Histogram as Superposition of PDF’s
(probability density functions)



Regions with
2 brightness levels,
different proportions

Corruption with
Gaussian noise,
individual distributions

Histogram:
Superposition of
distributions

Histogram Applications

Gaussian Mixture Model

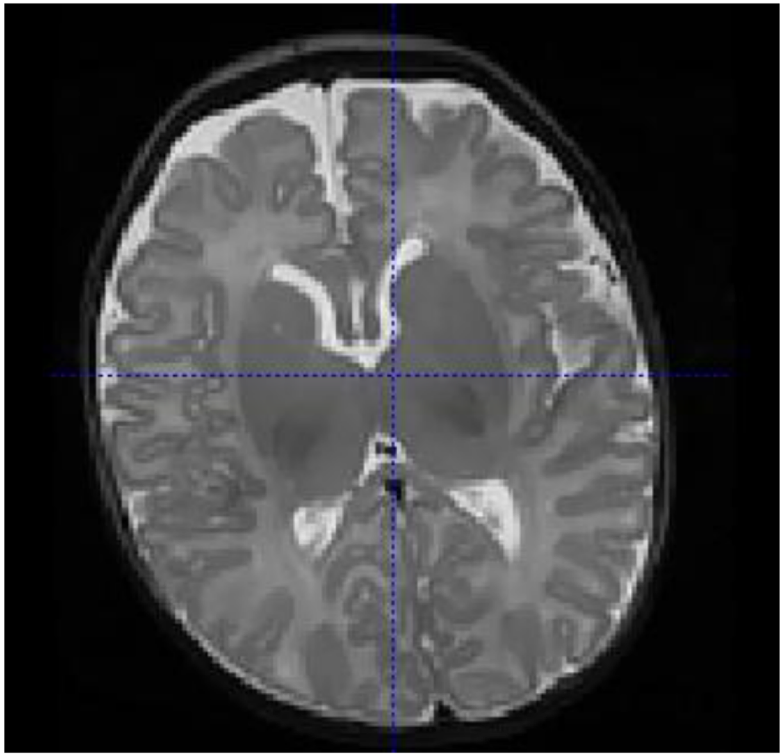
$$hist = a_1 G(\mu_1, \sigma_1) + a_1 G(\mu_1, \sigma_2)$$

more general with k classes :

$$hist = \sum_k a_k G(\mu_k, \sigma_k)$$

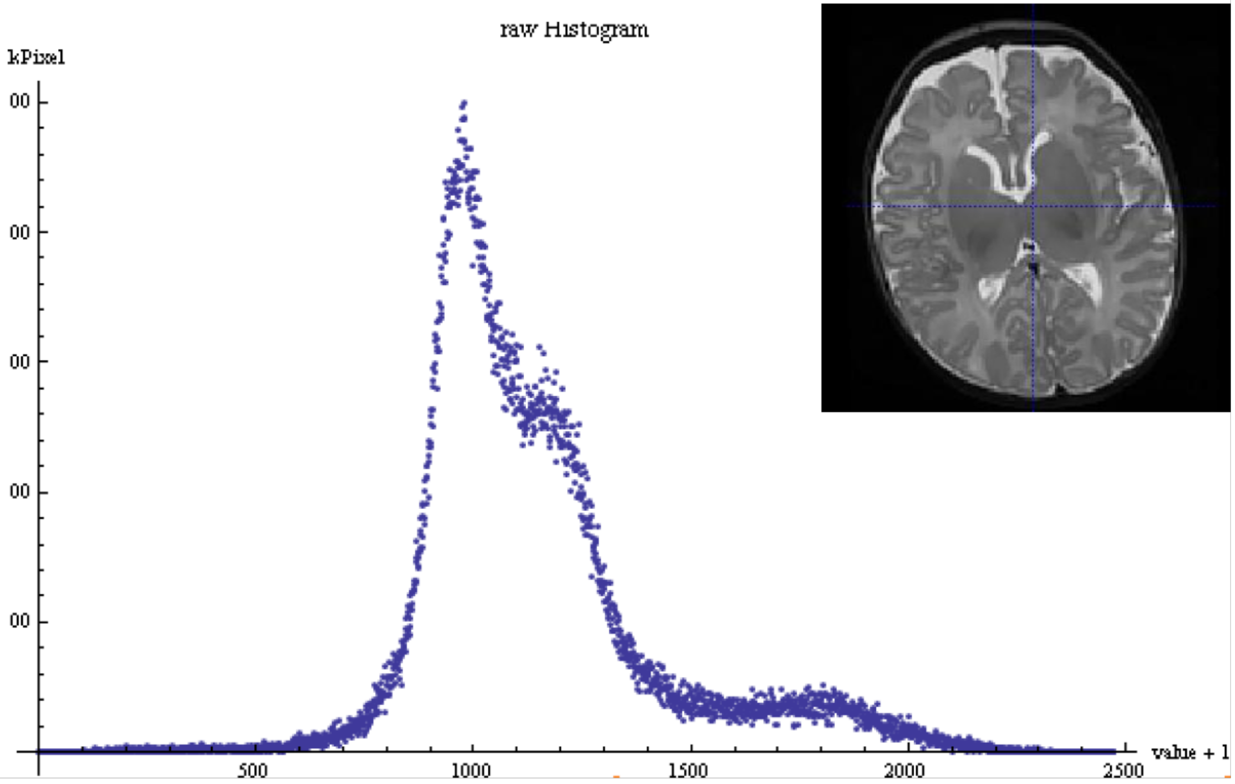
Histogram Applications

Example: MRI



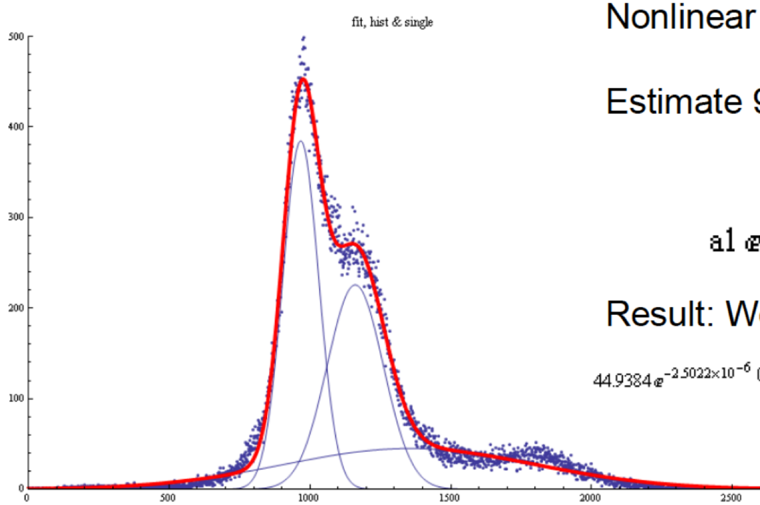
Histogram Applications

Example: MRI



Histogram Applications

Fit with 3 weighted Gaussians



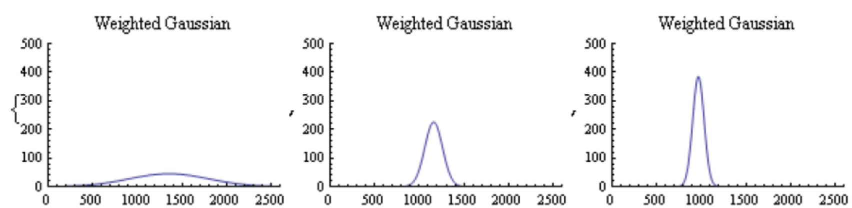
Nonlinear optimization

Estimate 9 parameters for best fit:

$$a1\, e^{-\frac{(x-my1)^2}{2\,sig1^2}} + a2\, e^{-\frac{(x-my2)^2}{2\,sig2^2}} + a3\, e^{-\frac{(x-my3)^2}{2\,sig3^2}}$$

Result: Weighted sum of Gaussians (pdf's):

$$44.9384\, e^{-2.5022\times10^{-6}\,(x-1353.63)^2} + 225.575\, e^{-0.0000503733\,(x-1160.5)^2} + 384.58\, e^{-0.000122748\,(x-967.112)^2}$$



Histogram Applications

Segmentation: Learning pdf's

set of pdf's:

$$G_k(\mu_k, \sigma_k \mid k), \quad (k = 1, \ldots, n)$$

calculate thresholds

assign pixels to categories

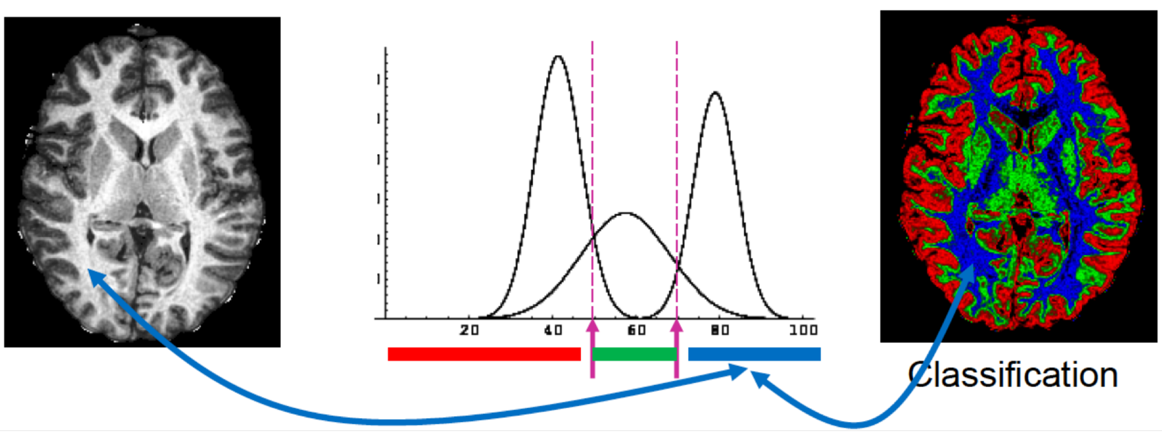


Image Enhancement in Spatial Domain

- Image Histogram
- Image Negative
- Contrast Stretching
- Power-Law Transformation
- Histogram Equalization
- Local Enhancement
- Image Subtraction
- Image Averaging
- Image Smoothing
- Image Sharpening

Noise

Application: Noisy Images

- Imagine N images of the same scene with random, independent, zero-mean noise added to each one
  - Nuclear medicine–radioactive events are random
  - Noise in sensors/electronics
- Pixel value is s+n

True pixel value

Random noise:
•Independent from one image to the next
•Variance = σ

Image Smoothing or Averaging

- A noisy image:

$$g(x,y) = f(x,y) + n(x,y)$$

■ Let $g(x, y)$ denote a corrupted image formed by the addition of noise, $\eta(x, y)$, to a noiseless image $f(x, y)$; that is,

$$g(x, y) = f(x, y) + \eta(x, y) \tag{2.6-4}$$

EXAMPLE 2.5: Addition (averaging) of noisy images for noise reduction.

Image Smoothing or Averaging

- A noisy image:

$$g(x,y) = f(x,y) + n(x,y)$$

- Averaging M different noisy images:

$$\overline{g}(x,y) = \frac{1}{M}\sum_{i=1}^{M} g_i(x,y)$$

- As M increases, the variability of the pixel values at each location decreases.
    - This means that g(x,y) approaches f(x,y) as the number of noisy images used in the averaging process increases.

Example

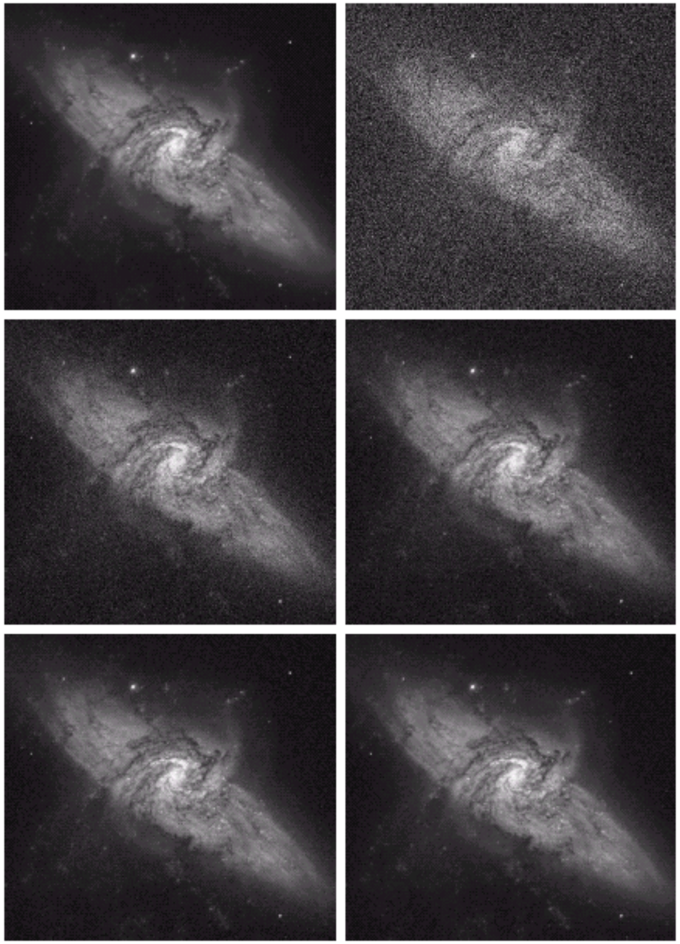


FIGURE 3.30 (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8, 16, 64$, and 128 noisy images. (Original image courtesy of NASA.)