07.08.2019

Digital Image Processing (CSE/ECE 478)

Lecture 3 : Intensity Transforms and Histogram Processing

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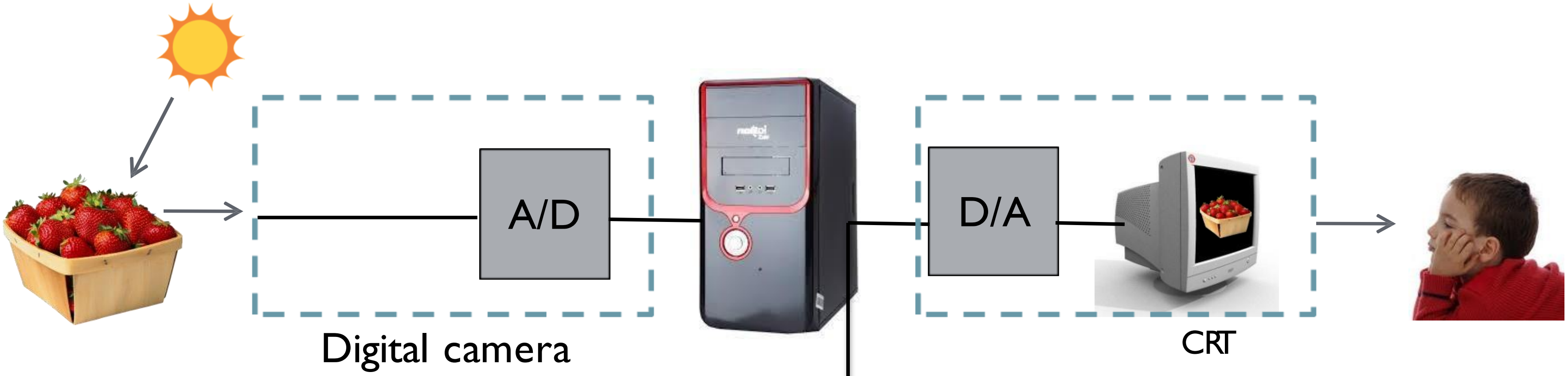
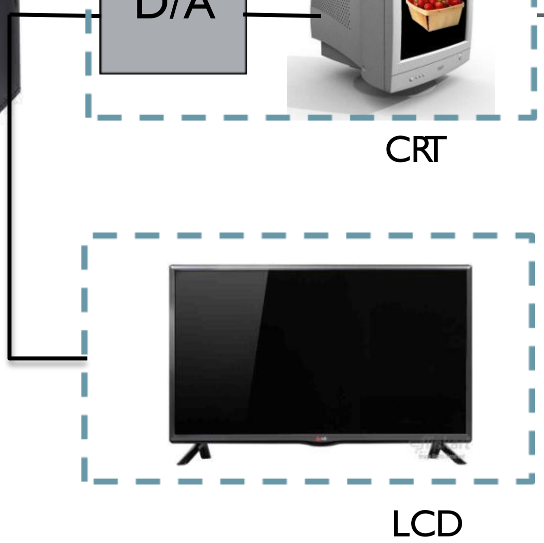
Announcements

- Assignment – I will be released today
- Tutorials will start from this Saturday
  - 3.30PM – 4.30PM
  - H-203
- Add/Drop is done

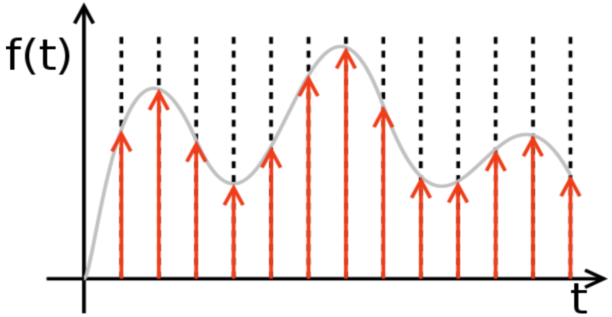
Previous Lecture





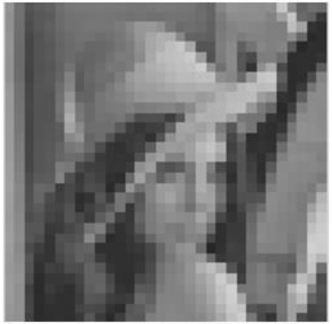
- Digital Image Acquisition
- Sampling & Quantization

Recap …

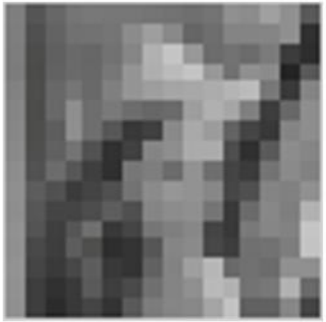


Sampling

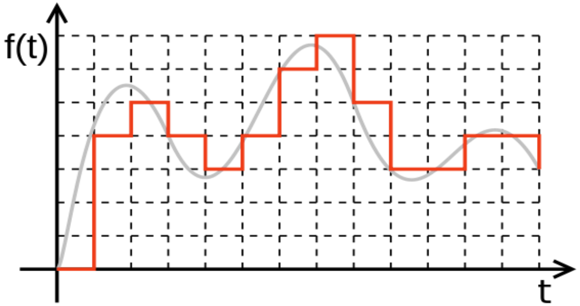
256 × 256



32 × 32



16 × 16



Quantization

8 bits per pixel

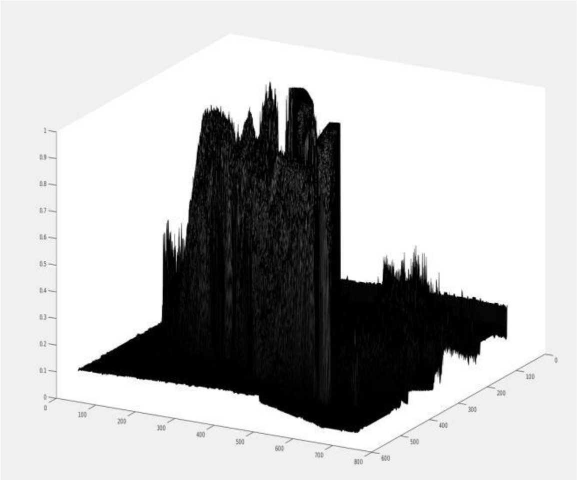
4 bits per pixel

2 bits per pixel

1 bit per pixel

Image as a function / 3D surface

- $f(x,y) = z$
- Domain : (x,y)
- Range = Intensity



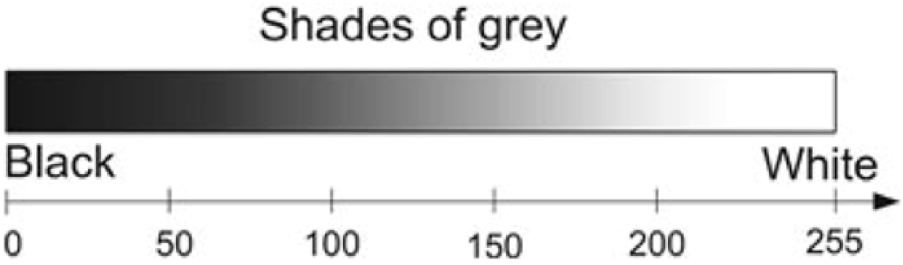
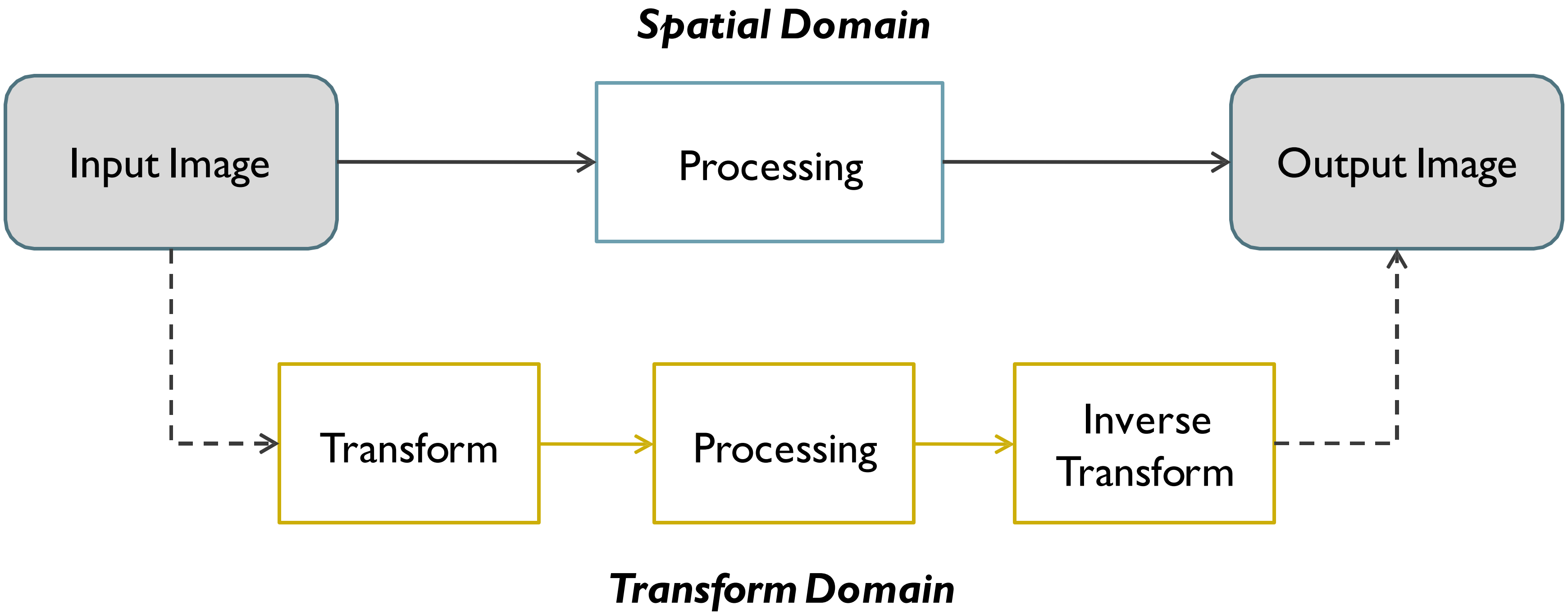


Image Processing – Two Paradigms

- Directly manipulating pixels in spatial domain
- Manipulating in transform domain

Spatial vs. Transform Domain Processing



Spatial vs. Transform Domain Processing

Bandhani / Bandhej

Tie Dye

Spatial vs. Transform Domain Processing

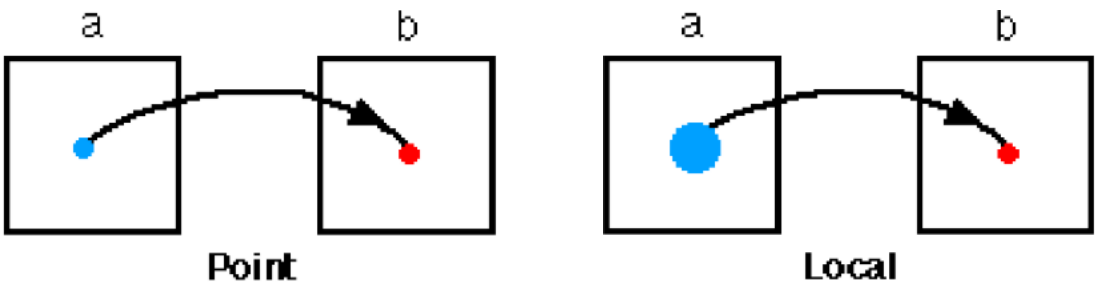
Transform (Tie)

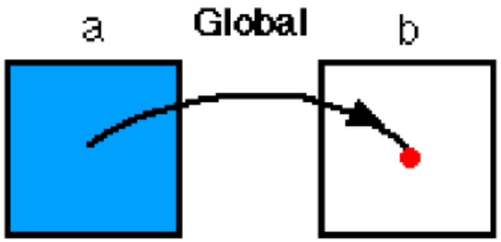
Process (Dye)

Inverse Transform (Untie)

Spatial Domain Processing

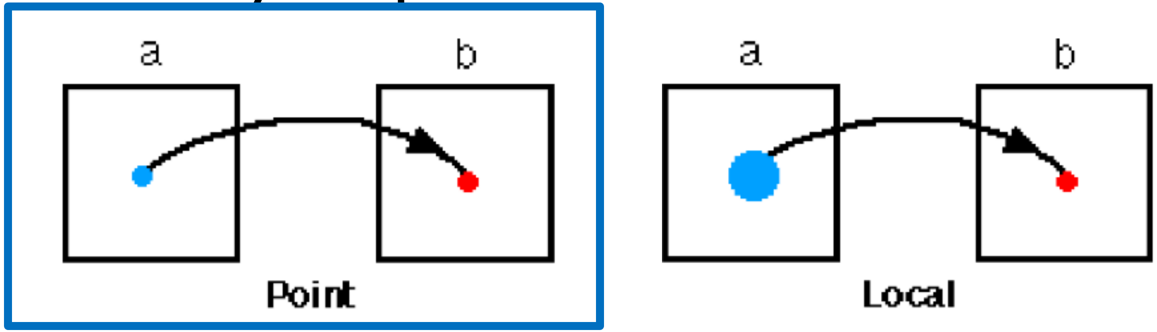
- Manipulating Pixels Directly in Spatial Domain
- Point to Point
- Neighborhood to Point
- Global Attribute to Point



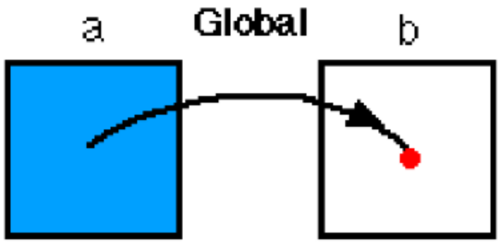


Spatial Domain Processing

- Manipulating Pixels Directly in Spatial Domain
- **Point to Point**



- Neighborhood to Point
- Global Attribute to Point



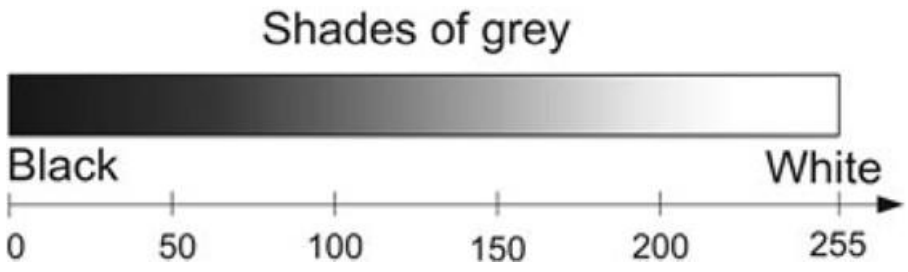
Intensity Transforms

- $f(x,y) = z$
- $z' = g(z) = g(\ f(x,y)\ )$
- Function g is a mapping between intensity value **z** at pixel (x,y) to a new value **z'**

Intensity Transforms

- $g = z + K$
- $g = z - K$
- $g = Kz$
- $g = K_1 z + K_2$

What is common?



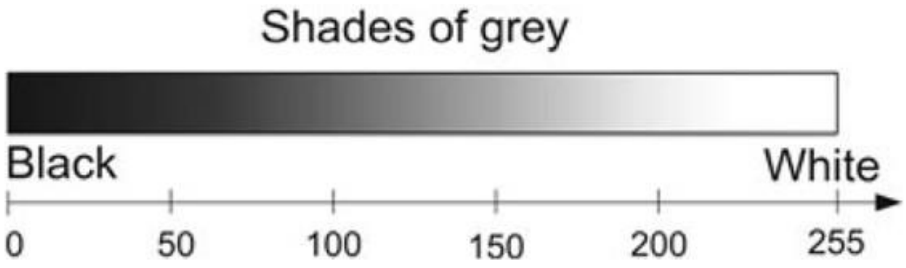
Intensity Transforms

- $g = z + K$
- $g = z - K$
- $g = Kz$
- $g = K_1 z + K_2$

Linear Transforms

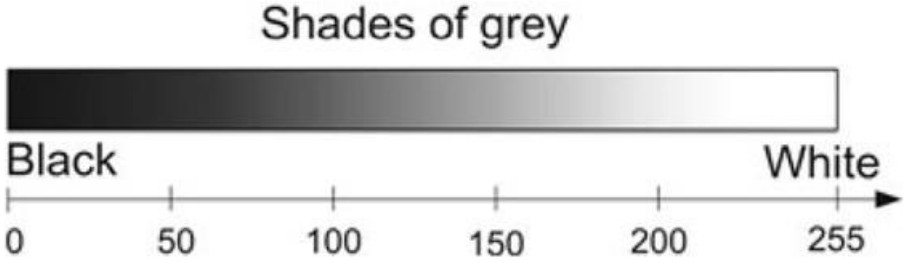
Intensity Transforms

- What form can function g take ?
- Are there any constraints ?



Intensity Transforms

- What form can function g take ?
- Are there any constraints ?
  - Clamp to [0,255]



Standard Intensity transformations

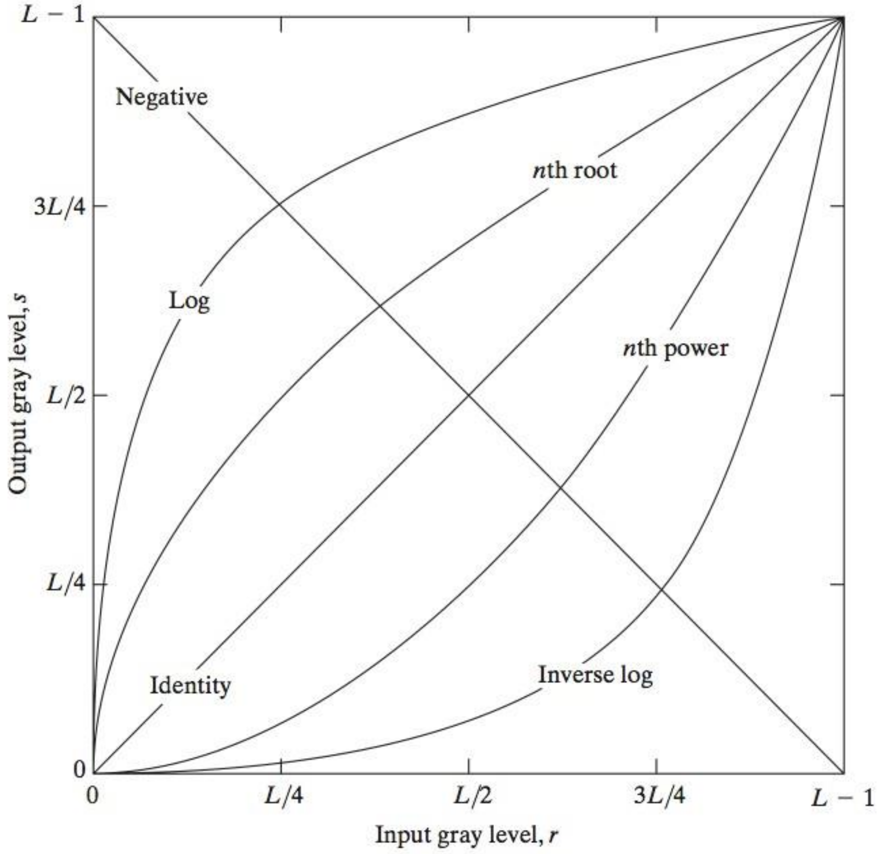
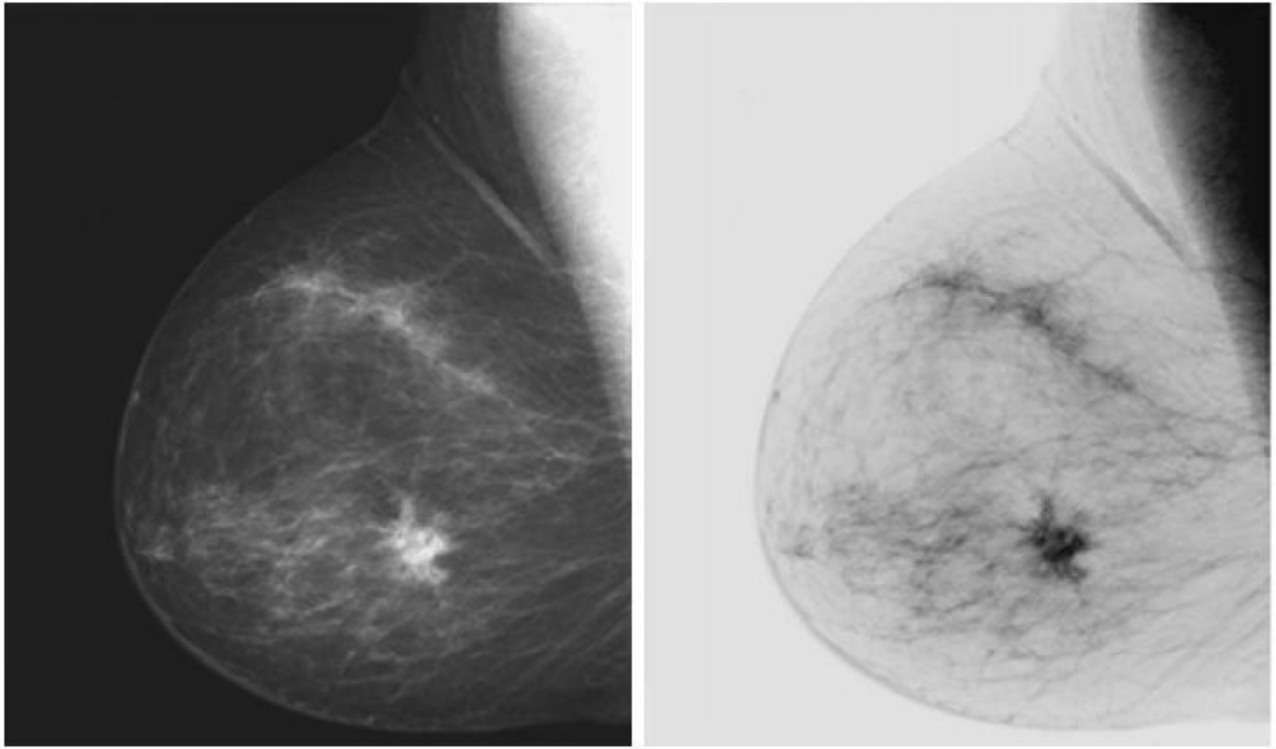


Image Negatives



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.)

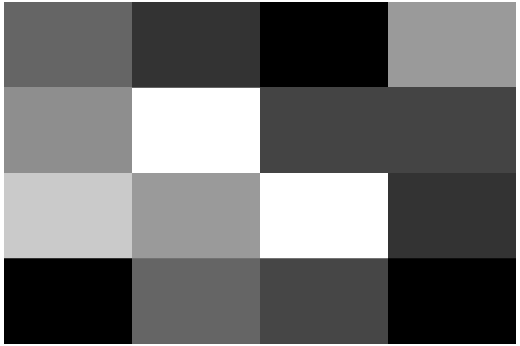
Intensity levels: $[0, L-1]$

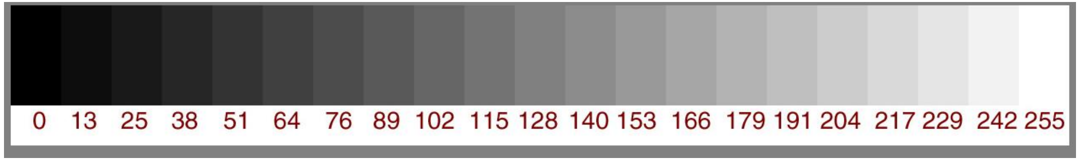
Transformation: $s = T(r) = L - 1 - r$

What is a digital image?

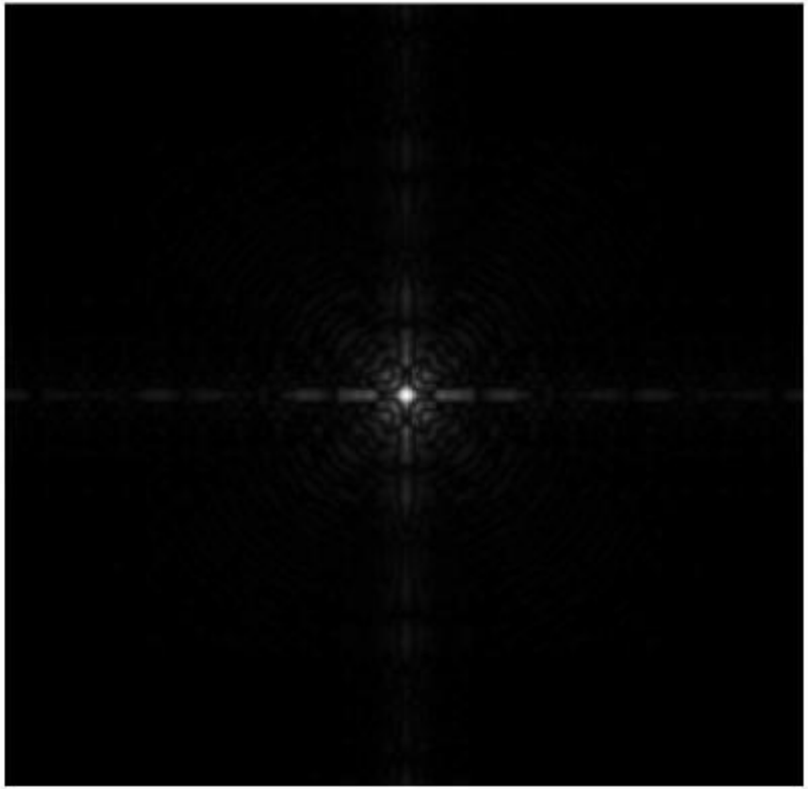
2D matrix of intensities (gray or color values) or numbers

100	50	0	150
90	255	70	70
200	150	255	50
0	100	80	0



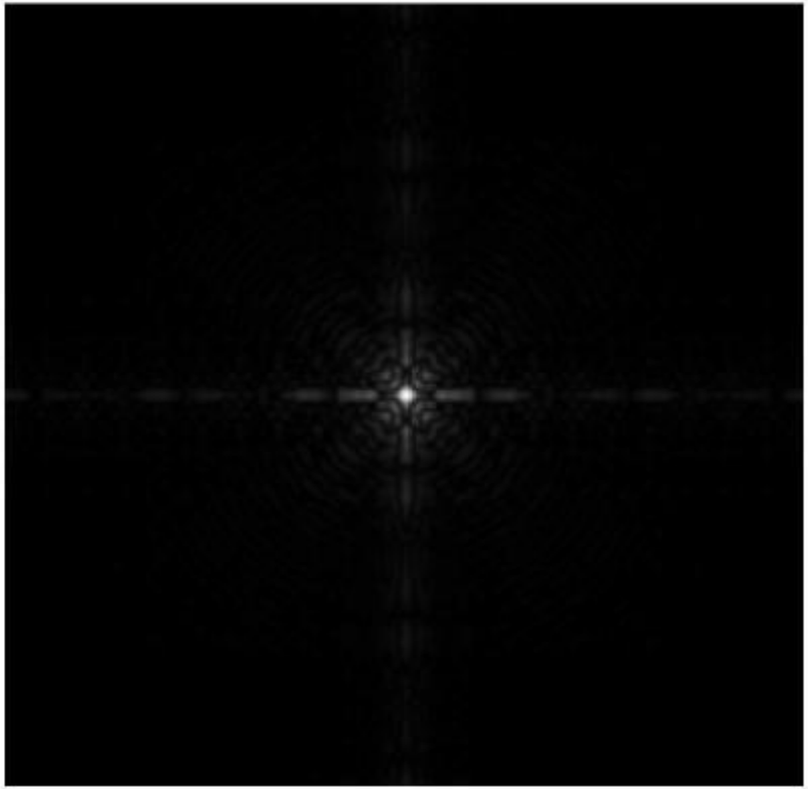


Fourier Magnitude Spectrum



Range : $[0, 10^6]$

Fourier Magnitude Spectrum



- Clamp to [0, 255]
- Normalize to min : $J = \dfrac{I}{min(I)}$
- Normalize to max : $J = \dfrac{I}{max(I)}$
- Normalize to range :

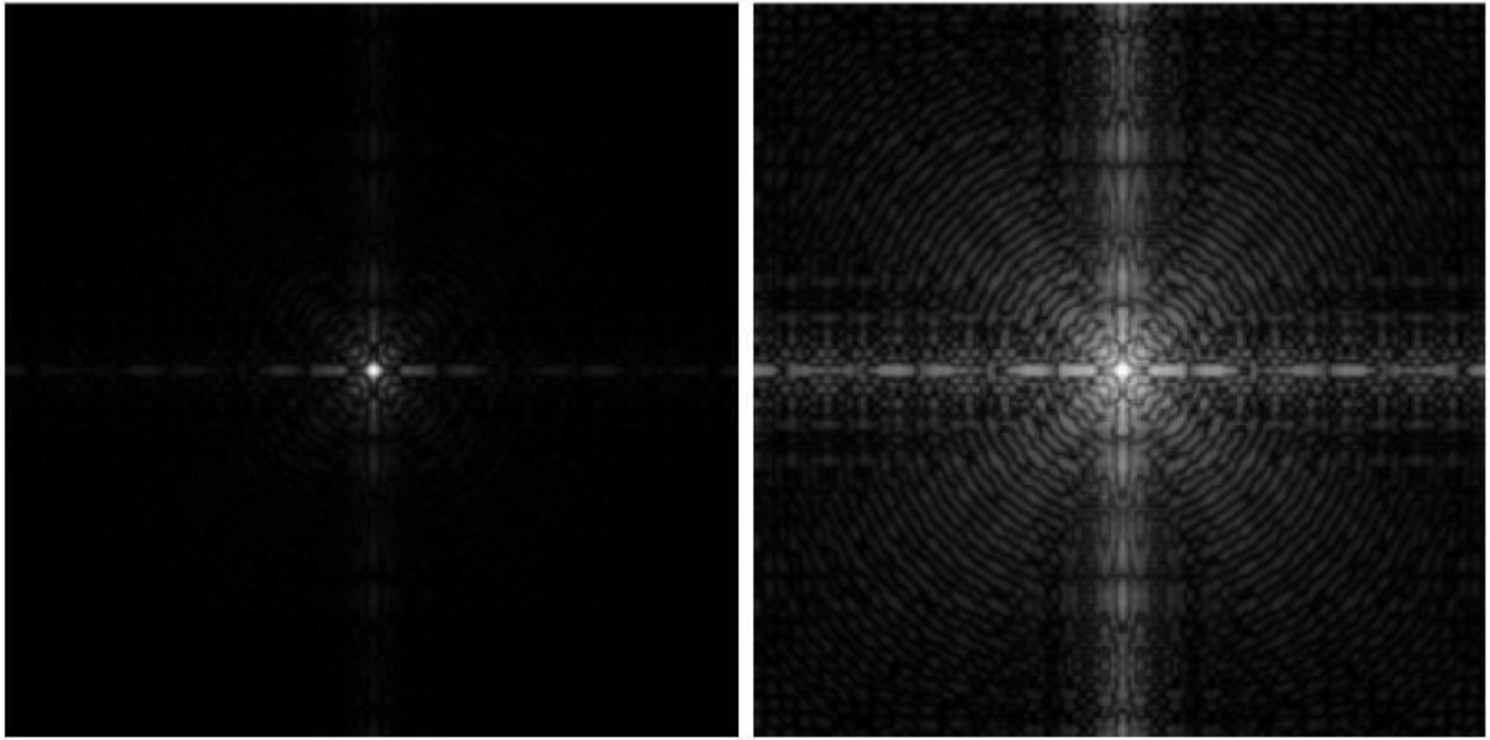
$$J = \mathtt{round}\left(255 * \frac{I - min(I)}{max(I) - min(I)}\right)$$

Range : $[0, 10^6]$

Log Transformations

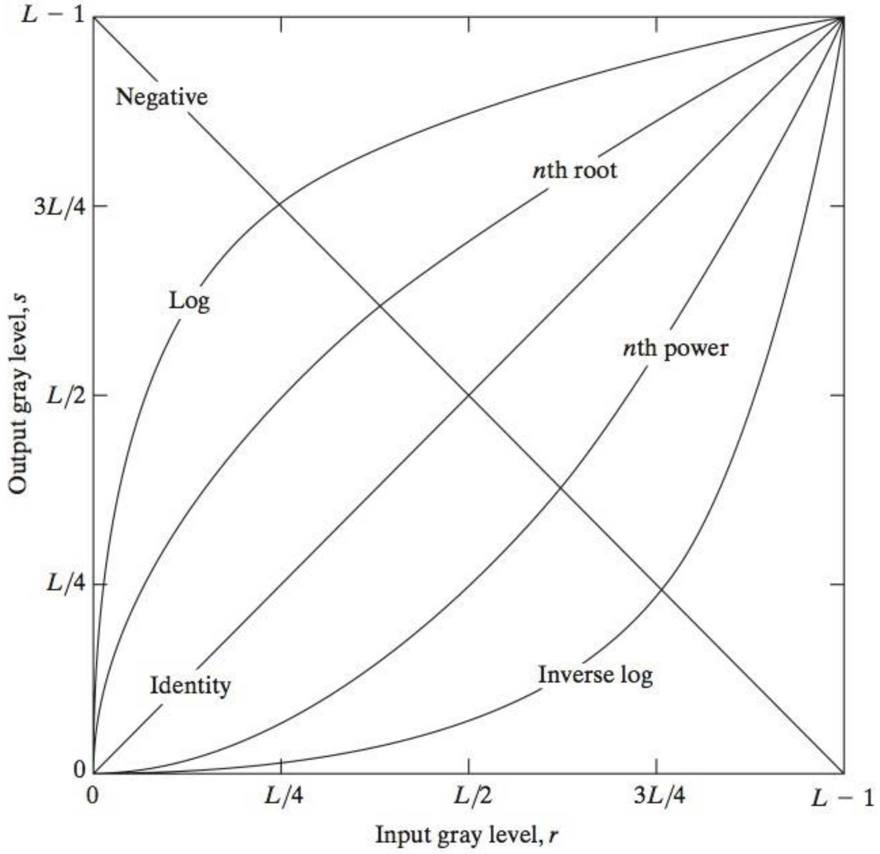
a b

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

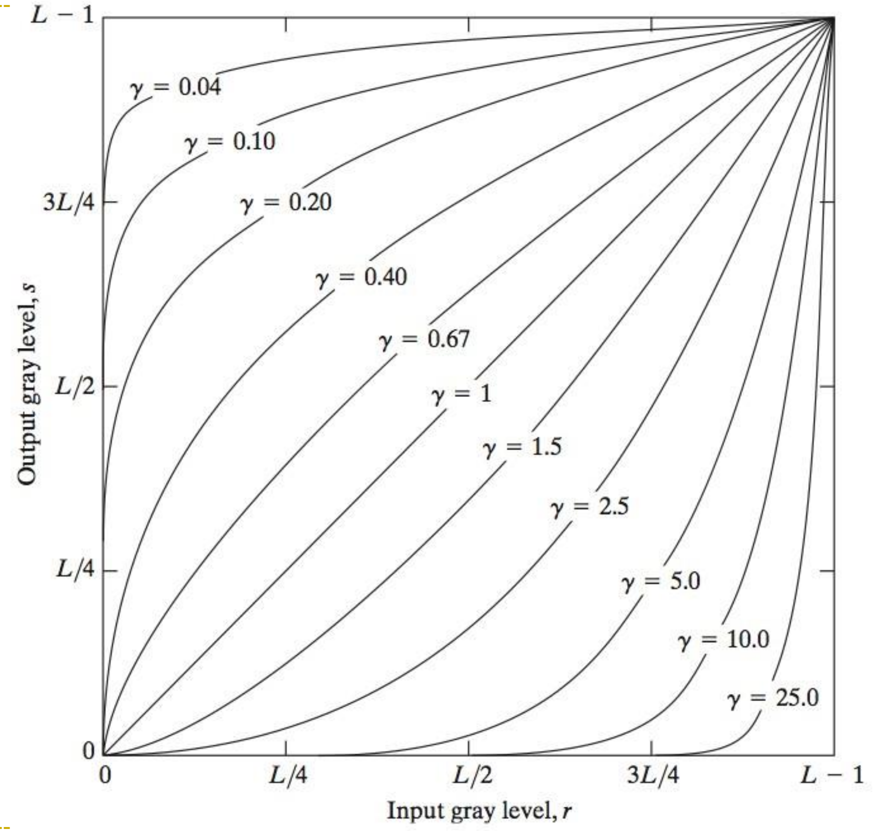


$$s = T(r) = c\ log(1 + r)$$

Standard Intensity transformations



Power-Law (Gamma) Transformations



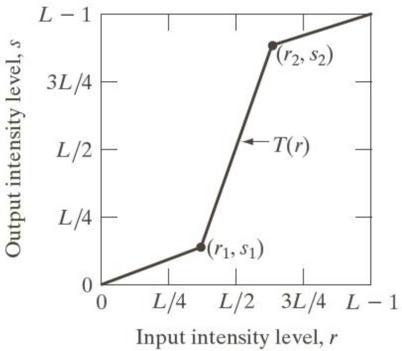
$$s = c\, r^{\gamma}$$

Power-Law Transformations

a b
c d

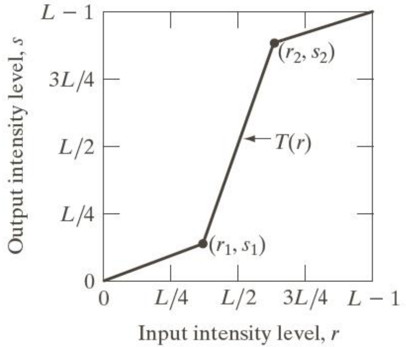
FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively. (Original image for this example courtesy of NASA.)

Piecewise-Linear Transformations



- Can be arbitrarily complex
- Finer control over transformation

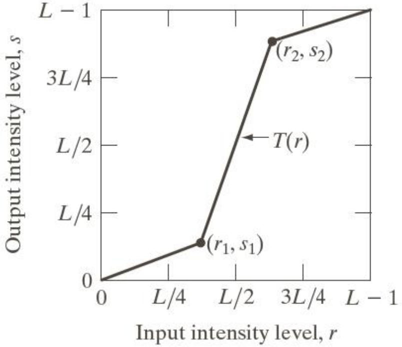
Piecewise-Linear Transformations - Contrast stretching

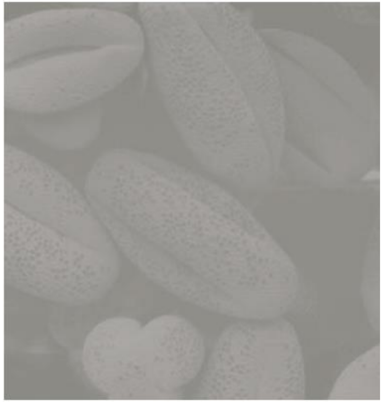


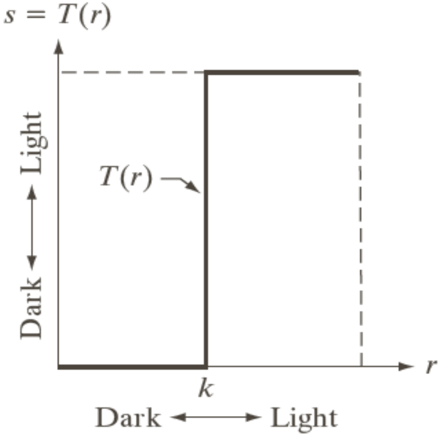
- Expand intensity range to full intensity range

What are the constraints on (r1,s1) and (r2,s2) ?

Piecewise-Linear Transformations





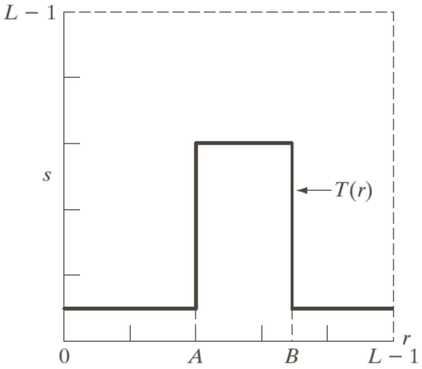


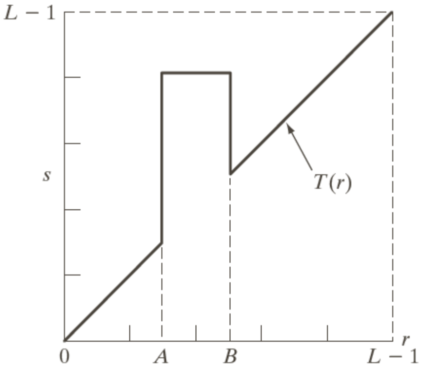
(r1,s1) = ?
(r2,s2) = ?

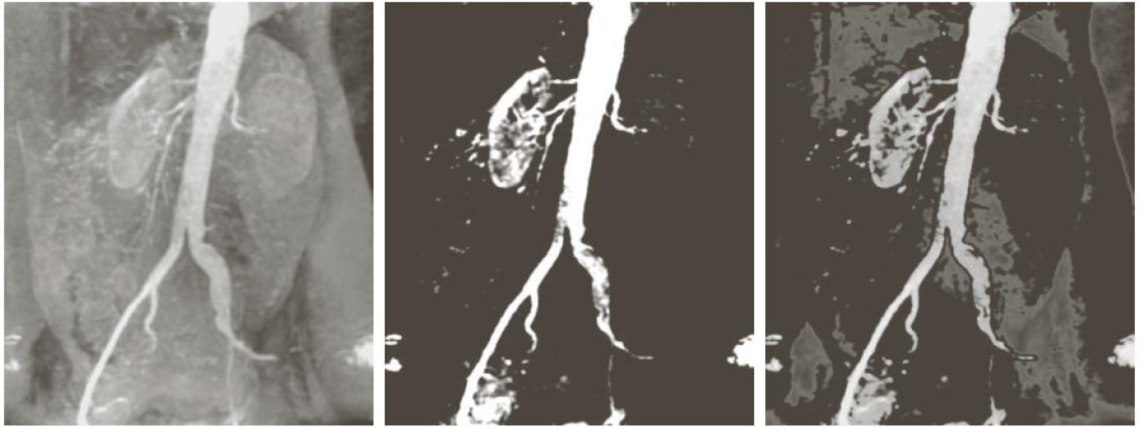
Intensity Slicing

a b

FIGURE 3.11 (a) This transformation highlights intensity range [A, B] and reduces all other intensities to a lower level. (b) This transformation highlights range [A, B] and preserves all other intensity levels.

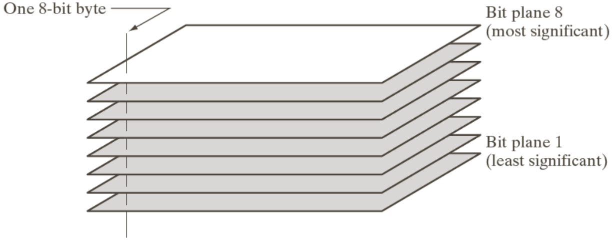






a b c

Bit plane slicing



a	b	c
d	e	f
g	h	i

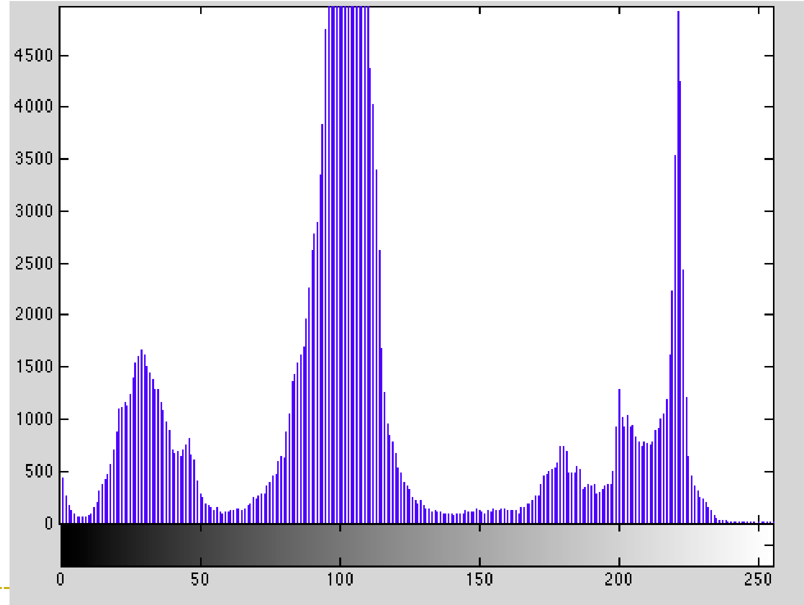
FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

Histogram

$$h_r(i) = n_i$$

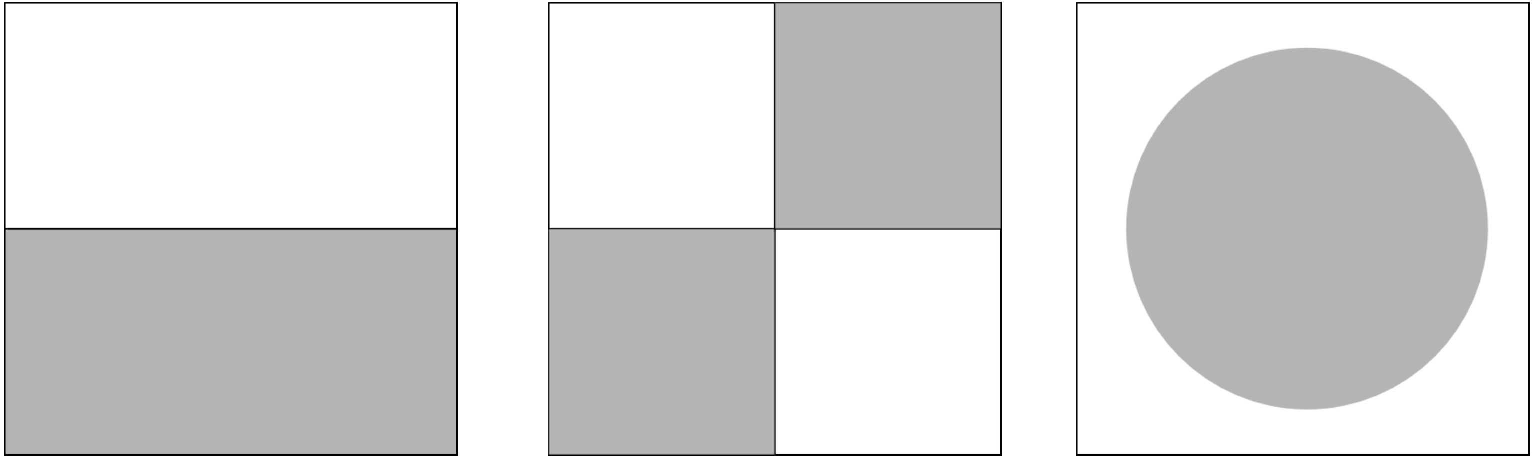
i → intensity value, range [0, L-1]

n_i → number of pixels with intensity i



Histograms

- Different images can have same histogram



- No information about spatial distribution of intensity values

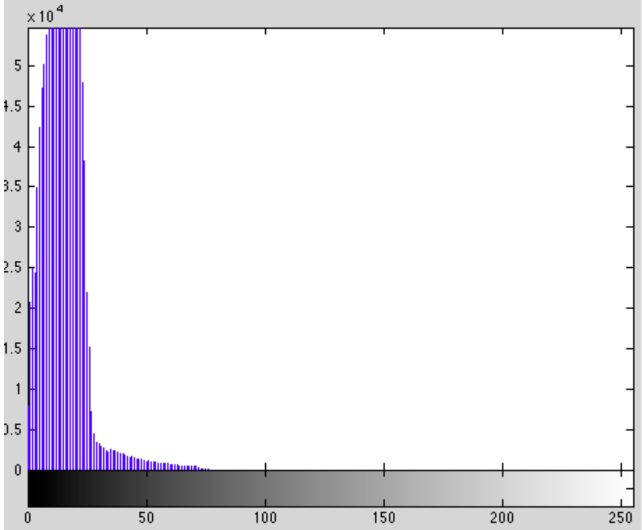
Histograms

- What can we infer from histograms?

Histogram viewing standard in most DSLR cameras

Histograms

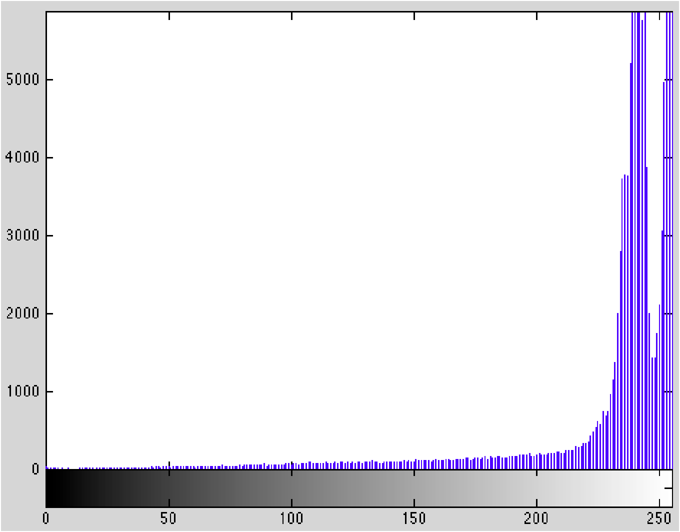
- Histograms and brightness



Under exposure

Histograms

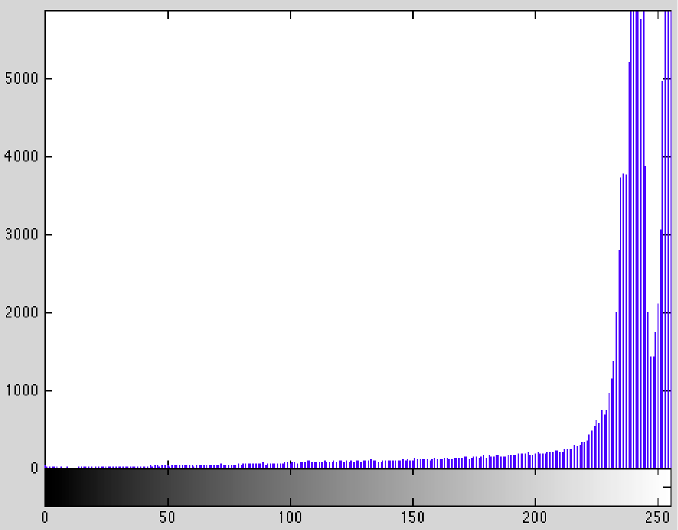
- Histograms and brightness



Over exposure

Histograms

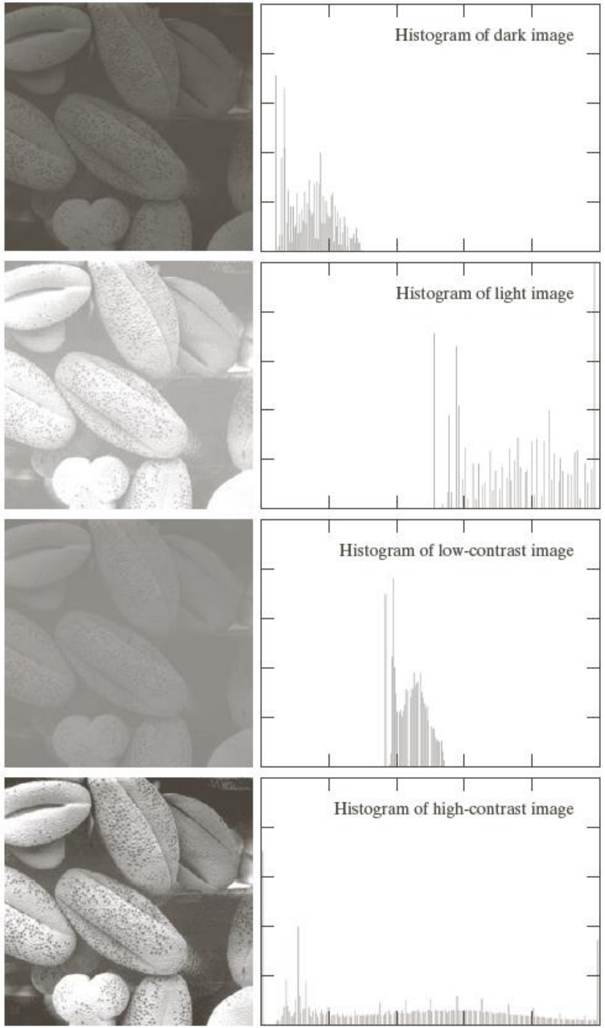
- Histograms and brightness



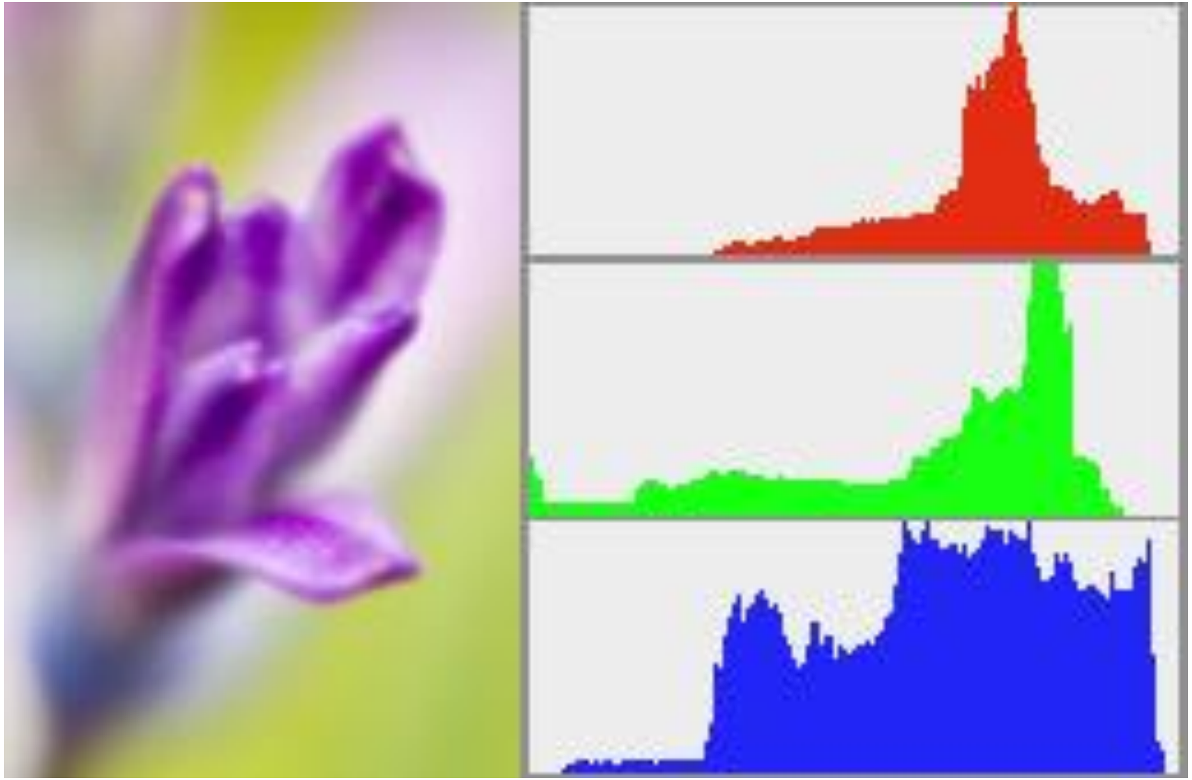
Over exposure

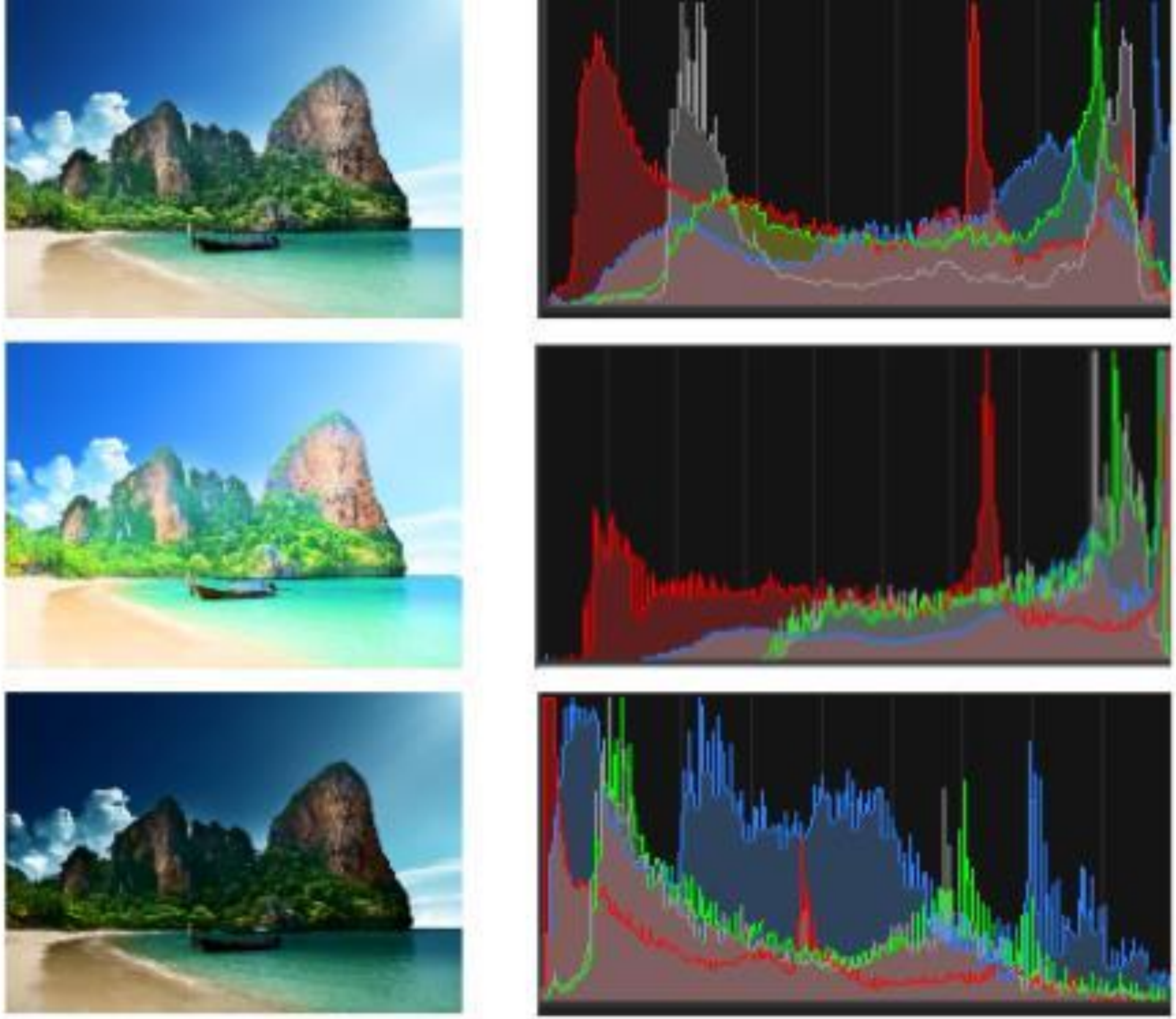
Histograms

- Histogram and contrast



Histograms for RGB images





Time for Show & Tell!

Time for Show & Tell!

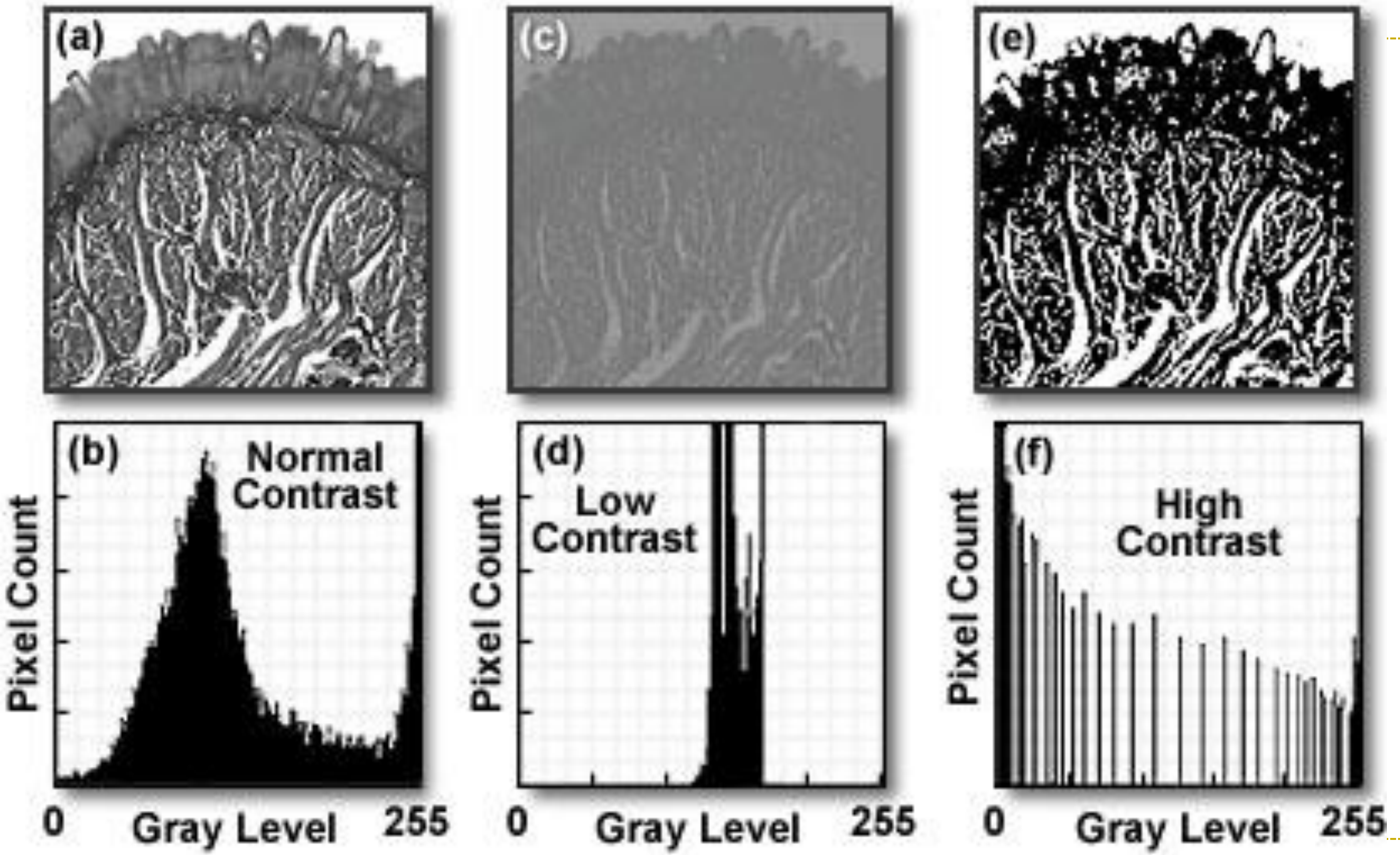
Brightness & Contrast

Subjective

- Brightness vs. Luminance vs. Contrast

Objective

Grayscale Histograms and Contrast Levels in Digital Images



Simultaneous Contrast & Perceived Brightness