Digital Image Processing (CSE/ECE 478)

Lecture-4: Recap/Discussion

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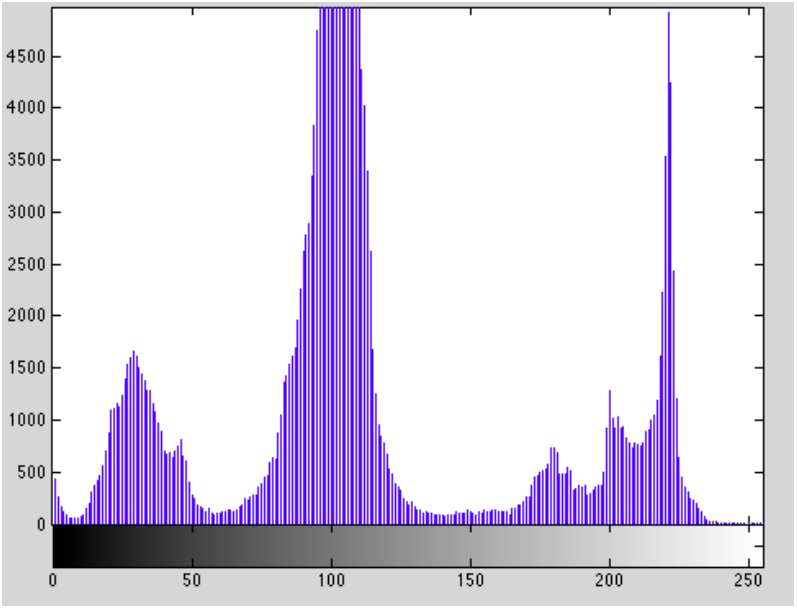
Histogram: An image representation + visualization

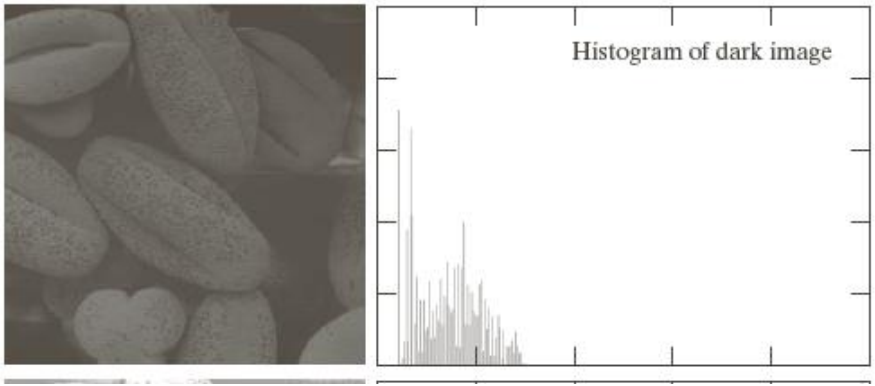
$$h_r(i) = n_i$$

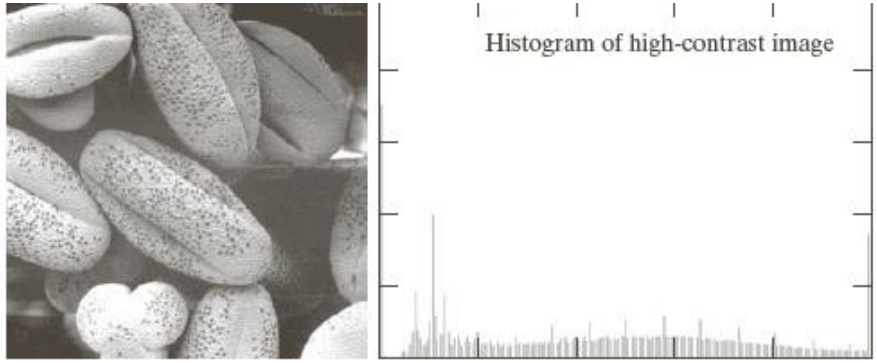
i → intensity value, range [0, L-1]

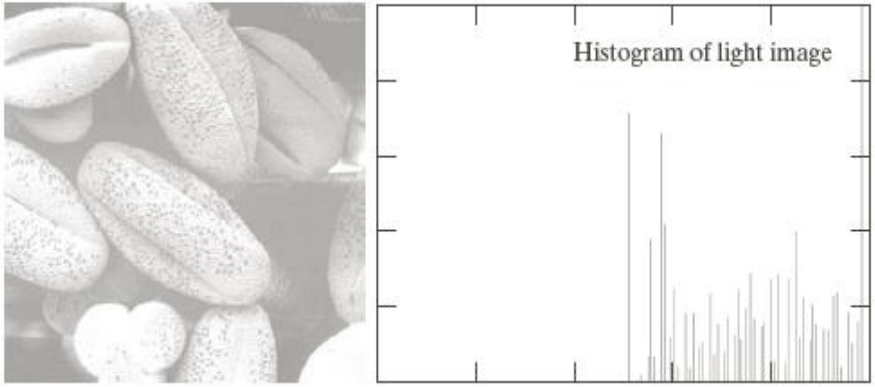
n_i → number of pixels with intensity i

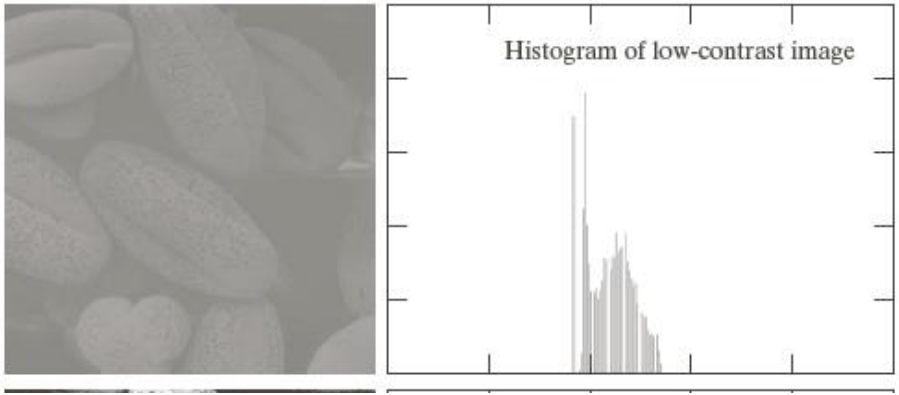


Histograms and Contrast

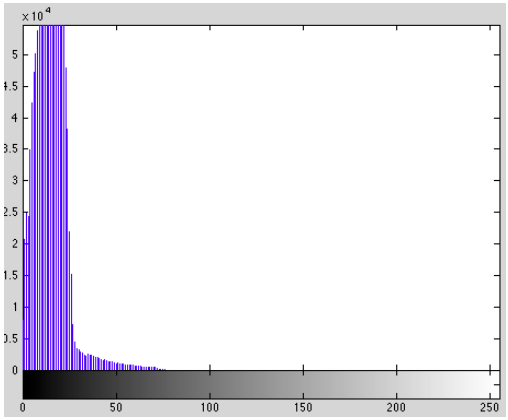


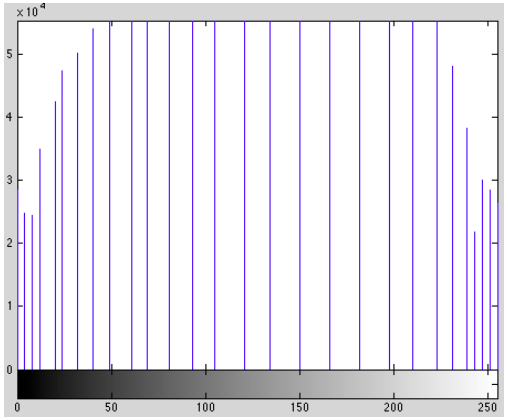






Histogram Equalization



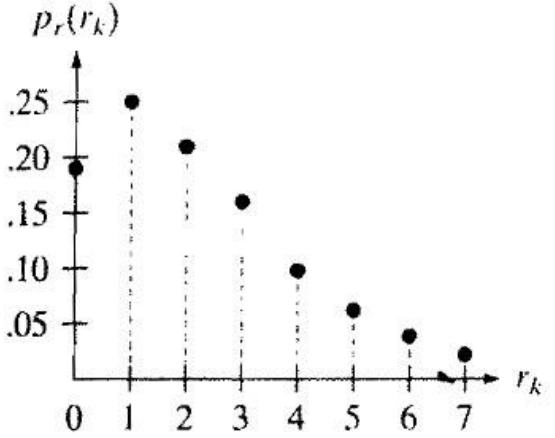


Histogram Equalization - Example

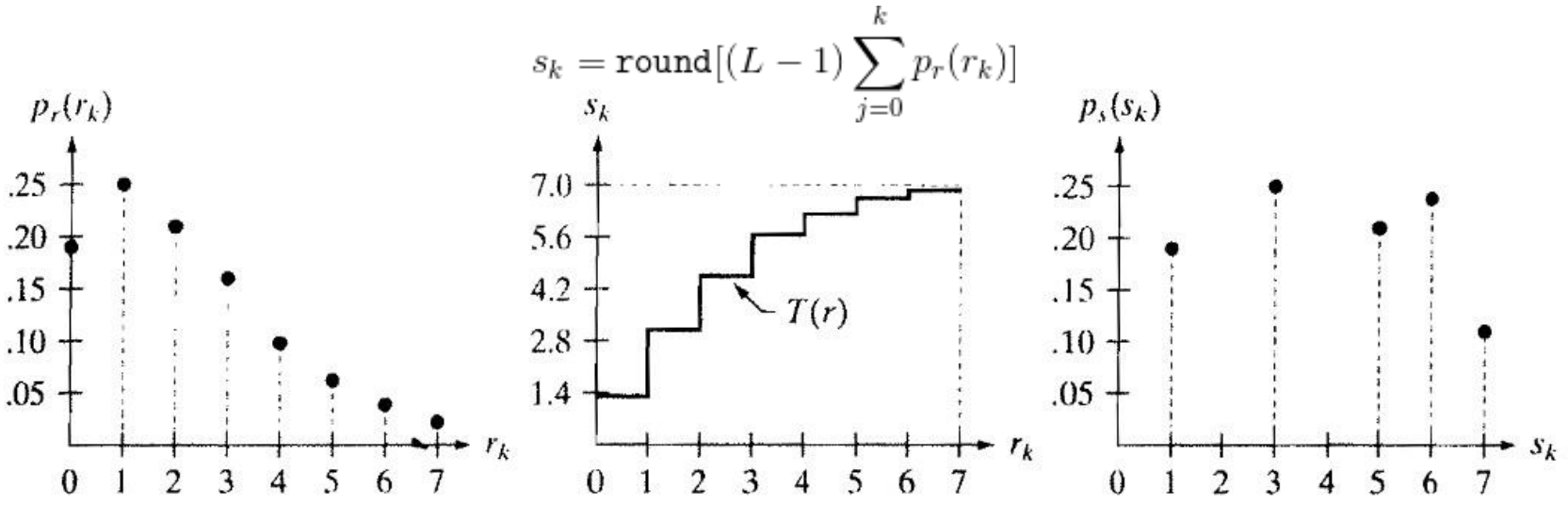
64 x 64 image

3-bits / pixel

r_k	n_k	$p_r(r_k) = n_k/MN$
$r_0 = 0$	790	0.19
$r_1 = 1$	1023	0.25
$r_2 = 2$	850	0.21
$r_3 = 3$	656	0.16
$r_4 = 4$	329	0.08
$r_5 = 5$	245	0.06
$r_6 = 6$	122	0.03
$r_7 = 7$	81	0.02



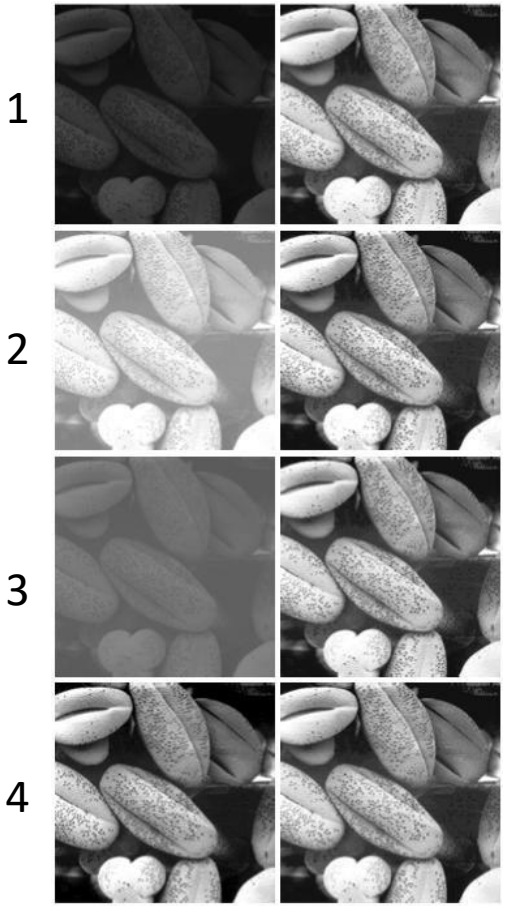
Histogram Equalization - Example



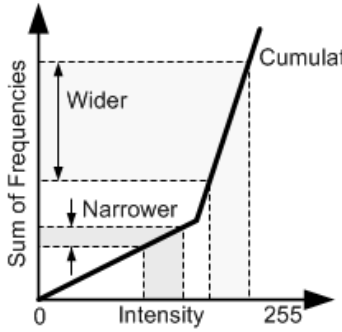
a b c

FIGURE 3.19 Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.

Histogram Equalization



$$s_k = T(r_k) = \texttt{round}\left((L-1)\sum_{j=0}^{j=k} p_r(r_j)\right)$$



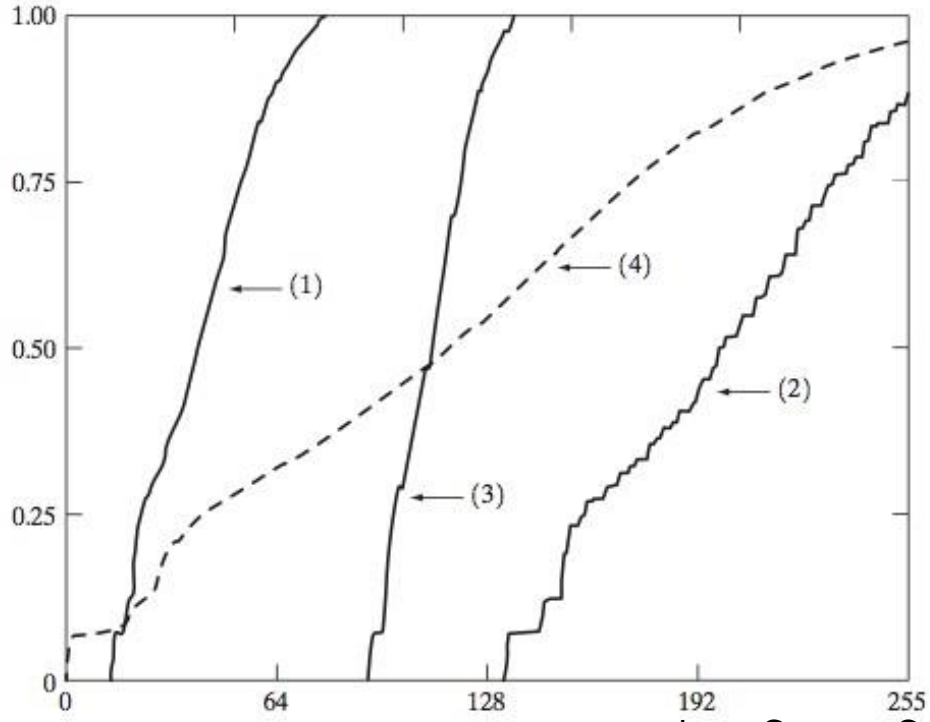


Image Courtesy: Gonzalez and Woods

Histogram Equalization v/s Contrast Enhancement

Contrast Enhancement

Histogram equalization

Histogram Equalization

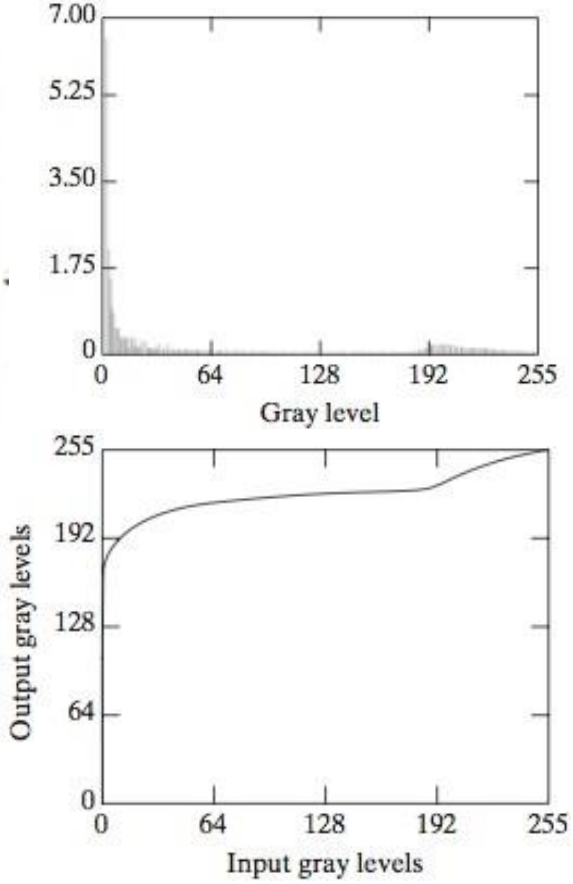
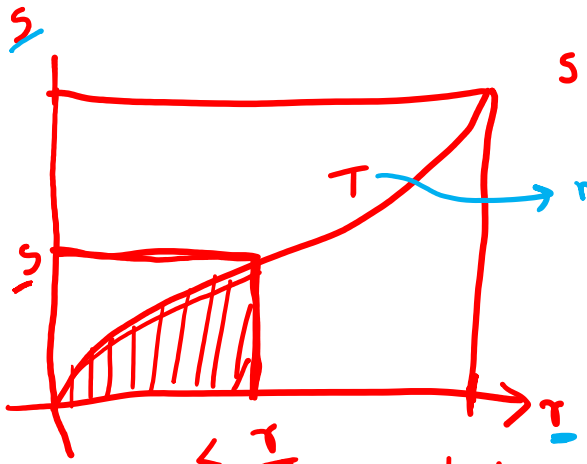


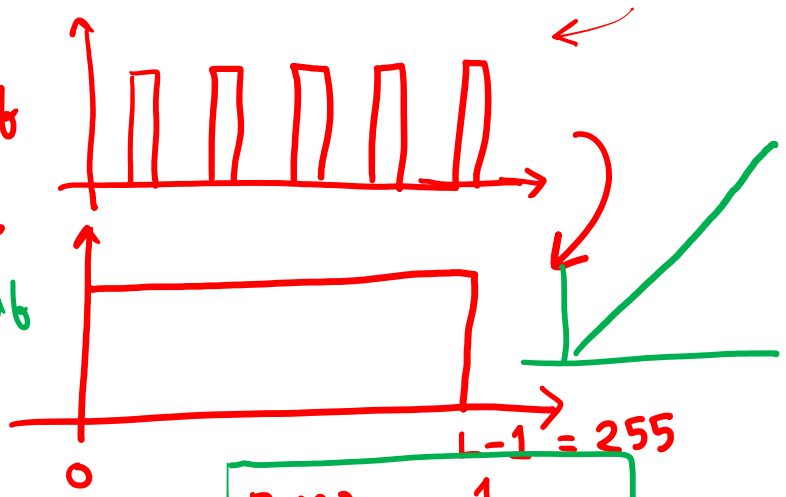
Image Courtesy: Gonzalez and Woods

Histogram Equalization



$s = T(r)$

L = # of bits / word



$$p_s(s) = \frac{1}{(L-1)}$$

$$\int_0^{L-1} p_s(s) = 1$$

$$p_s(s)\,ds = p_R(r)\,dr$$

$$\frac{1}{L-1}\,ds = p_R(r)\,dr$$

$$\Rightarrow ds = (L-1)\,p_R(r)\,dr$$

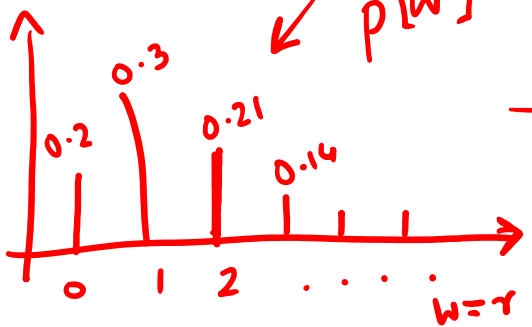
$$p_s(s) = p_R(r)\frac{dr}{ds}$$

$$s = T(r) = (L-1)\int_0^r p_R(w)\,dw \quad \Rightarrow \quad s = (L-1)\int_0^r p_R(w)\,dw$$

Leibniz formula

Histogram Equalization

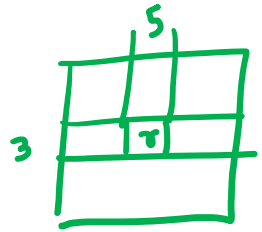
$p(s) = \frac{1}{L-1}$

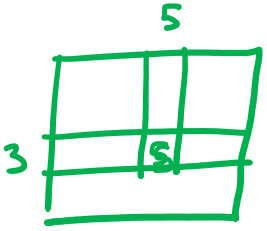


$$s = T(r) = (L-1)\int_{w=0}^{r} P_s(w)\,dw$$

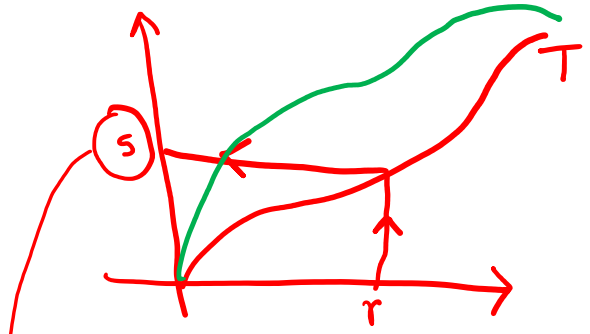
digital equivalent

$$s = \text{round}\left((L-1)\sum_{w=0}^{r} p[w]\right)$$



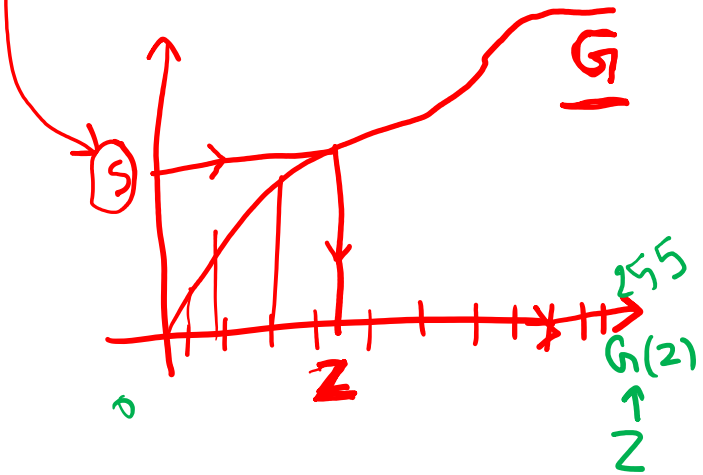


Histogram specification



$s = T(r)$ $P_s(s)$

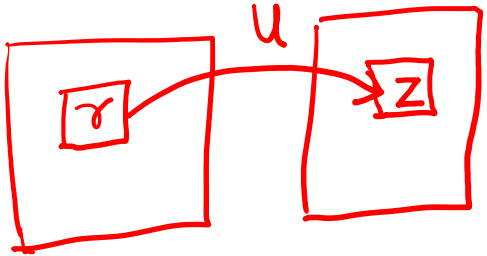
$$s_k = T(r_k) = \texttt{round}\left((L-1)\sum_{j=0}^{j=k} p_r(r_j)\right)$$



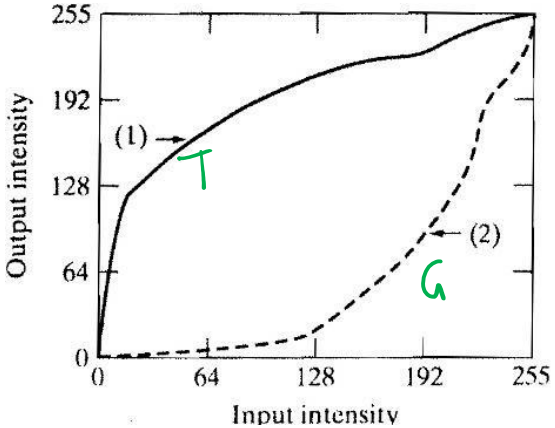
$s = G(z)$

$\Rightarrow z = G^{-1}(s) = G^{-1}(T(r))$

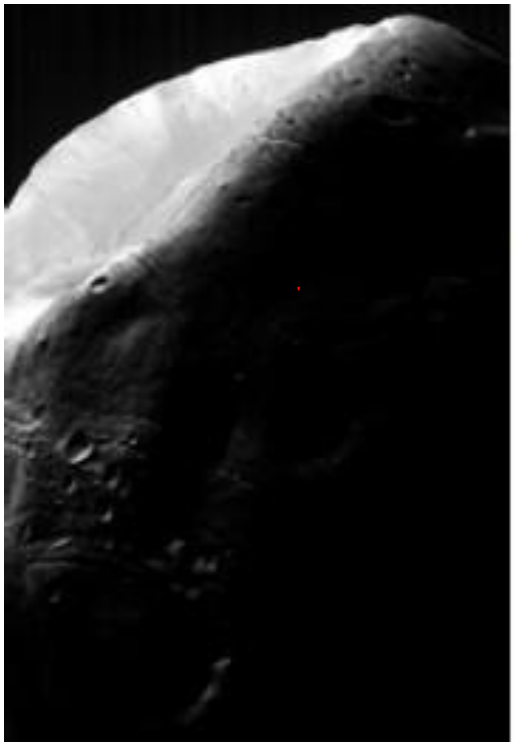
$z = U(r)$



Histogram Specification / Matching [GW Section 3.3.2]



(1)



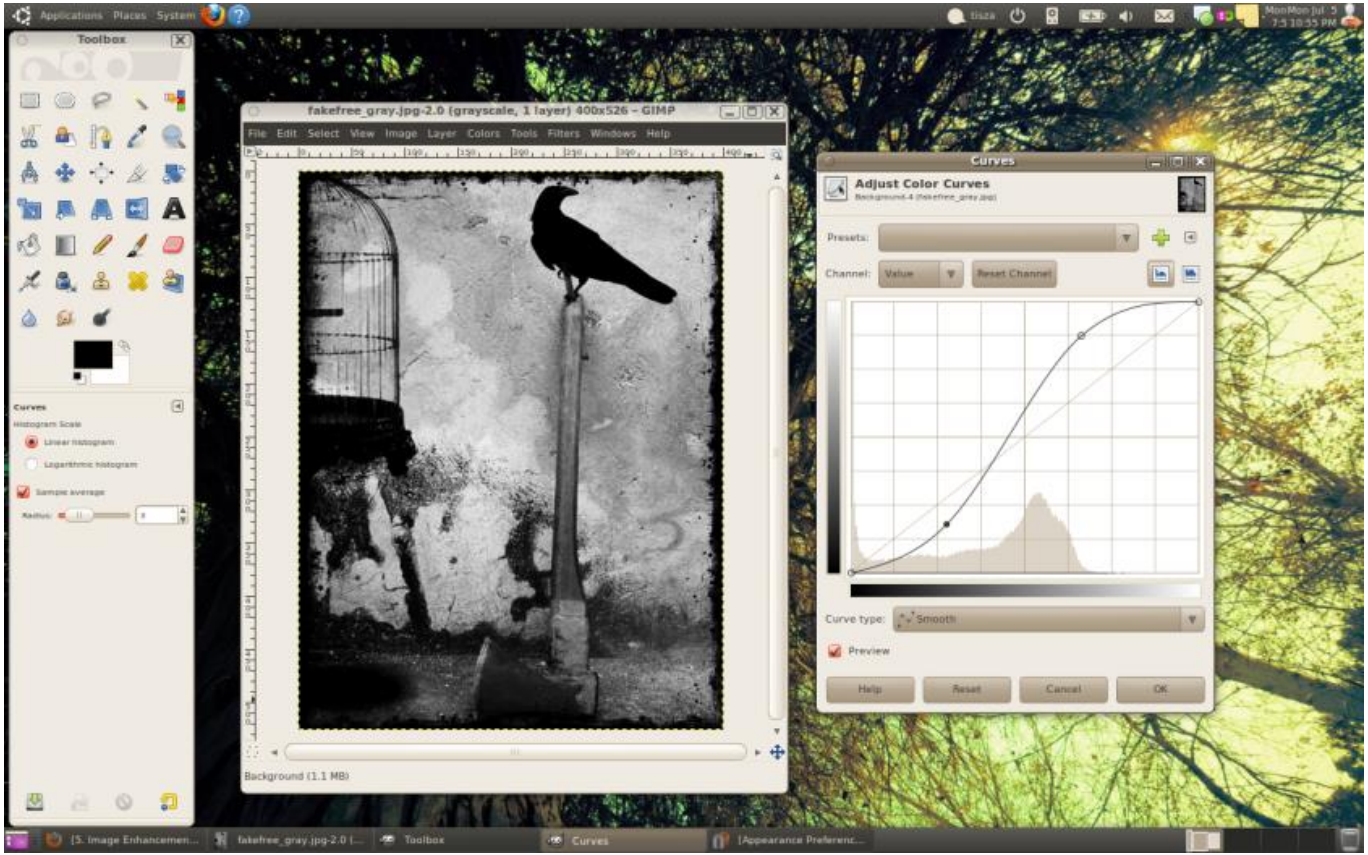
↖ cumulative

(2)

Image Courtesy: Gonzalez and Woods

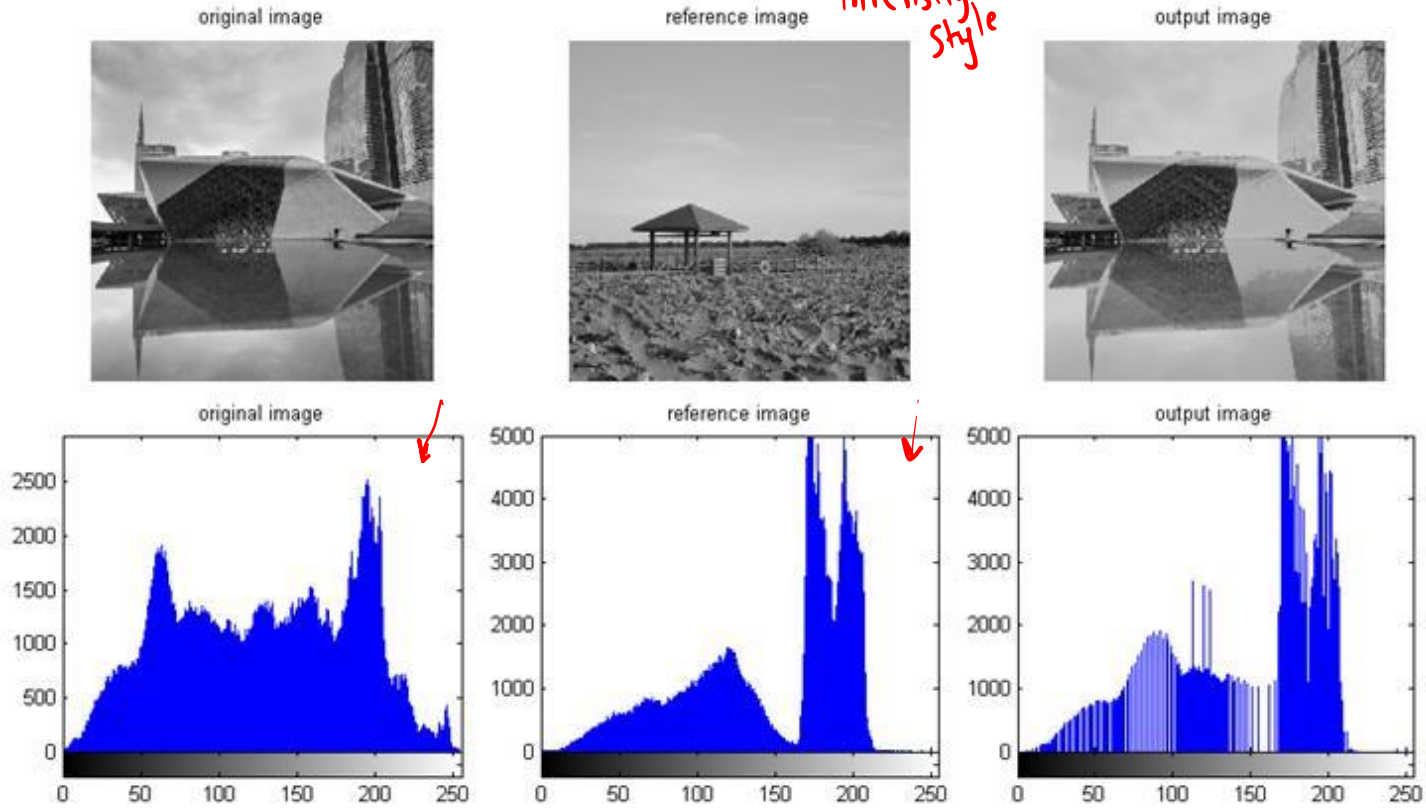
Histogram specification (custom curve)

GIMP



https://theiszm.wordpress.com/2010/07/06/5-image-enhancement-by-histogram-manipulation/

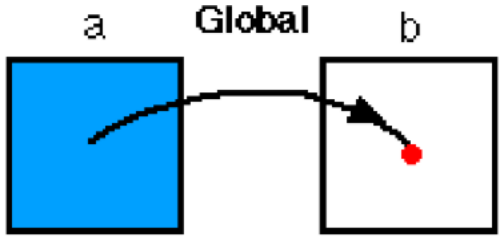
Histogram specification (curve from a reference image)



https://images1.programmersought.com/152/73/733d674297c6e27a58bdc3d852dca118.png

Histogram Processing

- Global to Point



Histogram : Discussion

- A visualization
- A useful statistical representation of image intensities
  - Not dependent on image size (after normalization)
- Drawbacks
  - No spatial information
  - Intensity-centric
  - Raw (unnormalized form): Image-size dependent
- Equalization:
  - An image ‘normalization’ approach
  - Improves global contrast, but can also boost noise

References

- Gonzalez, Woods textbook : Chapter – 3.3.1 to 3.3.3

31.08.2021

Digital Image Processing (CSE/ECE 478)

Lecture-5: Enhancement using Histogram Statistics

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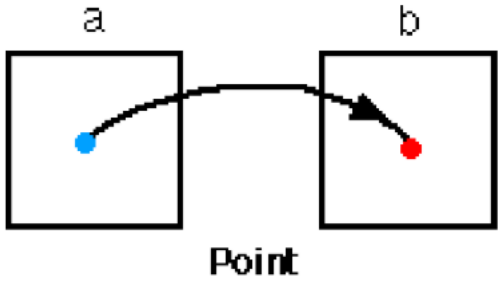
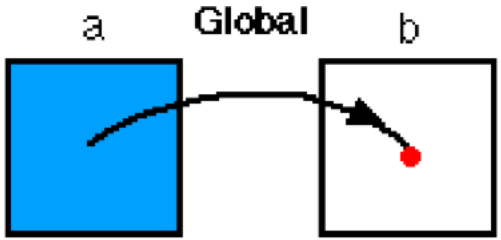
- Point to Point



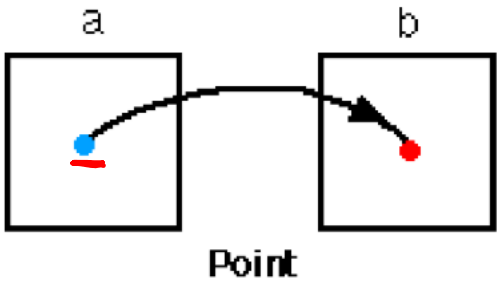
Intensity Transforms

- Global Attribute to Point



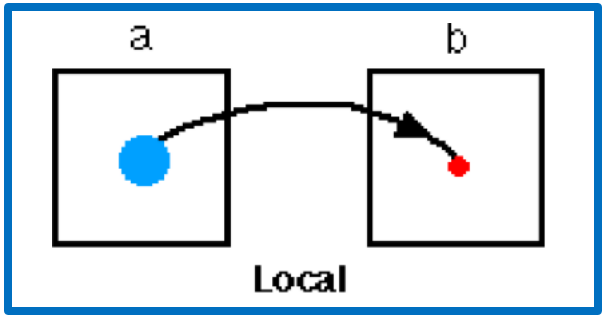
Histogram Equalization

- Point to Point

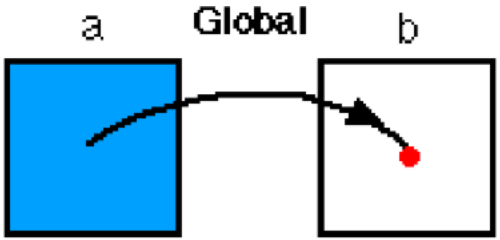


Intensity Transforms

- **Neighborhood to Point**

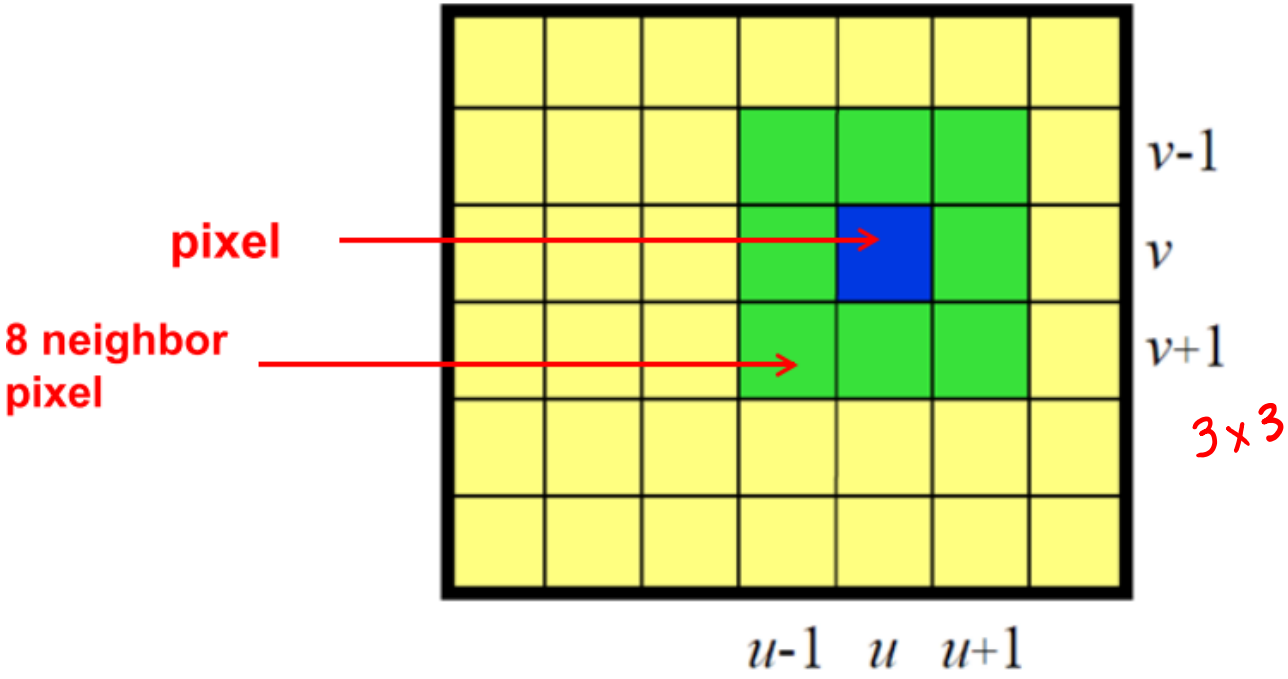


- Global Attribute to Point

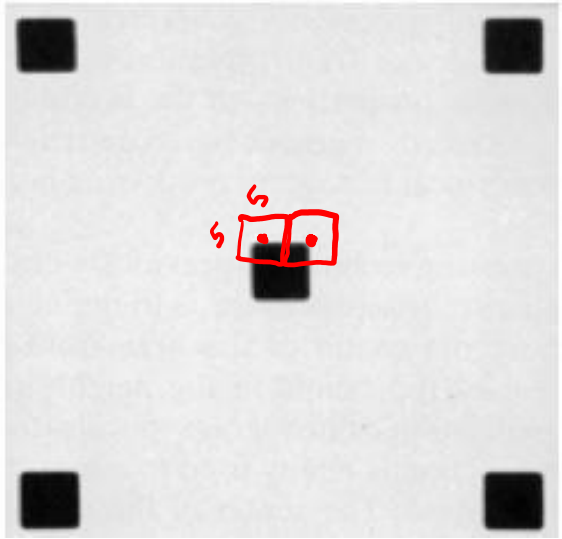


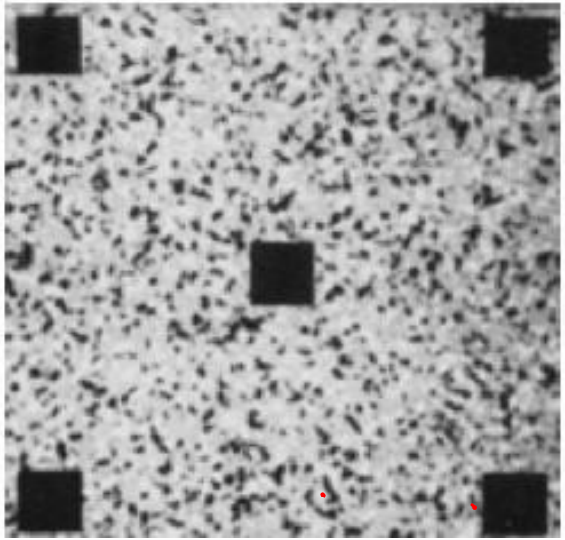
Histogram Equalization

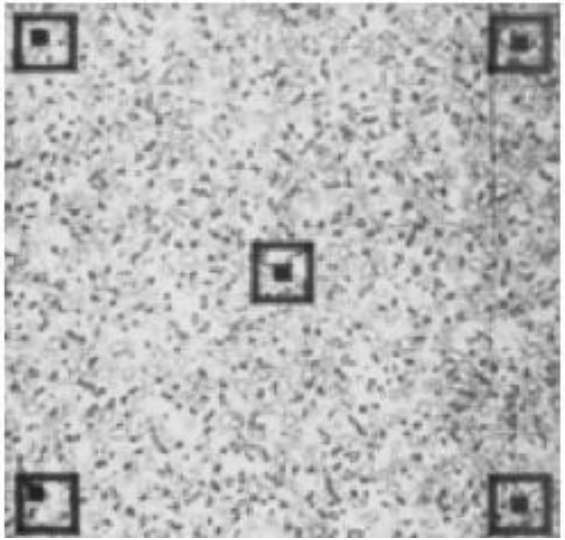
Neighborhood



Local Histogram Processing





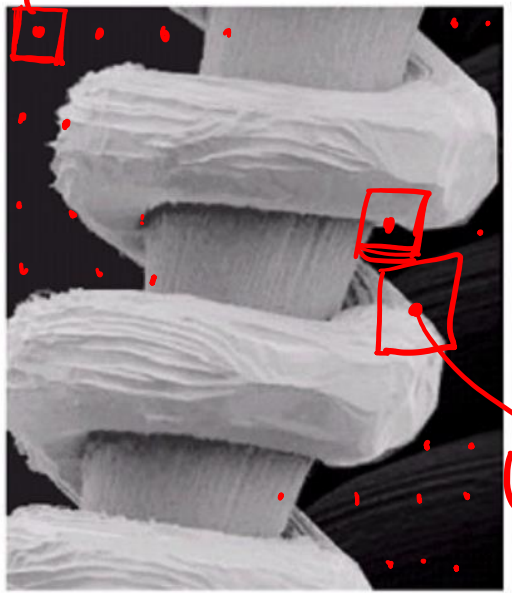


Global Hist Eq

Local Hist Eq

Image Courtesy: Gonzalez and Woods

Conditional Image Enhancement



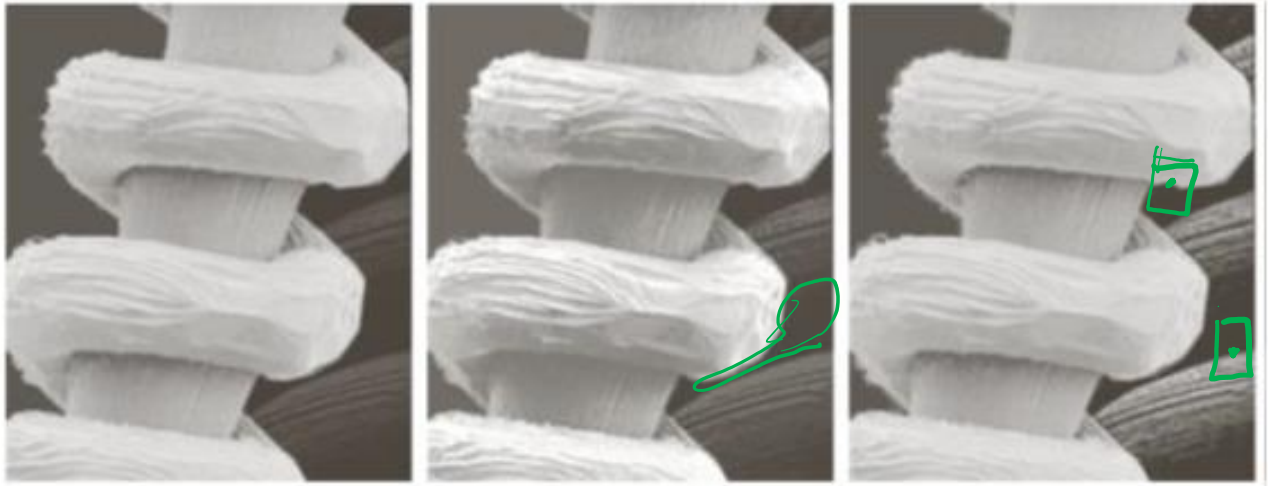
- Objective for given image: Enhance dark areas while leaving light areas unchanged
  - we use some statistical parameters
    - global:
      - $p(r_i) = \frac{n_i}{n}$
      - $m(r) = \sum_{i=0}^{L-1} p(r_i)\, r_i$
      - $\sigma^2(r) = \sum_{i=0}^{L-1} (r_i - m)^2\, p(r_i)$
    - local:
      - $p(r_{s,t})$: neighborhood normalized histogram at coordinates (s,t) using a mask centered at (x,y)
      - $m_{S_{xy}} = \sum_{(s,t)\in S_{xy}} p(r_{s,t})\, r_{s,t}$
      - $\sigma^2(S_{xy}) = \sum_{(s,t)\in S_{xy}} [r_{s,t} - m_{S_{xy}}]^2\, p(r_{s,t})$

$k_3\sigma(r) \leq \sigma_{S_{xy}} \leq k_2\sigma(r)$, $k_2 < 1$

1) Identify 'dark' area, & 'light' pixels → unchanged

2) Enhance dark area

Image Enhancement Using Histogram Statistics



a b c

FIGURE 3.27 (a) SEM image of a tungsten filament magnified approximately 130×. (b) Result of global histogram equalization. (c) Image enhanced using local histogram statistics. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)