# Lecture 1: Image Enhancement - Spatial Domain

**BioE 244**
**Medical Image Processing and Analysis**



## Image Enhancement in the Spatial Domain

- Image Intensity/Contrast Transforms
- Image Histogram Analysis
- Arithmetic/Logical Image Operations
- Spatial Filtering (*Klifa*)



## Spatial Domain Image Operations

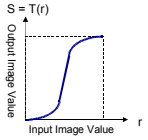
- Spatial operators act directly on the pixels comprising the image, unlike frequency domain operators which act on the frequency representation of the image.
- g(x,y) = T[ f(x,y) ]
  - f(x,y) - input image
  - g(x,y) - output image
  - T - spatial operator

*g(x,y)* = T ( *f(x,y)* )

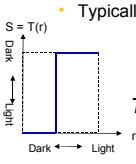


## Intensity/Contrast Transformations

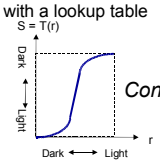
- Point Pixel/Voxel Processing
  - 1 x 1 neighborhood: s = T(r)
  - "Intensity or graylevel transformation", "pixel mapping"




  - Typically implemented with a lookup table



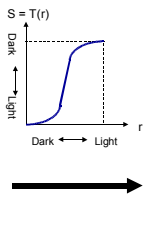

*Threshold*




*Contrast Stretch*



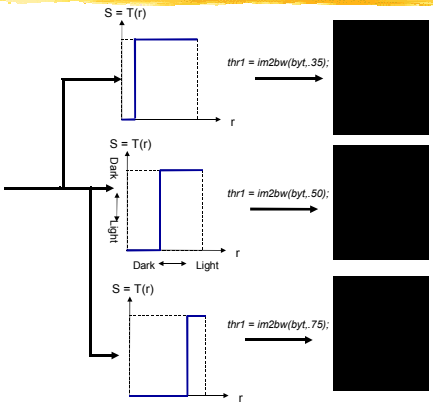
## Contrast Stretching



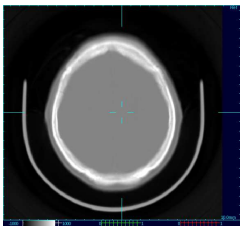

*J = imadjust(I) maps the values in intensity image I to new values in J such that 1% of data is saturated at low and high intensities of I. This increases the contrast of the output image J. This syntax is equivalent to imadjust(I,stretchlim(I)).*



## Thresholding



## CT intensity Range and Intensity Windowing



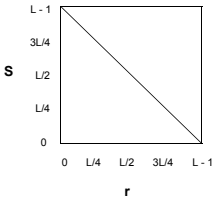
-1000HU to 1000 HU
mapped to 128 gray levels

-0HU to 100 HU
mapped to 128 gray levels



## Gray Level Transforms

- Image Negative, Inverse Transform
- s = L - 1 - r

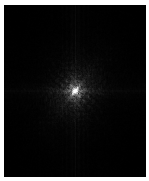


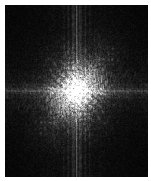

*imadjust(I, [0 ; 1], [1 ; 0]);*
*or*
*imcomplement(I)*

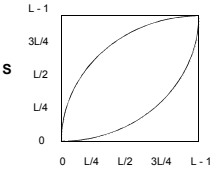


## Gray Level Transforms

- Log Transform
- s = c log(1+r)
- Compresses dynamic range of images that have large variation in intensities
- Most common display for FFTs



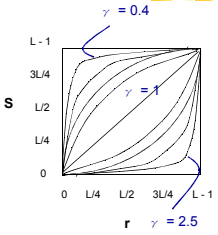







## Gray Level Transforms

- Gamma Correction, Power-Law Transform
- $s = c\, r^{\gamma}$
  - $\gamma$ = 1 => identity image
  - $\gamma$ < 1: maps narrow I range (dark) to a wider dynamic range
  - $\gamma$ > 1: maps wide range of I to narrow range
- Predominantly used for image capture, display, and printing




$\gamma$ = 1

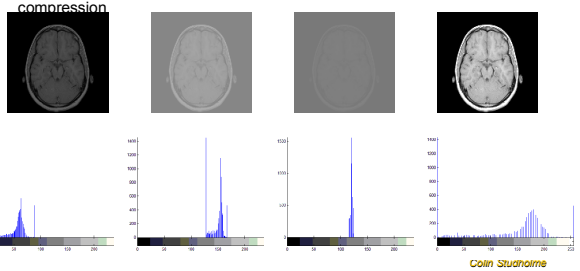
$\gamma$ = 0.4
*imadjust(I, [], [], 0.4);*

$\gamma$ = 2.5
*imadjust(I, [], [], 2.5);*



## Histogram Analysis

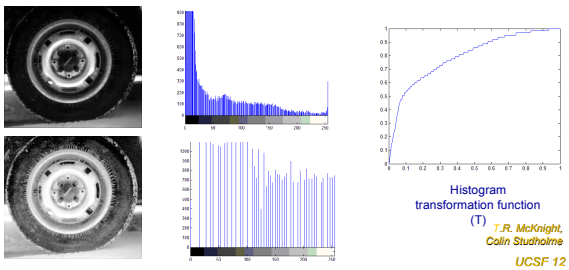
- The histogram (h) of an image with L graylevels is defined as $h(r_k) = n_k$, where $r_k$ is the k-th gray level and $n_k$ is the number of pixels with intensity $r_k$
- Histogram normalization: $p(r_k) = n_k / n_{total}$, for k = 0, 1, 2, …, L-1
- Useful for image enhancement, obtaining image statistics, segmentation, and compression





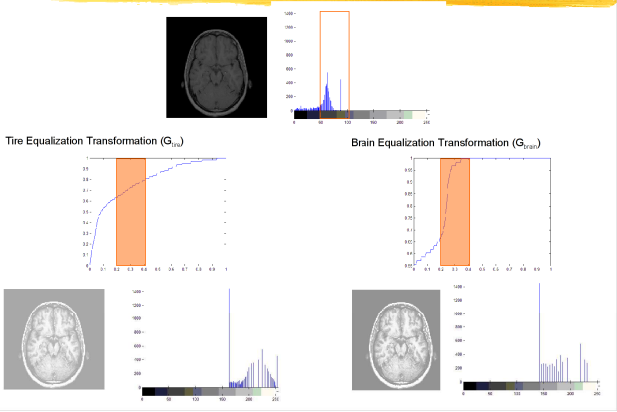
## Histogram Equalization

- Image Transformations (*T*): $s = T(r)$ $\quad 0 \le r \le 1$ (normalized intensities)
- Histogram equalization: $s_k = \sum_{j=0}^{k} \frac{n_j}{n}$ for $k$ = 0, 1, 2, …, L-1
- Spreads the histogram of the input image over a larger range of intensities



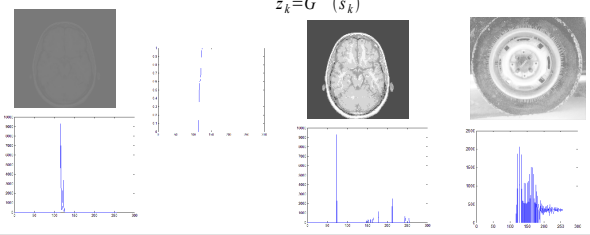
Histogram transformation function (T)

## Histogram Matching




## Histogram Matching

- Histogram matching, Histogram specification
- Histogram mapping of Image 1: $s_k = \sum_{j=0}^{k} \frac{n_j}{n}$ for k = 0,1,2,…,L-1
- Histogram of Image 1: $G(z_k) = \sum_{i=0}^{k} p_z(z_i)$ for k = 0,1,2,…,L-1
- Histogram matching to Image 2: $z_k = G^{-1}(s_k)$ for k = 0,1,2,…,L-1

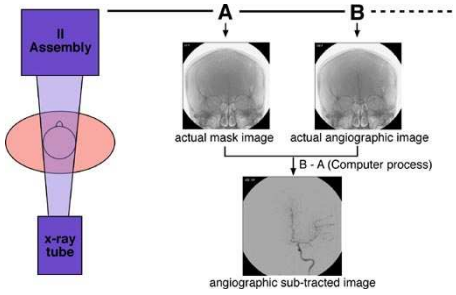


## Arithmetic & Logic Image Operations

- Pixel-by-pixel mathematical operations
- Arithmetic (eg addition, subtraction, division, etc)
- Logic (eg AND, OR, NOT) => used in masking operations

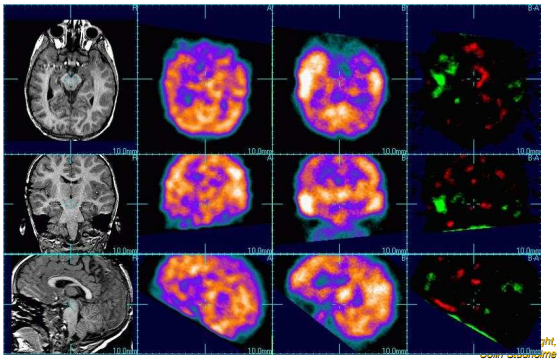


## Image subtraction in medical Imaging: DSA: digital Subtraction Angiography





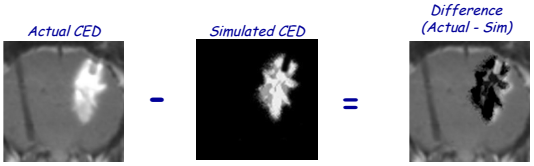

## Subtraction SPECT imaging (after registration)



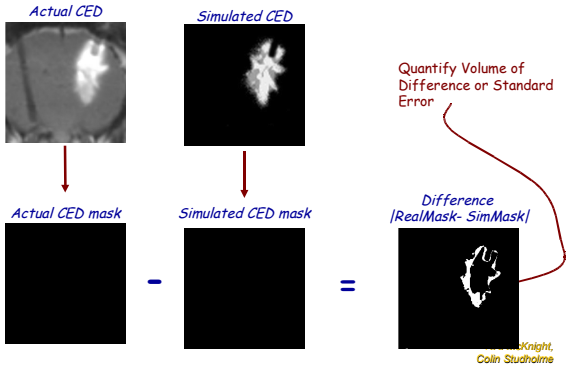


## Image Subtraction

Problem: We have used physiologic MRI data to simulate (predict) the distribution of gadolinium-labeled liposomes infused into pig brain by convection-enhanced delivery (CED). How do we evaluate the accuracy of our simulation?



## Image Subtraction: Masking






## Image Logic: Masking




## Spatial Filters

- Kernal
  - Small 2D array eg 3x3 neighborhood
  - "filter", "kernal", "template", "window"