Digital Image Processing (CSE/ECE 478)

Lecture # 02: Intensity Transformations

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Motivation

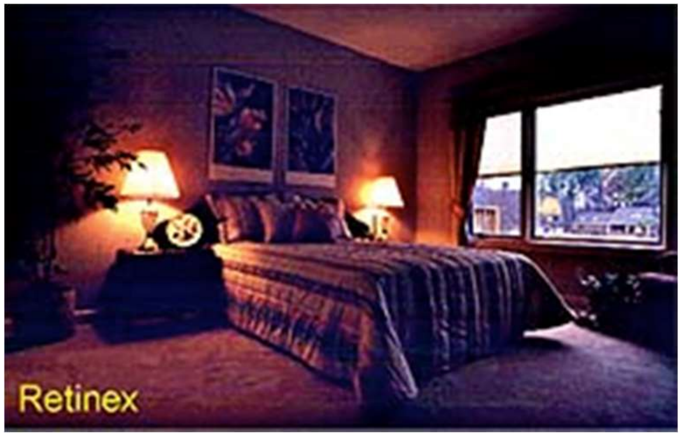


Image courtesy: NASA

Motivation

Image courtesy: rationalqm.us

Pointillism

- Conceived by French artist Paul Signac in 1885.
- Relies on the ability of the eye and mind of the viewer to blend the color spots into a fuller range of tones

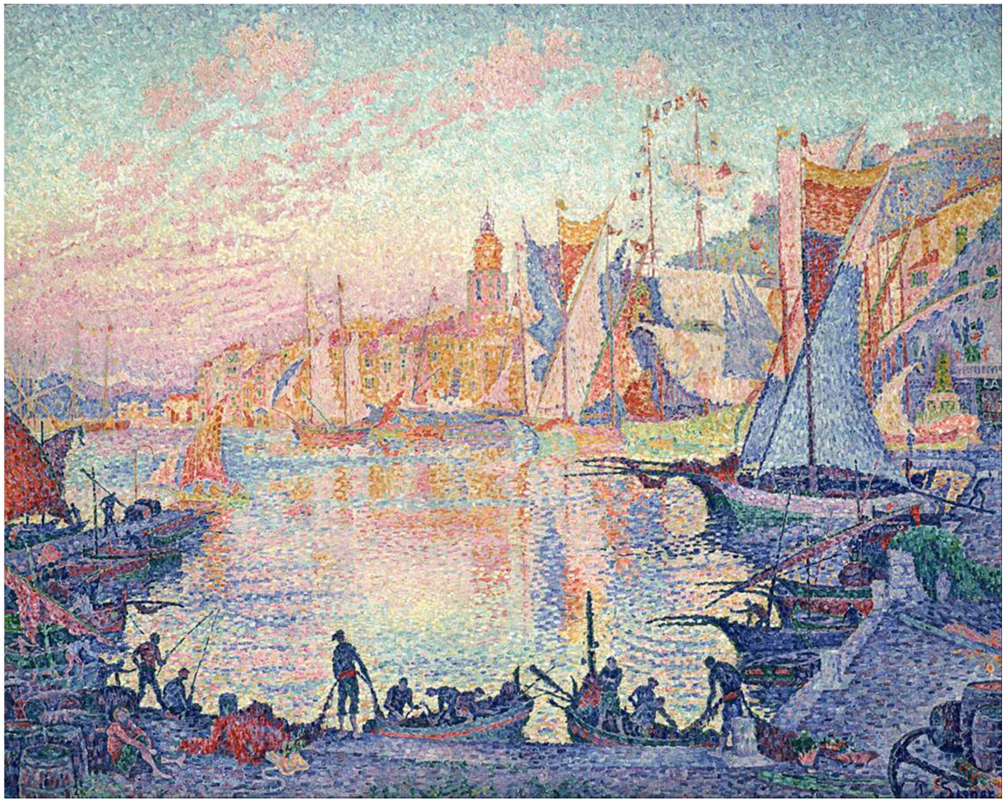


Image courtesy: wikipedia

Organization (today's lecture)

1. Intensity Transformation Functions

2. Histogram Processing

Point Operations

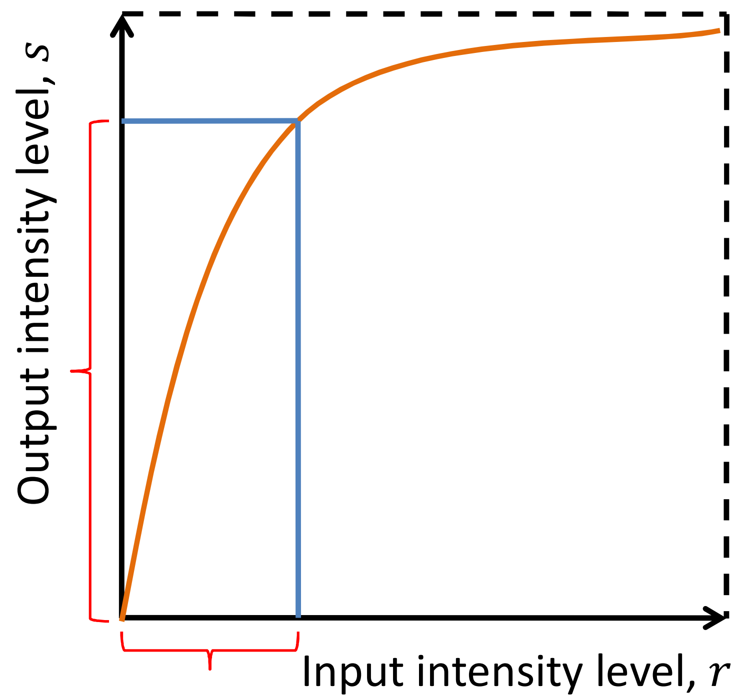
Organization (today's lecture)

1. Intensity Transformation Functions

2. Histogram Processing

Intensity transformation

- Input pixel $(r) \rightarrow$ output pixel (s)
- Independent pixel to pixel mapping



Standard Intensity transformations

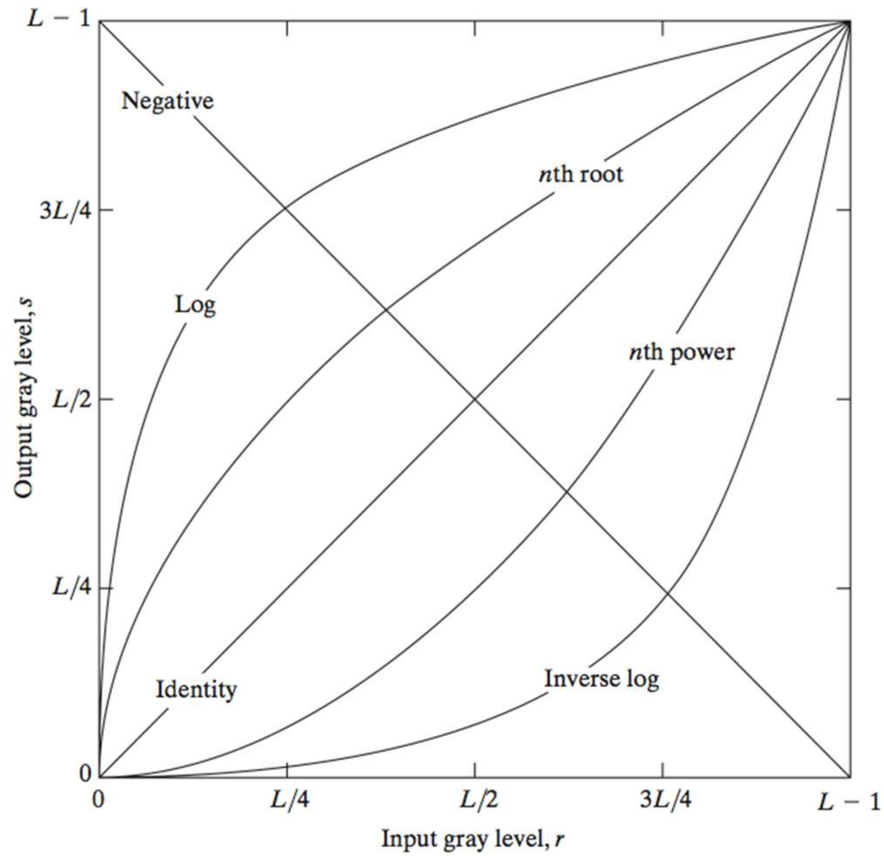
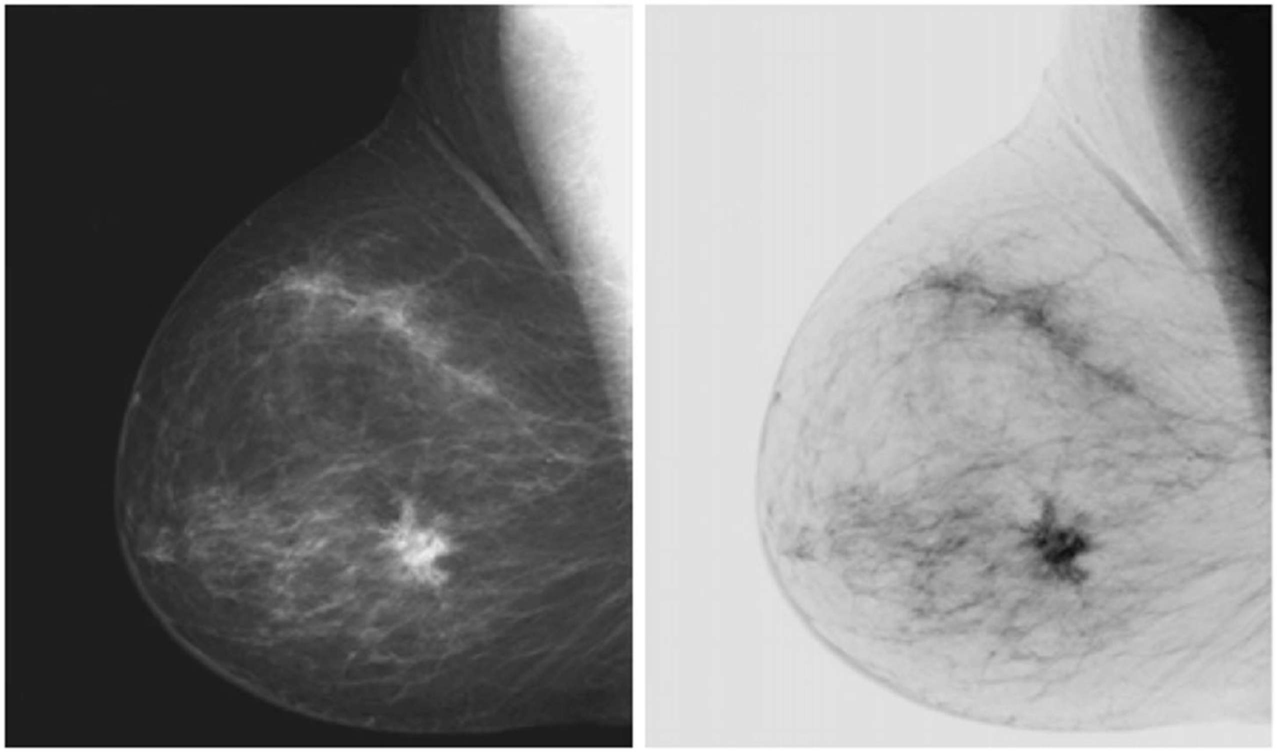


Image Negatives



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.)

Intensity levels: $[0, L-1]$

Transformation: $s = L - 1 - r$

Log Transformations

- The dark pixels in an **image** are assigned larger intensity values while the brighter pixels get a slight reduction in their intensity values.

- The value of c in the **log transform** adjust the kind of enhancement you are looking for.

$$s = c\ log(1 + r)$$

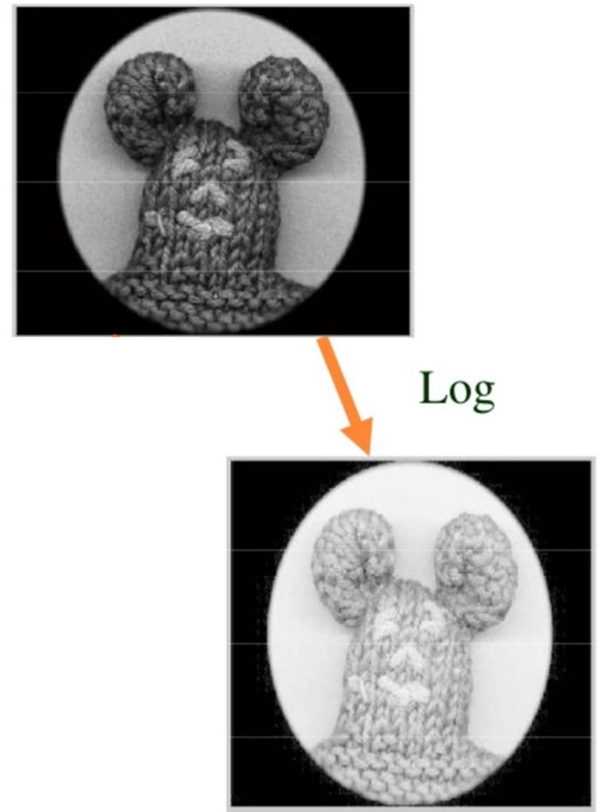
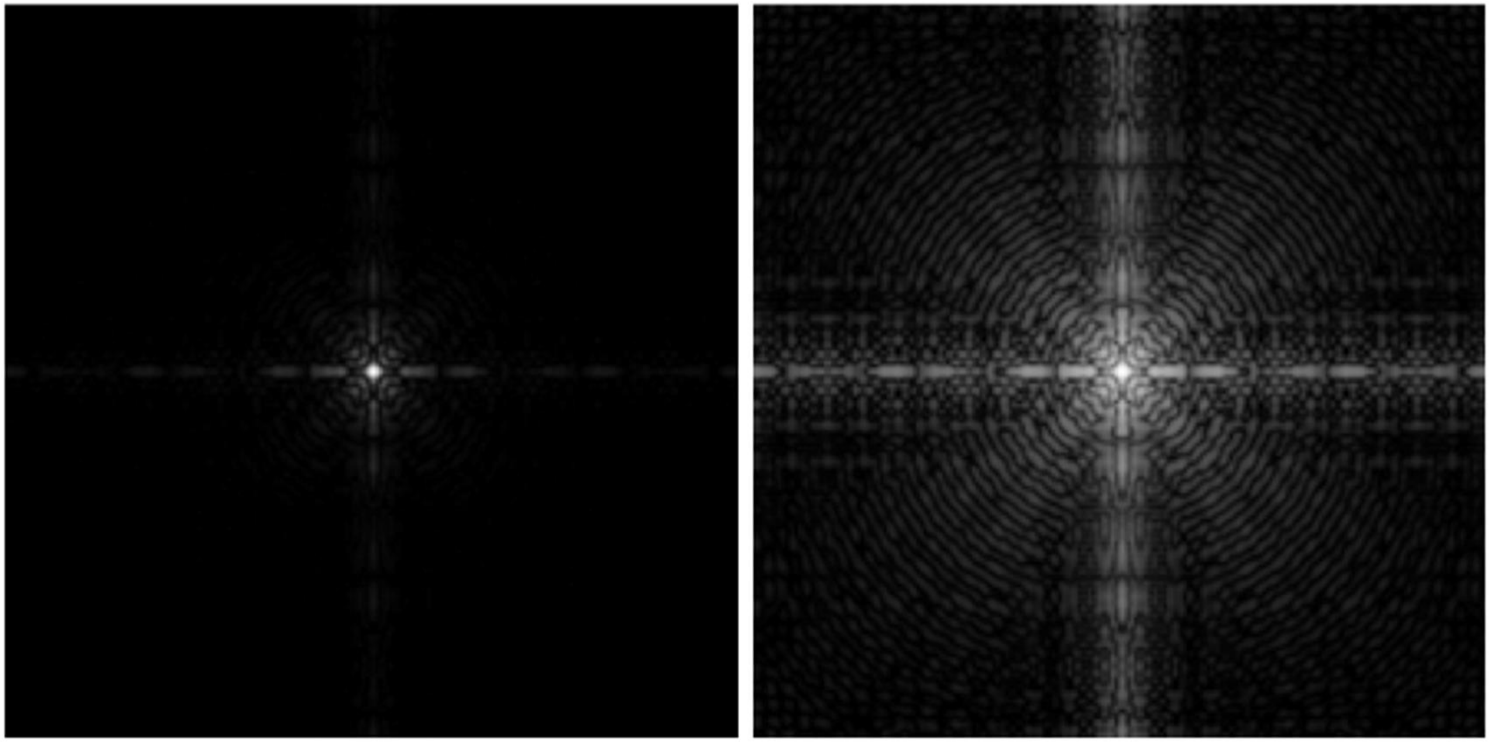


Image courtesy: Slideshare

Log Transformations

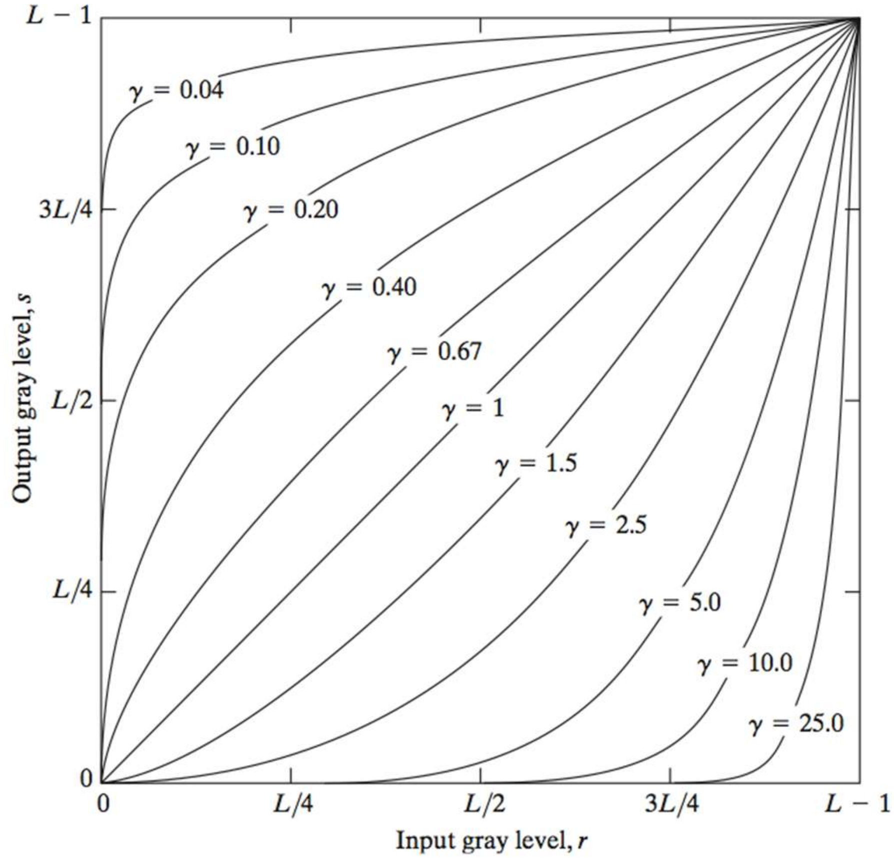
a b

FIGURE 3.5
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.



$$s = c\ log(1 + r)$$

Power-Law (Gamma) Transformations



$$s = c\, r^{\gamma}$$

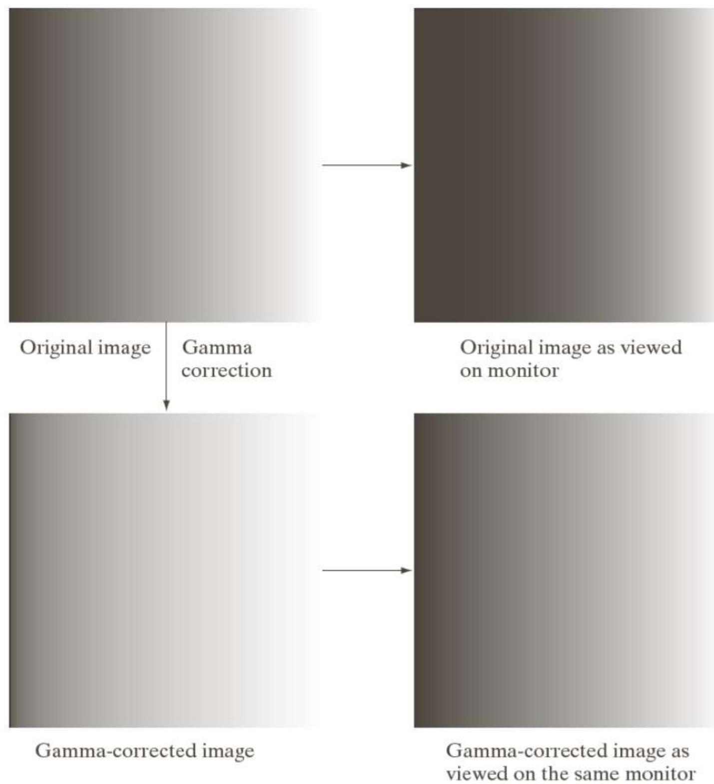
Power-Law (Gamma) Transformations

FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively. (Original image for this example courtesy of NASA.)

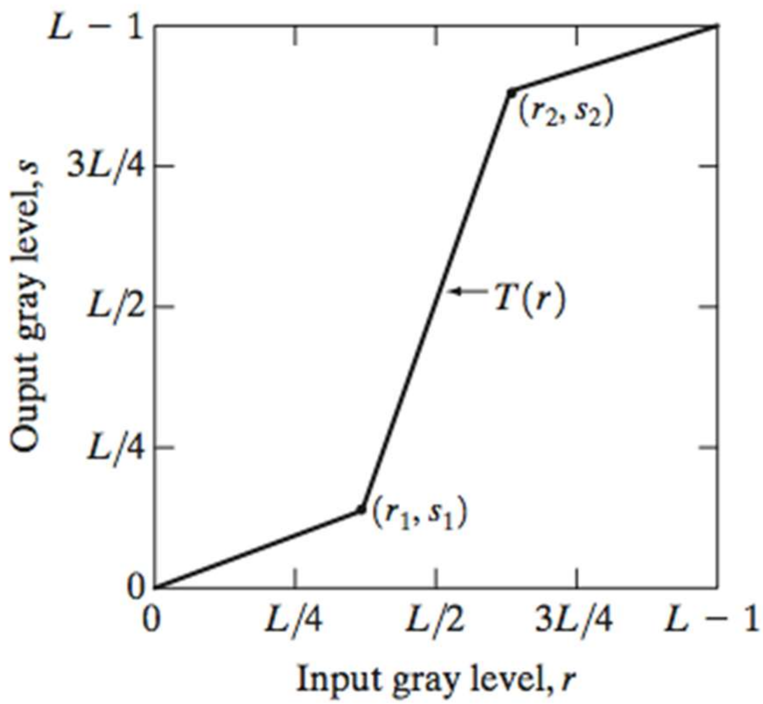
Power-Law (Gamma) Transformations

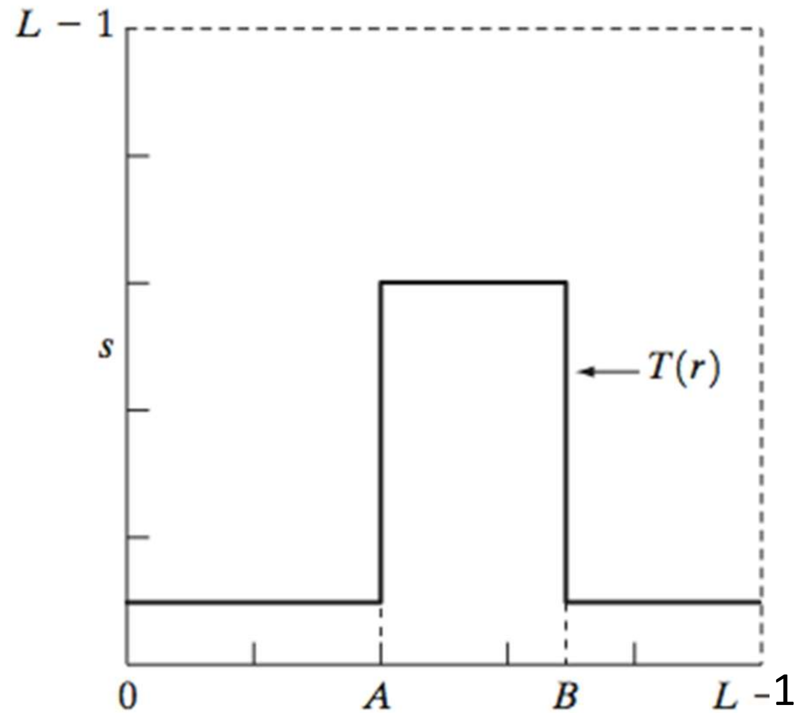
a b
c d

FIGURE 3.7
(a) Intensity ramp image. (b) Image as viewed on a simulated monitor with a gamma of 2.5. (c) Gamma-corrected image. (d) Corrected image as viewed on the same monitor. Compare (d) and (a).



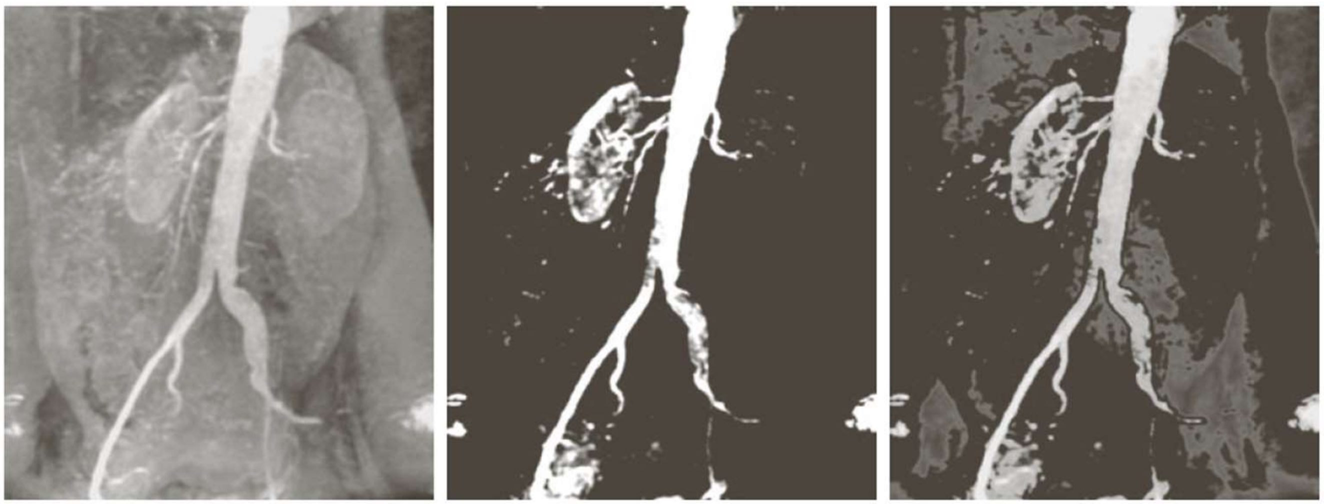
Piecewise Transformations





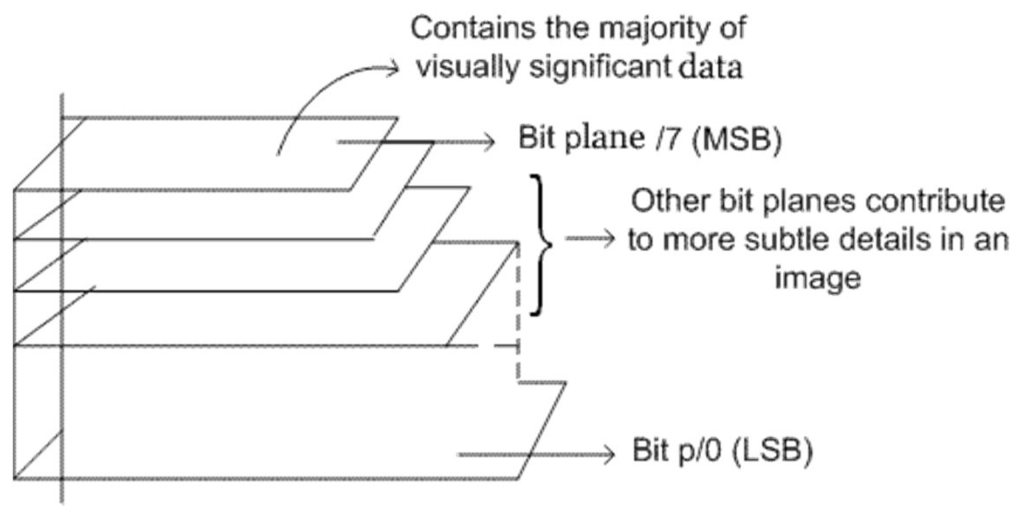
Piecewise Transformations: Contrast Stretching

Piecewise Transformations

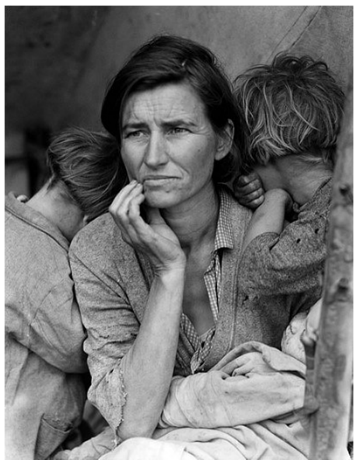


Bit Plane Slicing

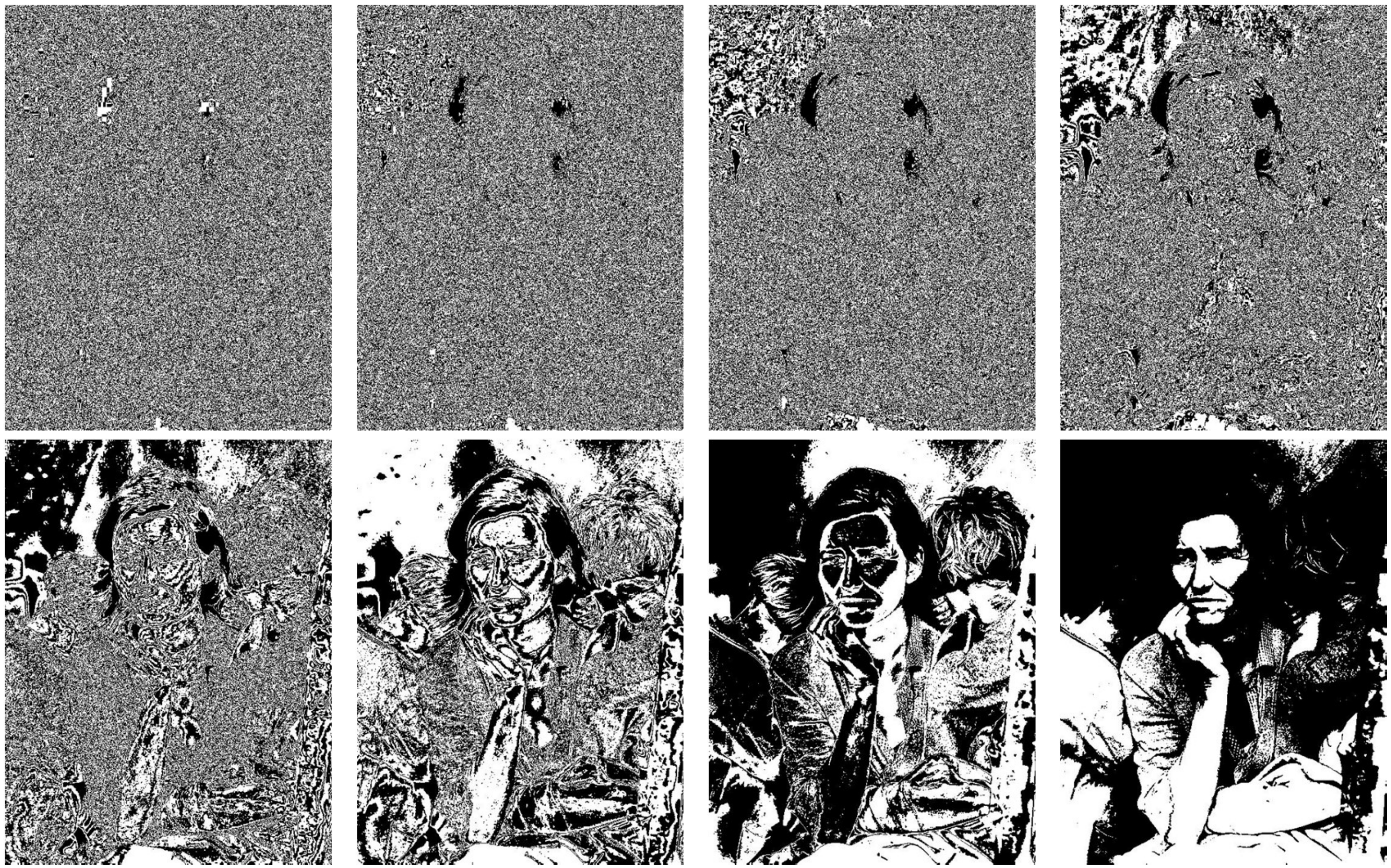
- Most Significant Bit (MSB) plane stores the structural information of the content.
- Least Significant Bit plane stores the details about image or the high frequency components of visual image.



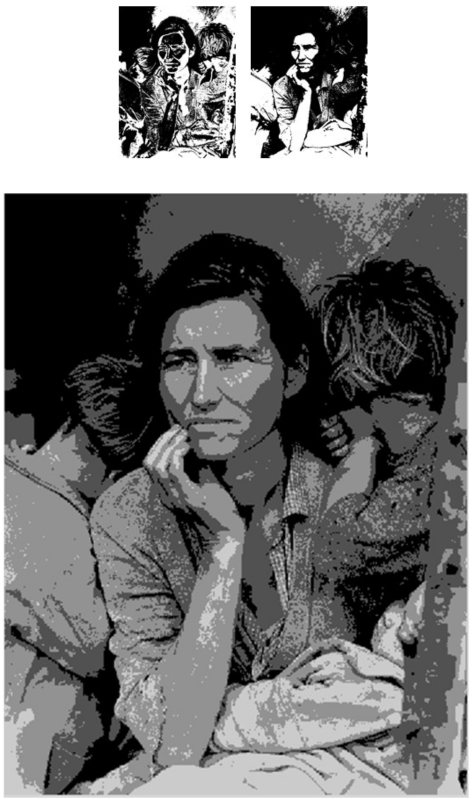
Bit Plane Slicing

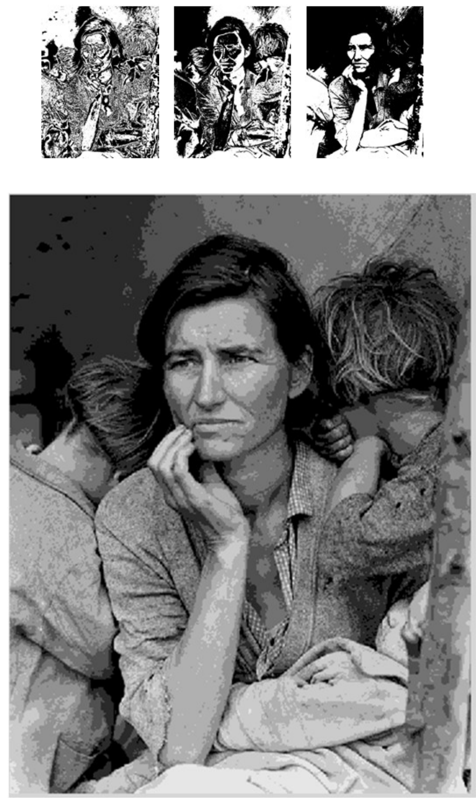


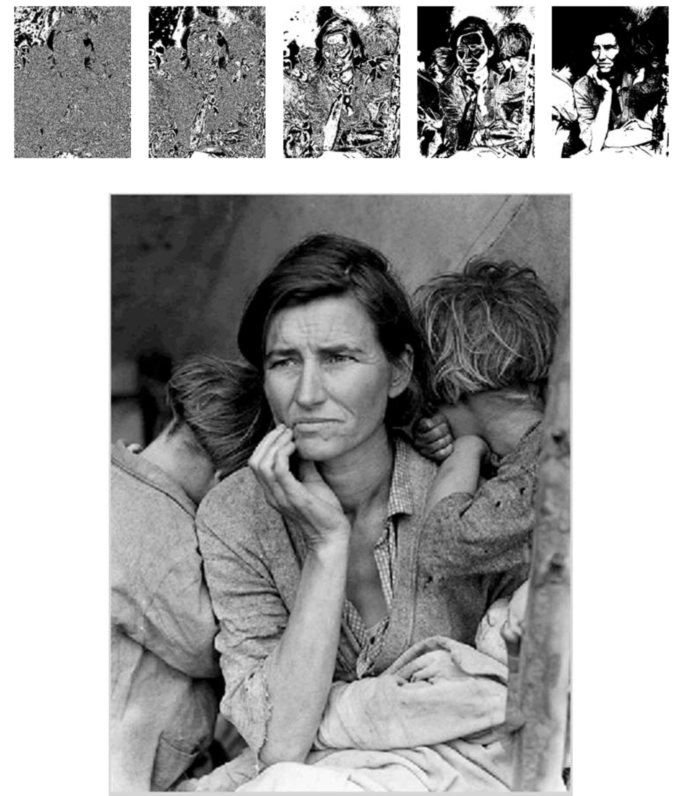
Dorothea Lange's
"Migrant Mother"



Bit Plane Slicing





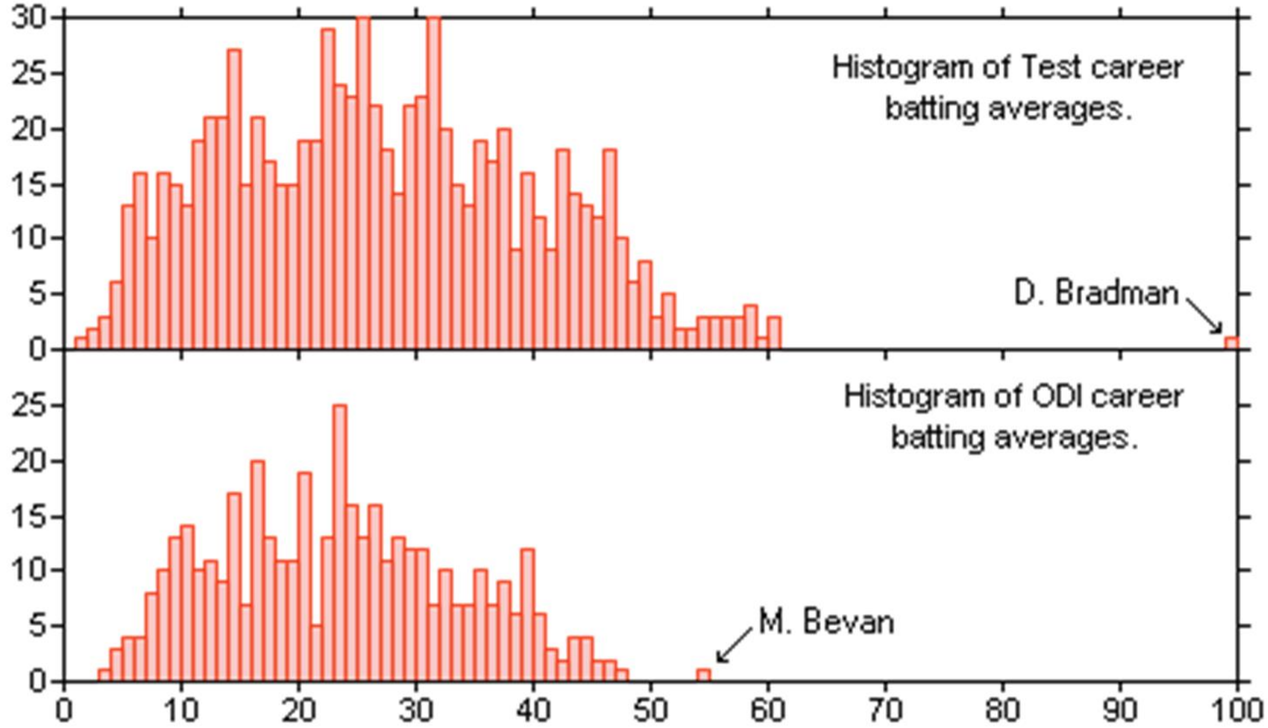


Organization (today's lecture)

1. Intensity Transformation Functions

2. Histogram Processing

Histogram



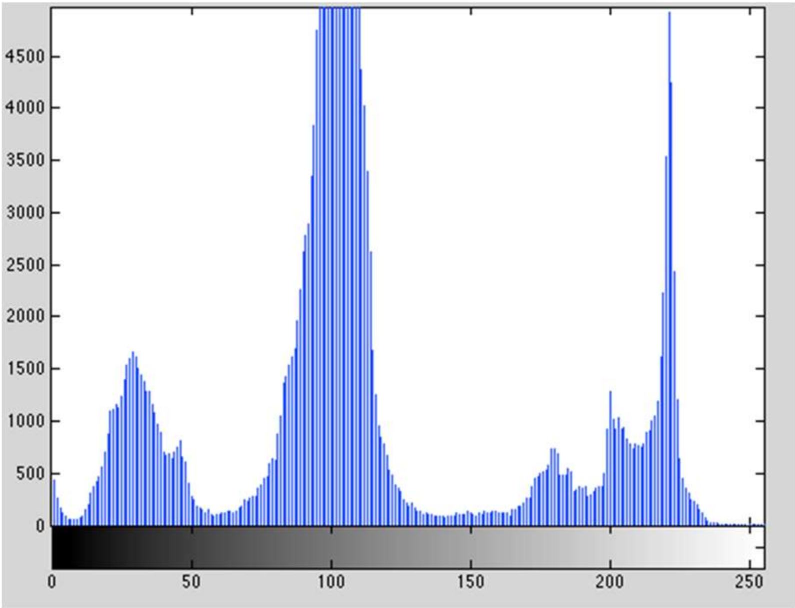
Courtesy: wikipedia

Histogram

$$h_r(i) = n_i$$

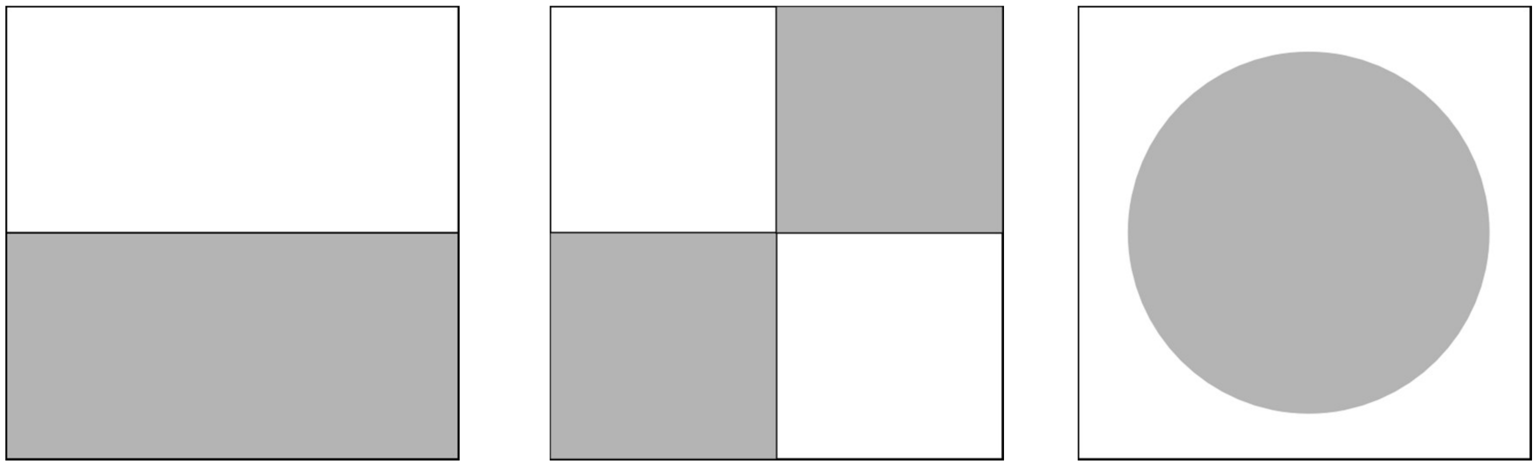
$i \rightarrow$ intensity value, range $[0, L-1]$

$n_i \rightarrow$ number of pixels with intensity i



Histograms

- Different images can have same histogram



- No information about distribution of intensity values

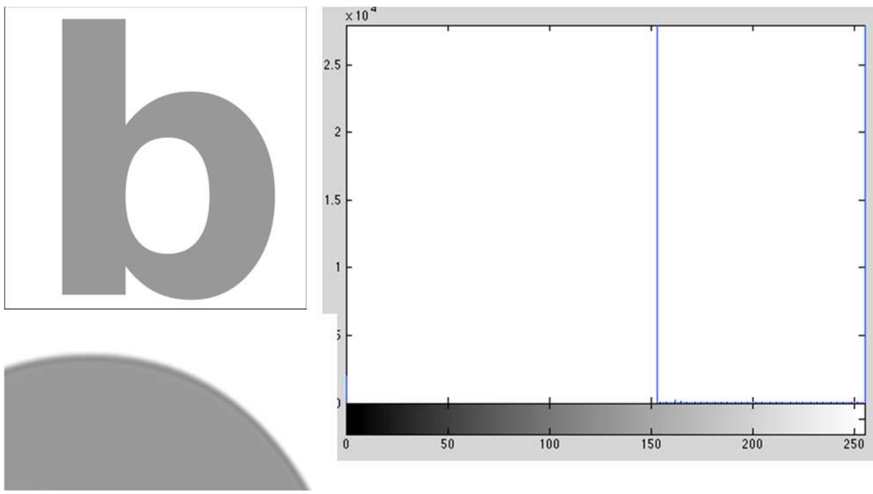
Histograms

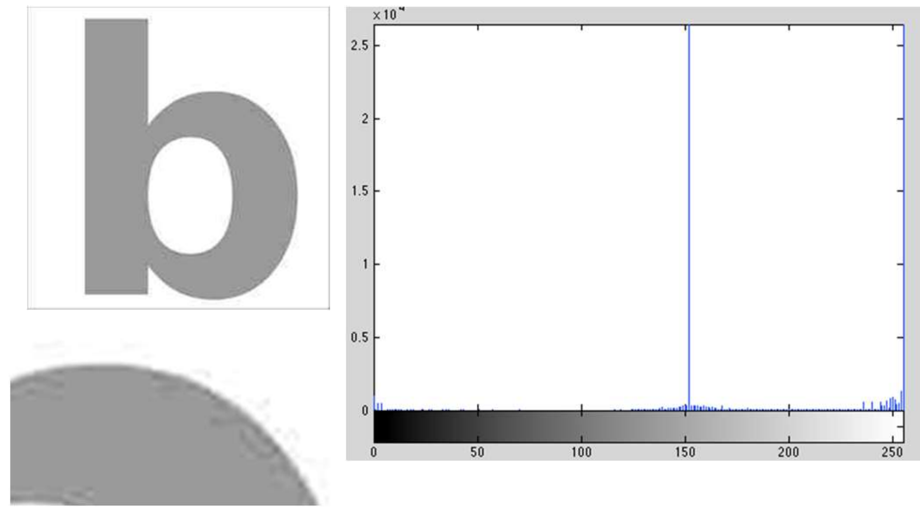
- What can we infer from histograms?

Histogram viewing standard in most DSLR cameras

Histograms

- Histograms can help interpret the images



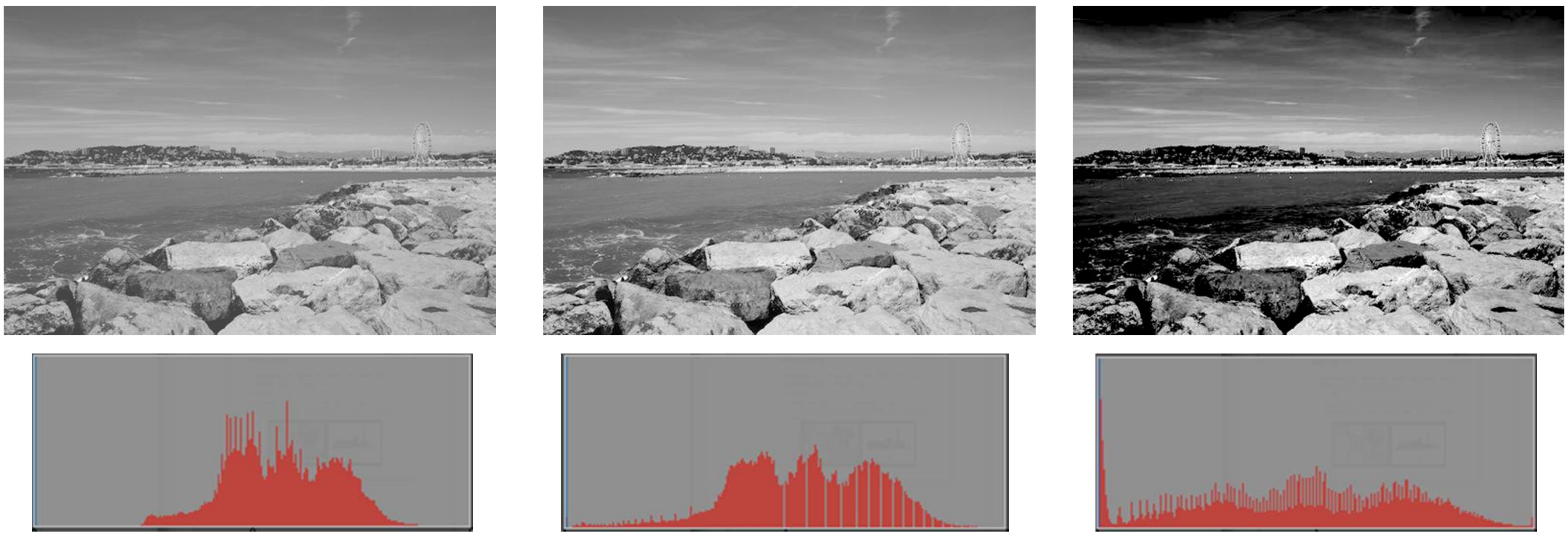


Original Image and histogram

Compressed Image and histogram

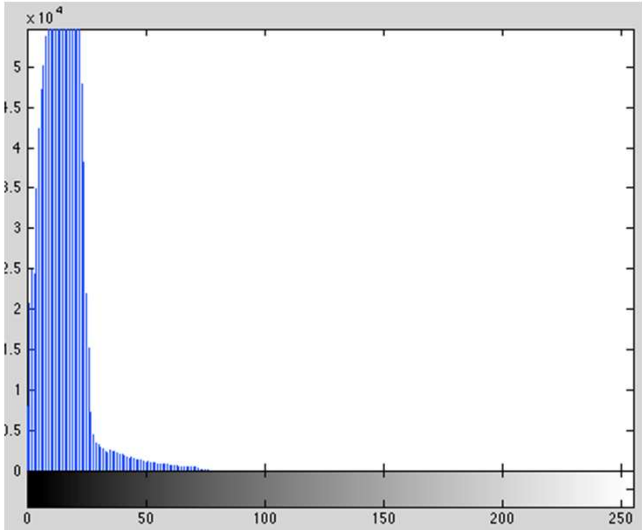
Histograms

- Histogram and contrast



Histograms

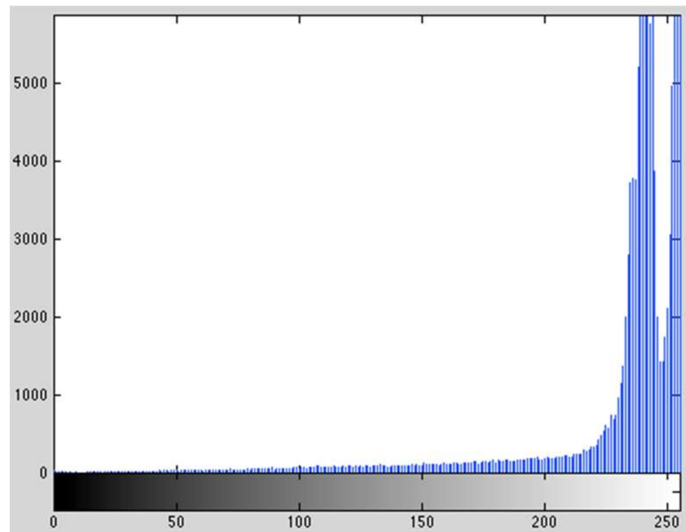
- Histograms and brightness



Under exposure

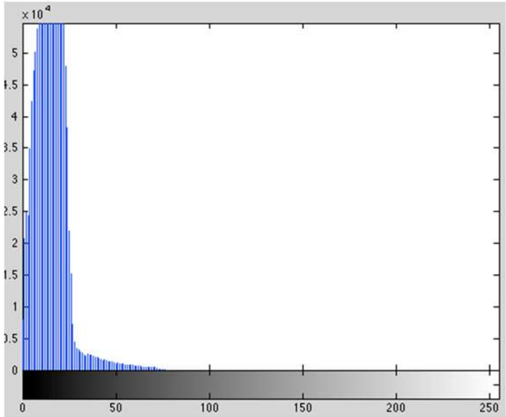
Histograms

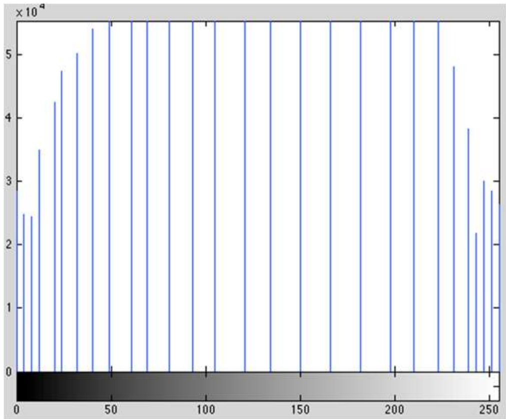
- Histograms and brightness



Over exposure

Histogram Equalization





Histogram Equalization

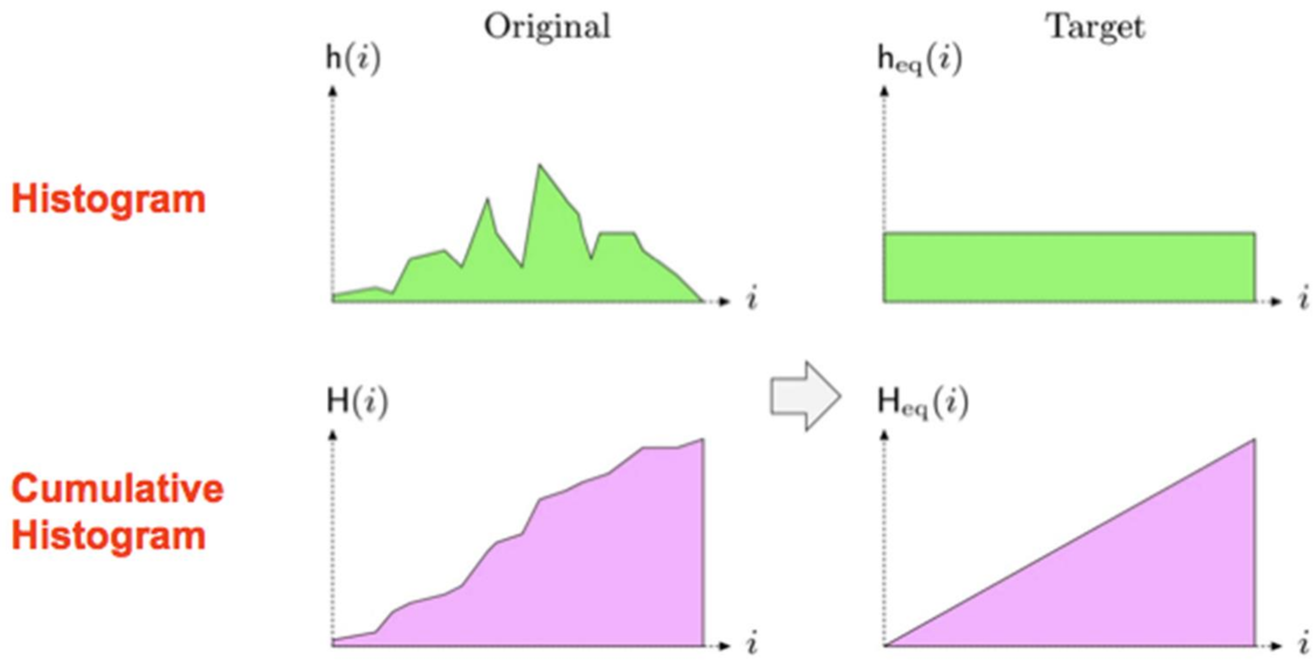


Image courtesy: *Worcester Polytechnic Institute*

Histogram Equalization

- Let $s = \mathrm{T}(r)$ be the transformation function and $p(r)$ and $p(s)$ be the pdf of intensity values for input & output image where $0 \le r, s \le 1$ and $p(r = i) = h(i) = \frac{n_i}{n}$
- The number of pixels mapped from r to s is unchanged:

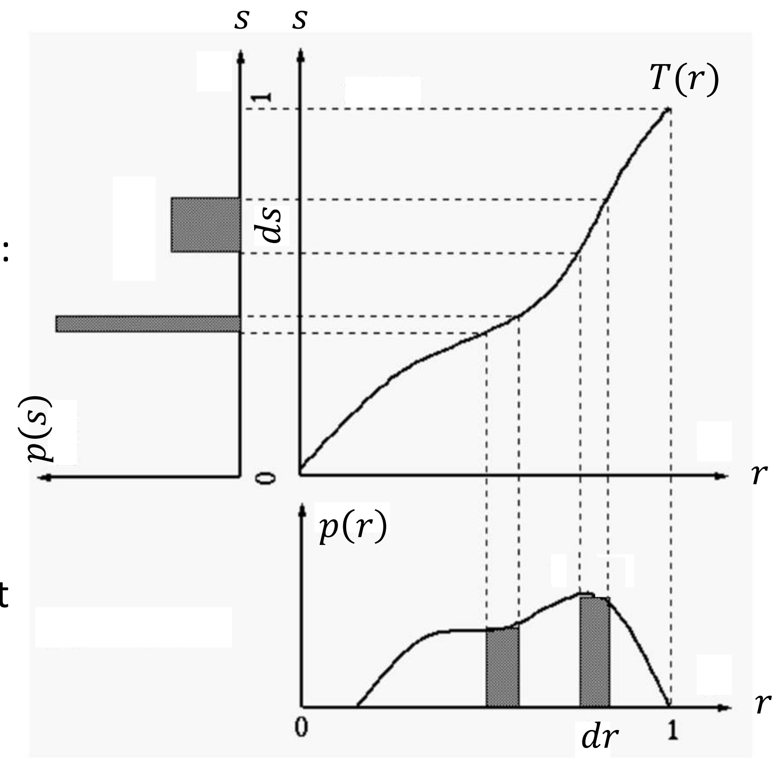
$$p(s)ds = p(r)dr$$

- To equalize the histogram of the output image, $p(s)$ should be a constant (uniform density):

$$p(s) = 1 \Longrightarrow \frac{ds}{dr} = p(r)$$

- The cdf of $p(r)$ is the transformation function $\mathrm{T}(r)$ that satisfies above equation:

if $s = P(r) = \int_0^r p(u)du$ then $\frac{ds}{dr} = p(r)$



Histogram Equalization

3 bit image of size 64×64 $i.e., L = 8$ and $n = 4096$

i	n_i	$p_r(i)$	$T(r_i)$	$s = \lfloor (L-1) * T(r_i) + 0.5 \rfloor$
0	790	0.19	0.19	$\lfloor 1.83 \rfloor = 1$
1	1023	0.25	0.44	3
2	850	0.21	0.65	5
3	656	0.16	0.81	6
4	329	0.08	0.89	6
5	245	0.06	0.95	7
6	122	0.03	0.98	7
7	81	0.02	1.00	7

Histogram Equalization

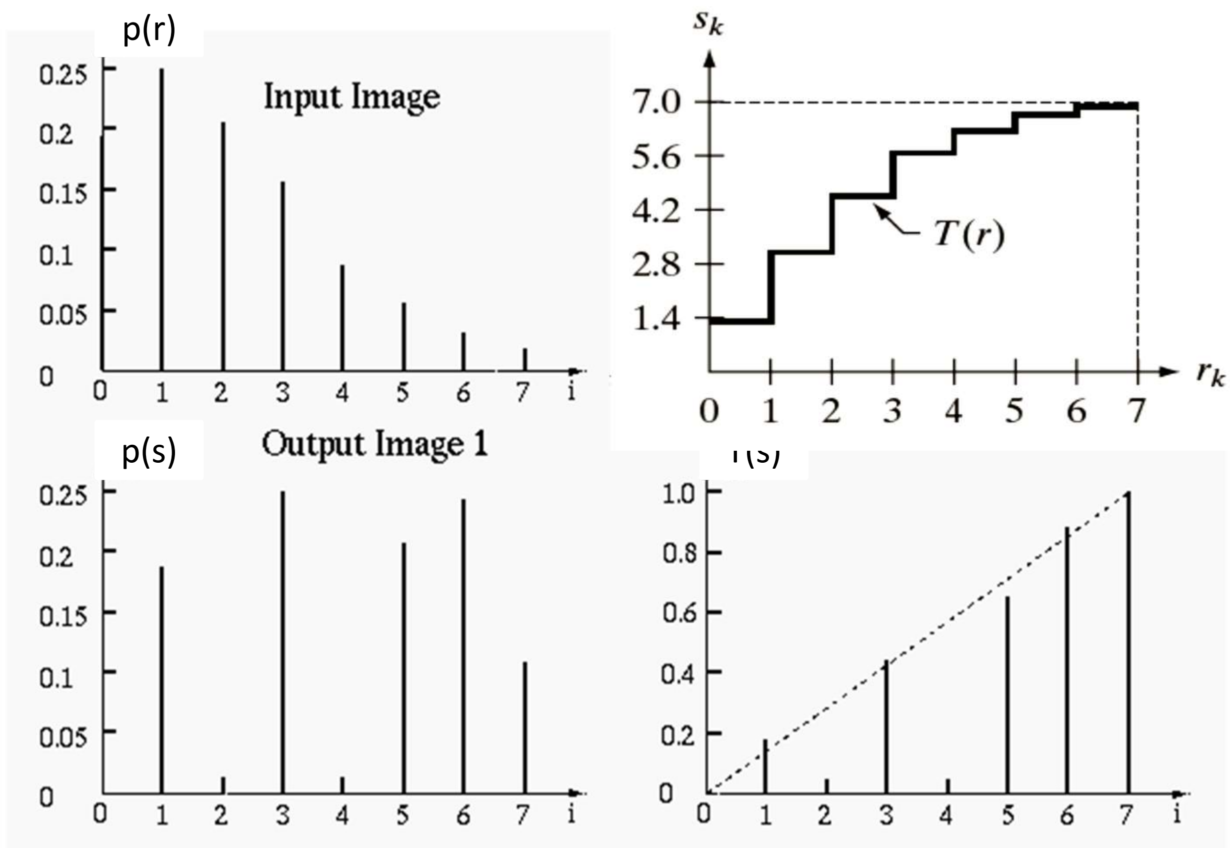
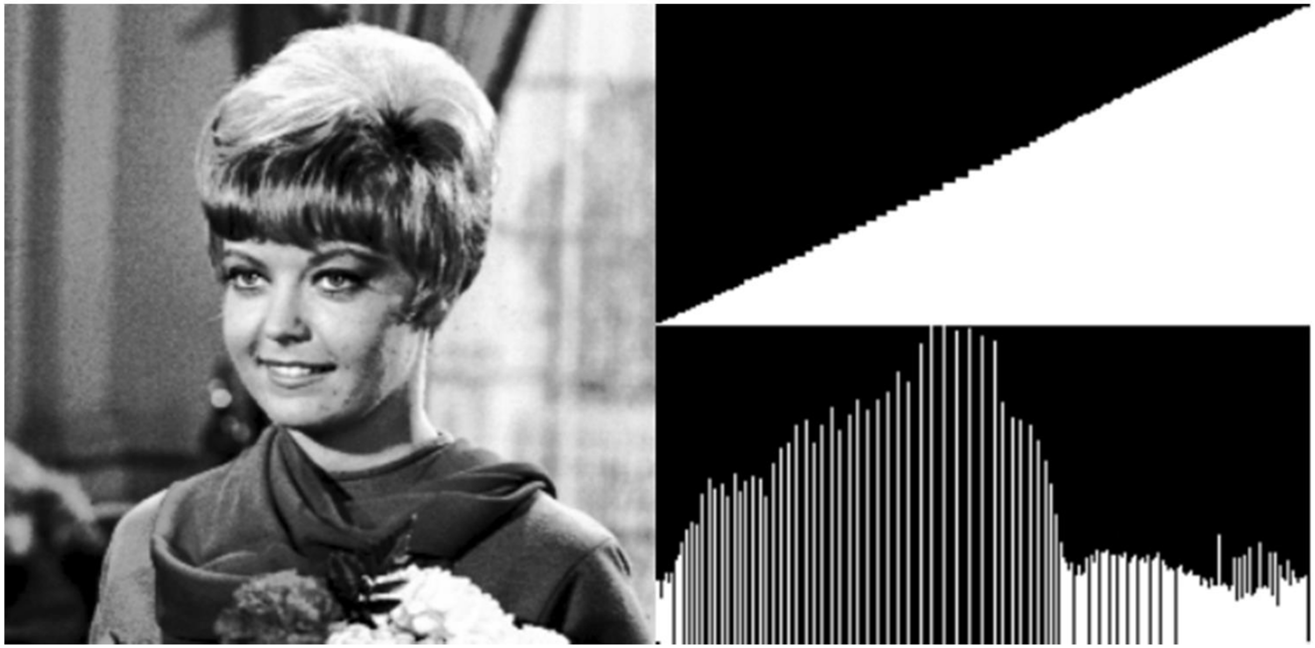


Image Courtesy: fourier.eng.hmc.edu/

Histogram Equalization



Cumulative histogram

Intensity histogram

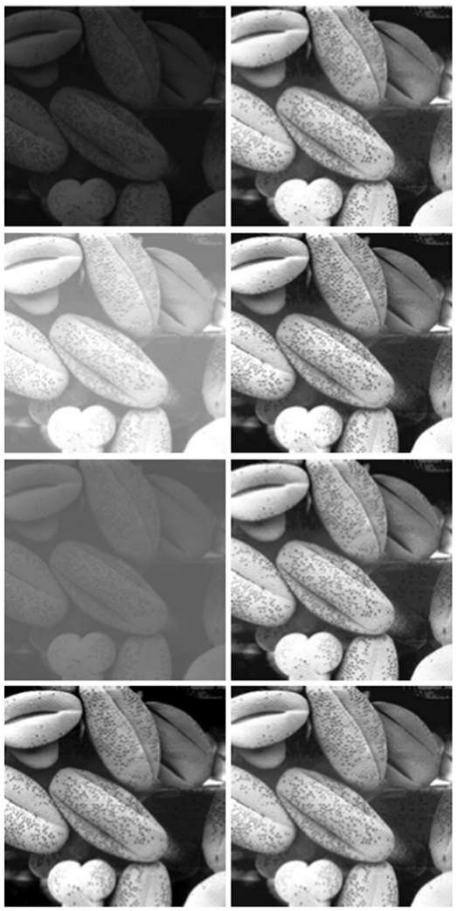
Histogram Equalization

(1) Dark

(2) Bright

(3) Low Contrast

(4) High Contrast



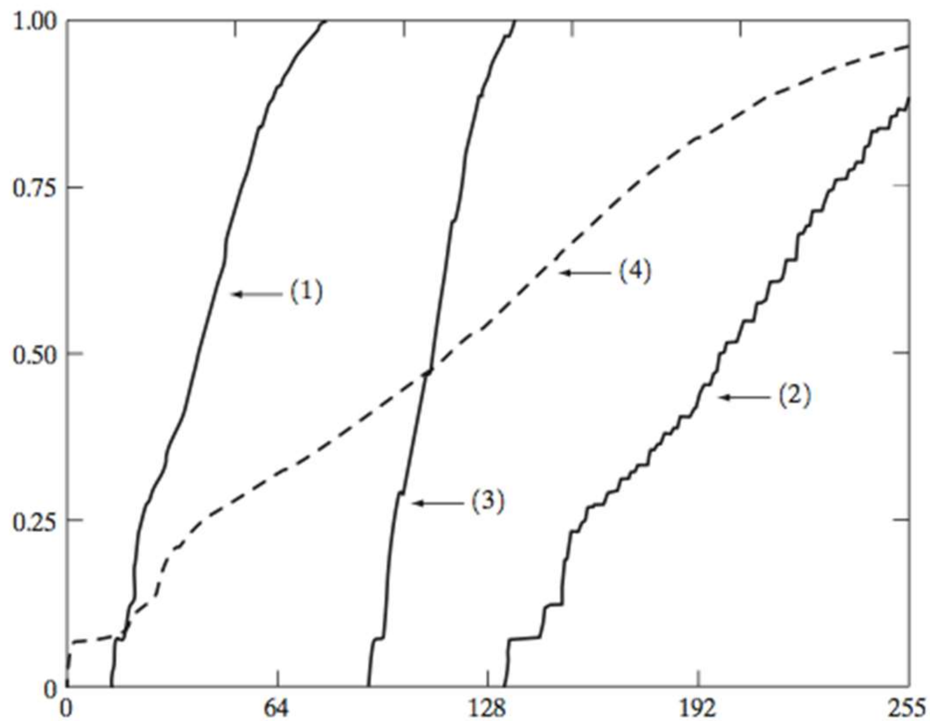


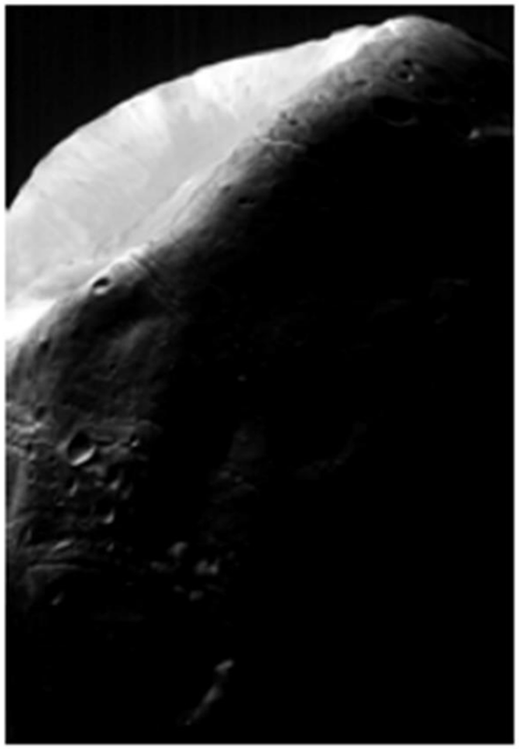
Image Courtesy: Gonzalez and Woods

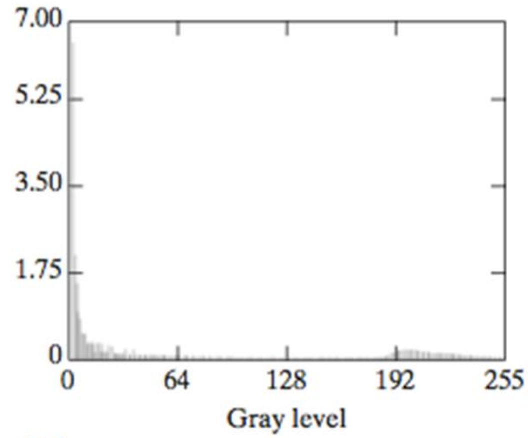
Histogram Equalization

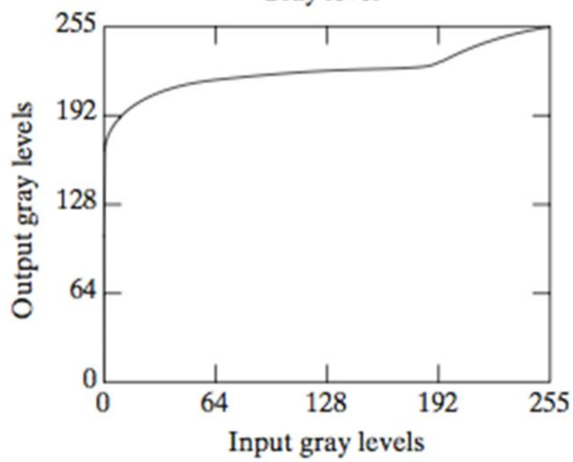
Intensity transformation

Histogram Equalization

Histogram Equalization







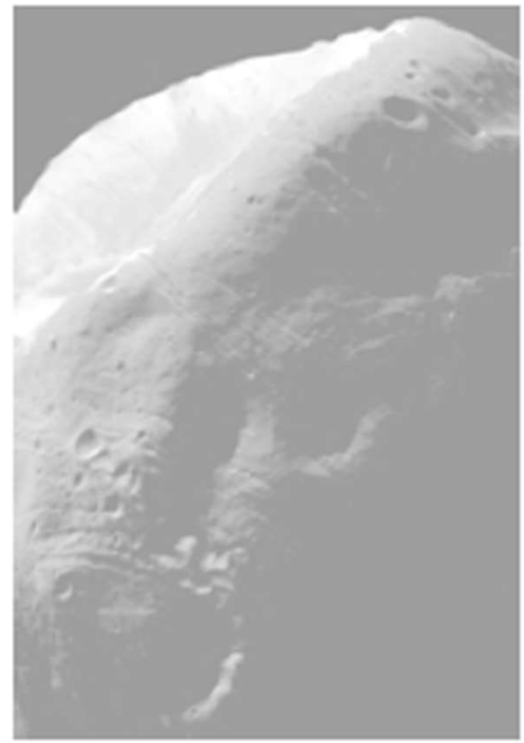
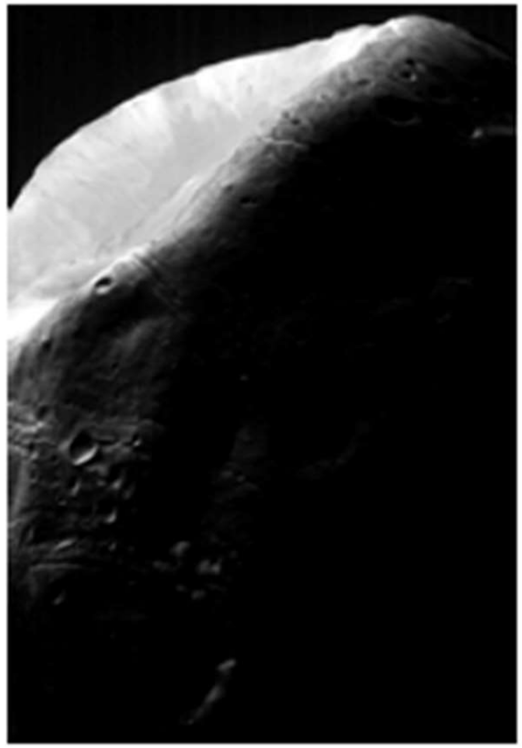


Image Courtesy: Gonzalez and Woods

Histogram Matching

- Specify shape of the target histogram (other than an uniform histogram)



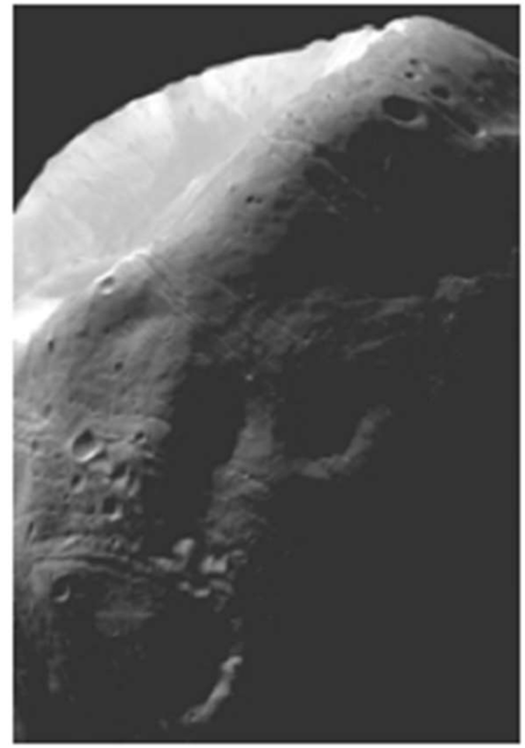


Image Courtesy: Gonzalez and Woods

Local Histogram Processing

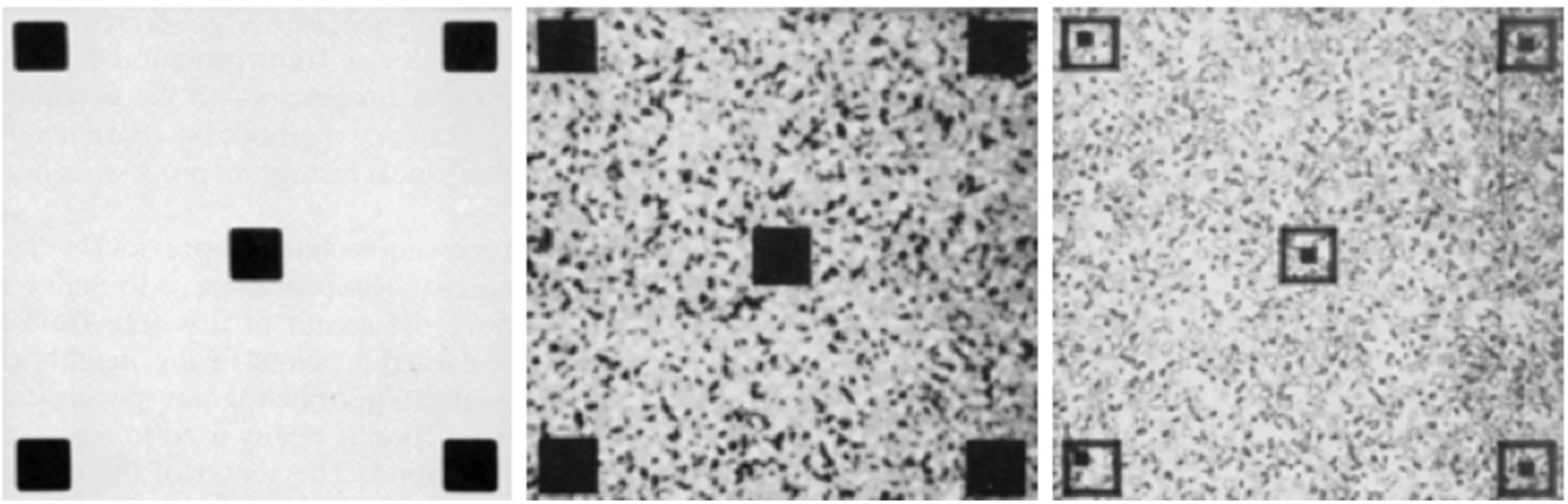
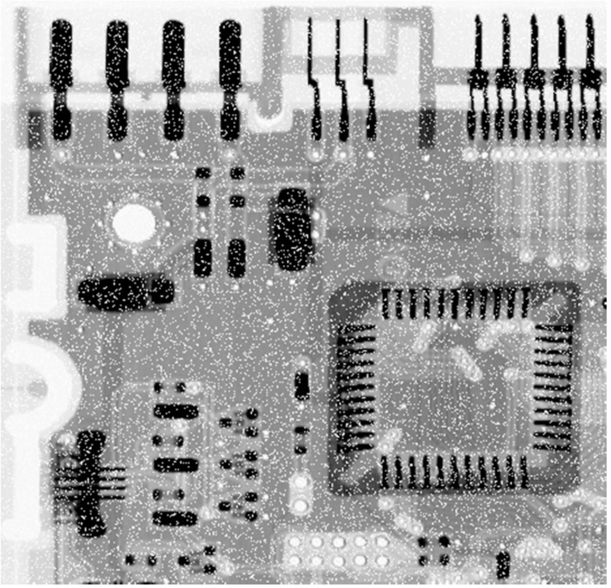


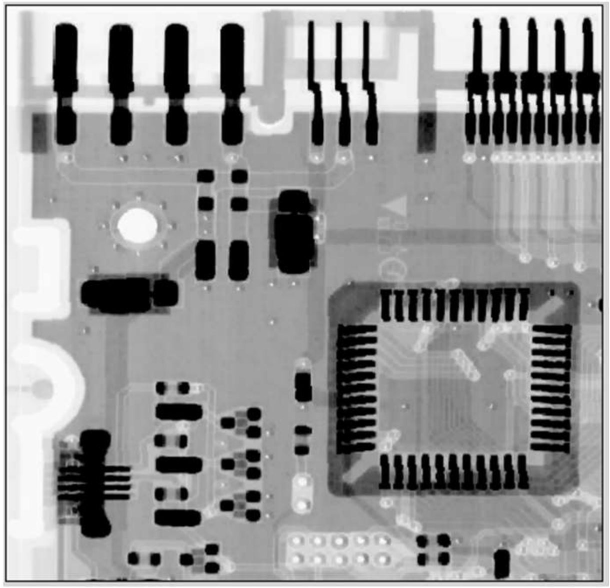
Image Courtesy: Gonzalez and Woods

What point operations can't do?

Image Sharpening

What point operations can't do?





Noise removal

Organization (today's lecture)

1. Intensity Transformation Functions

2. Histogram Processing

Spatial Filtering → Next class