21.08.2020

Digital Image Processing (CSE/ECE 478)

Lecture-3: Recap/Discussion

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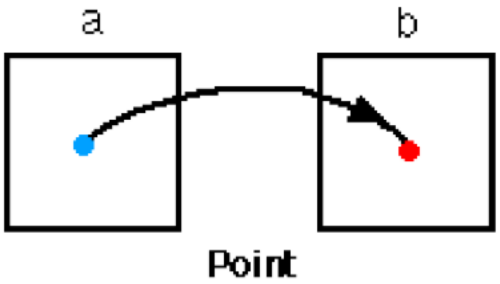
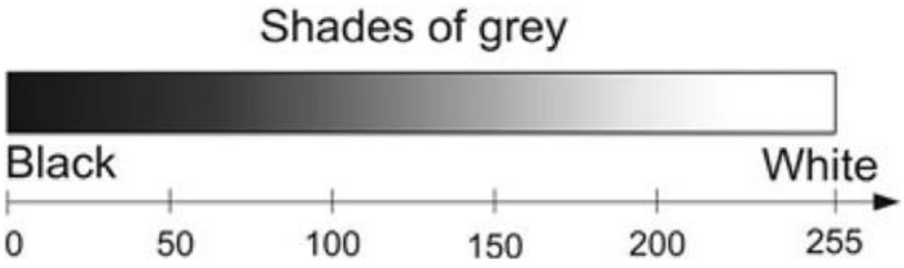
Spatial Domain Processing

- Manipulating Pixels Directly in Spatial Domain
- 3 approaches
- 1. Point to Point

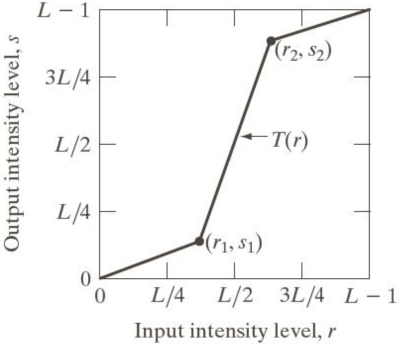


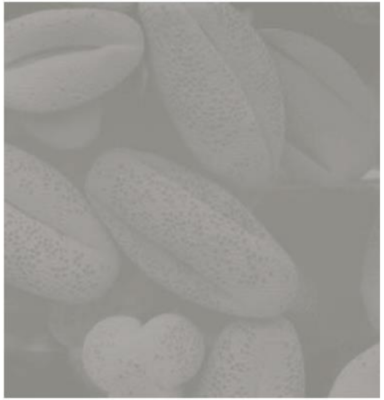
Linear Intensity Transforms

- $T(z) = z + K$
- $T(z) = z - K$
- $T(z) = Kz$
- $T(z) = K_1 z + K_2$

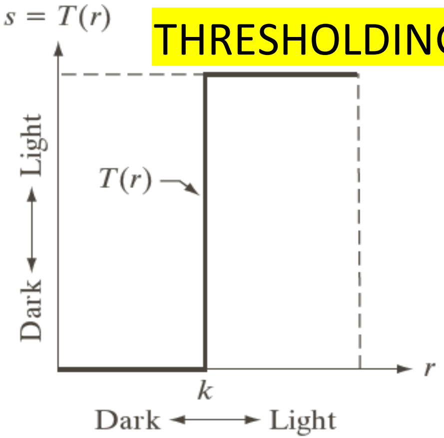


Piecewise-Linear Transformations



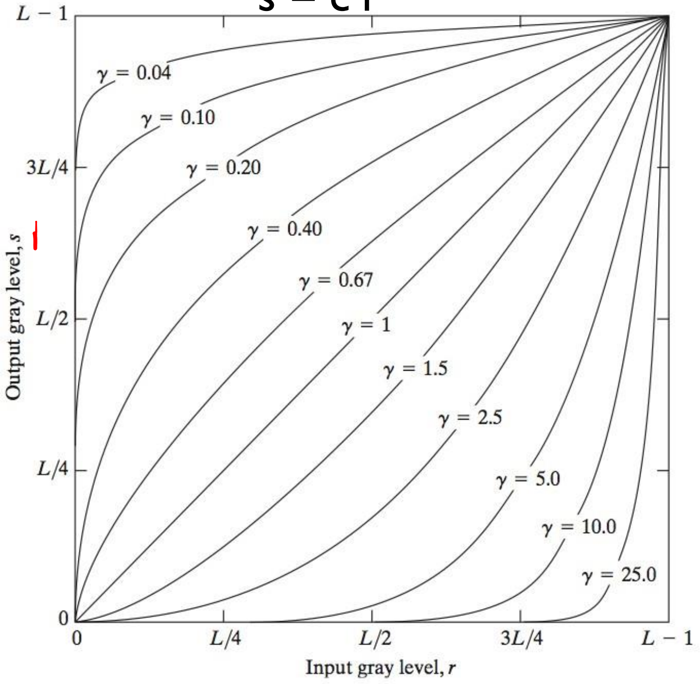


THRESHOLDING



Power-Law Transformations

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



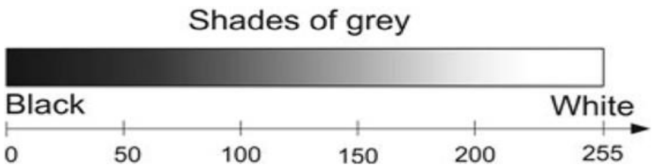
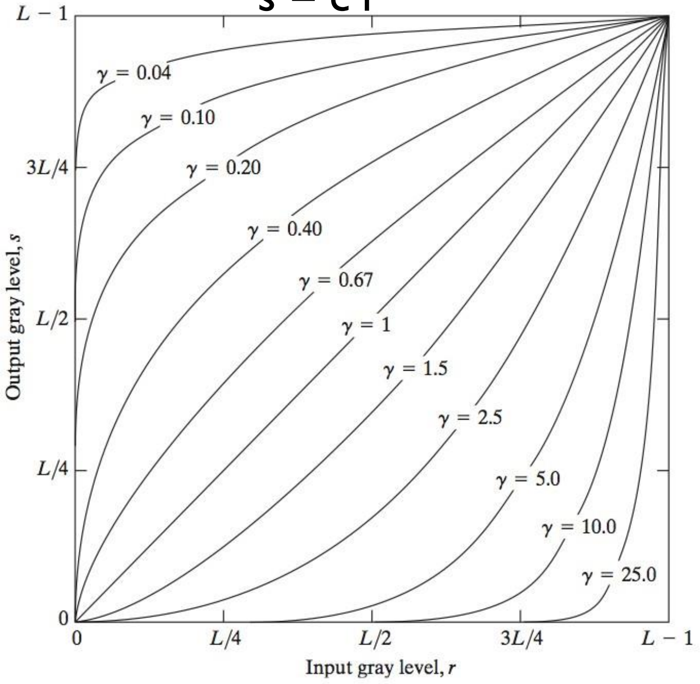
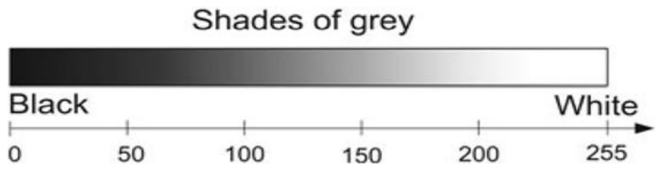


FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively. (Original image for this example courtesy of NASA.)

Power-Law Transformations

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



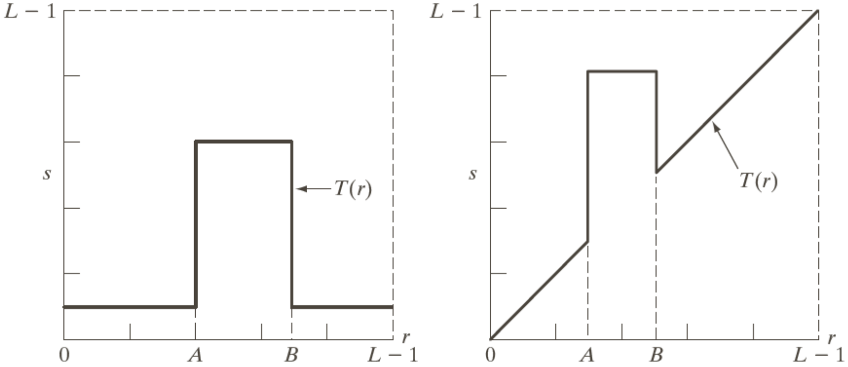


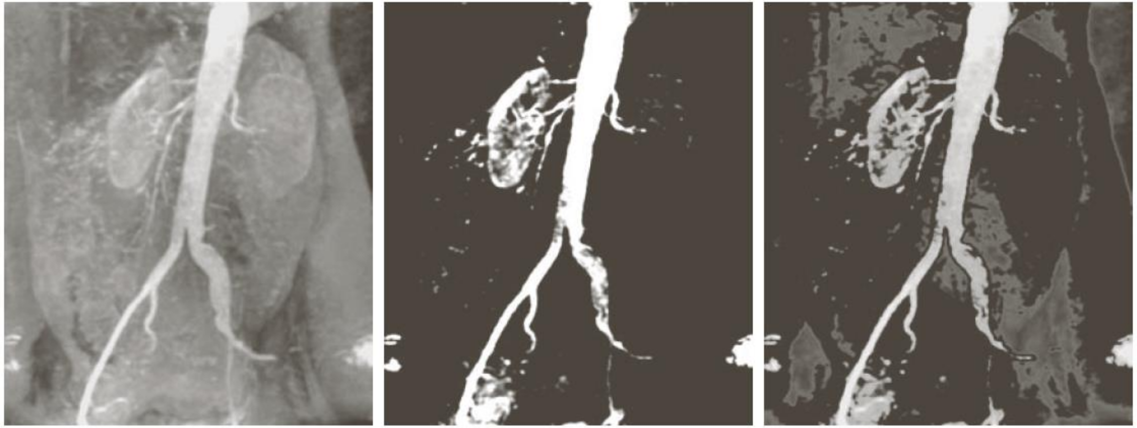
Demo:
https://colab.research.google.com/drive/11qIL0VKleZnONtPuxAryAf9WkUC7kEMI#scrollTo=aU5WQaqOpSCr&line=12&uniqifier=1

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.



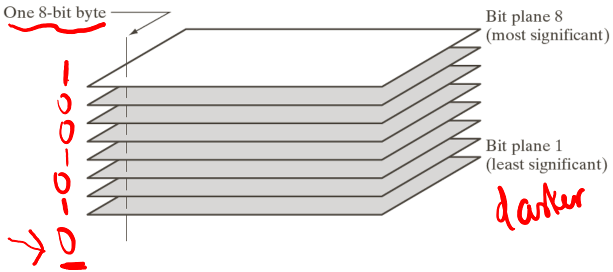


a b c

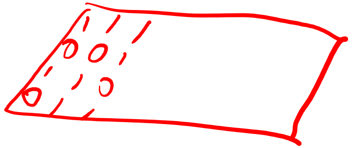
Bit plane slicing

brighter

8-bit



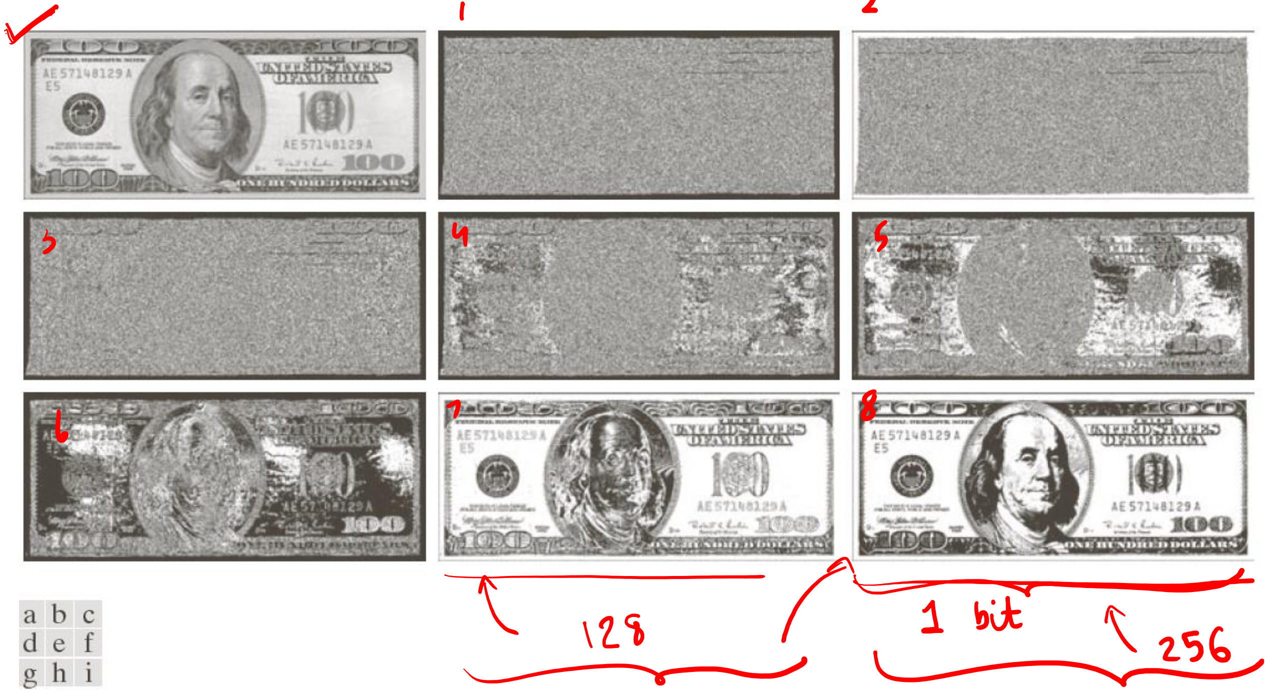
darker



0 0000000

0 1 0 0 0 0

1 0 0 0 00



128

1 bit

256

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.

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Lecture-4: Histogram Processing

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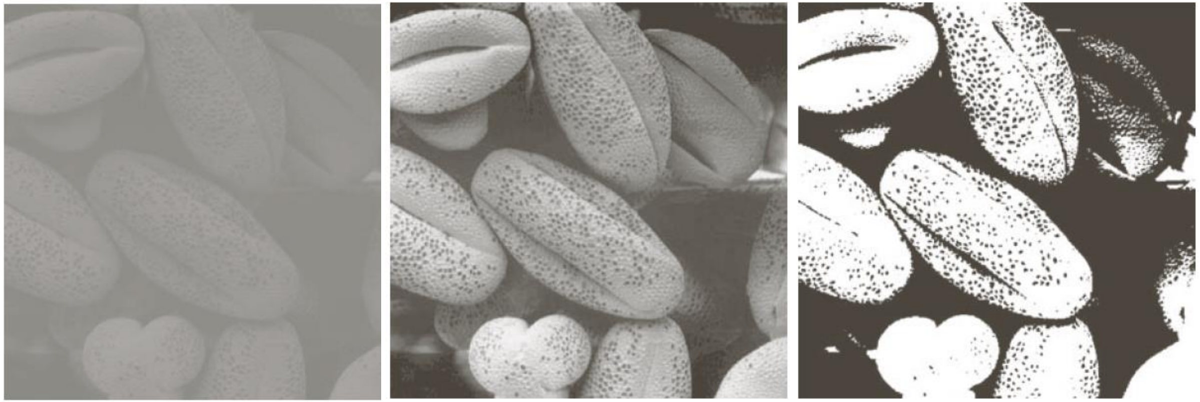
Piecewise-Linear Transformations



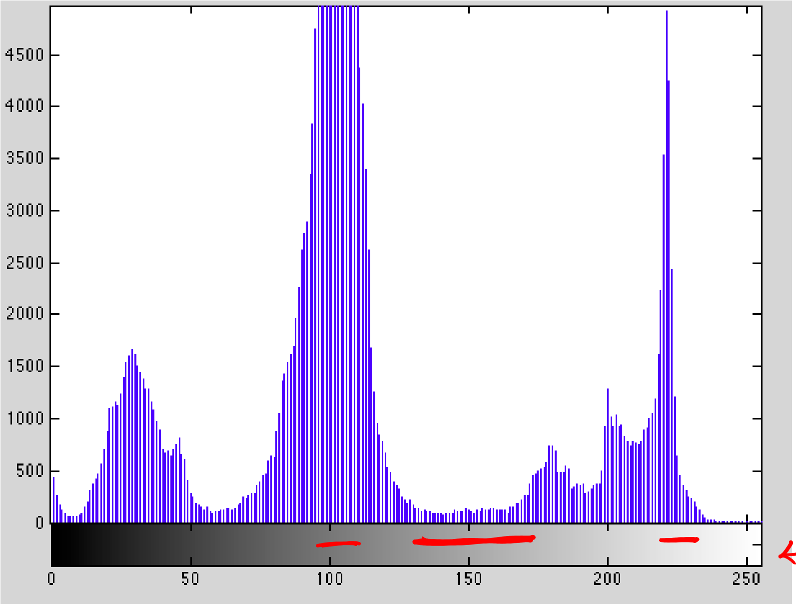
Histogram: An image representation + visualization

$$h_r(i) = n_i$$

i → intensity value, range [0, L-1]

n_i → number of pixels with intensity i

I



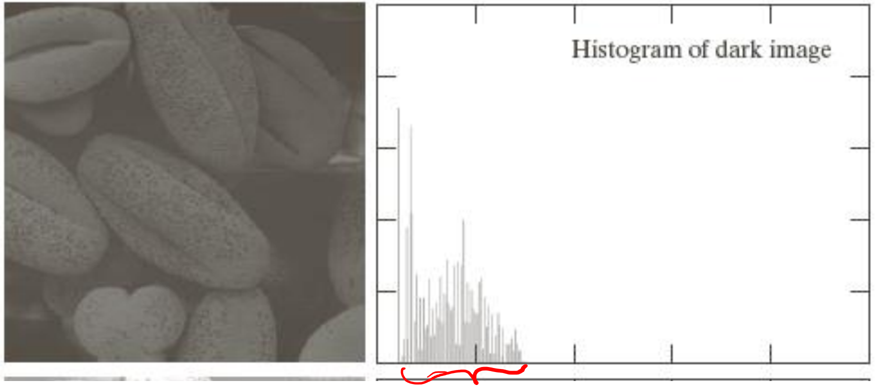
← 256 int

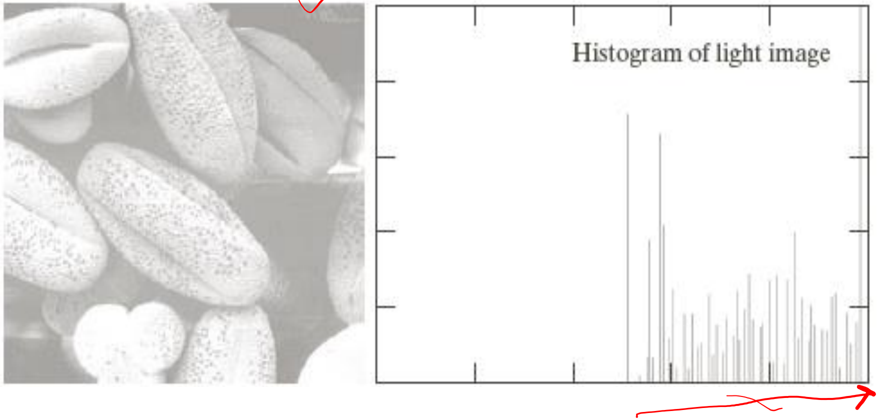
Histograms

- What can we infer from histograms?

Histogram viewing standard in most DSLR cameras

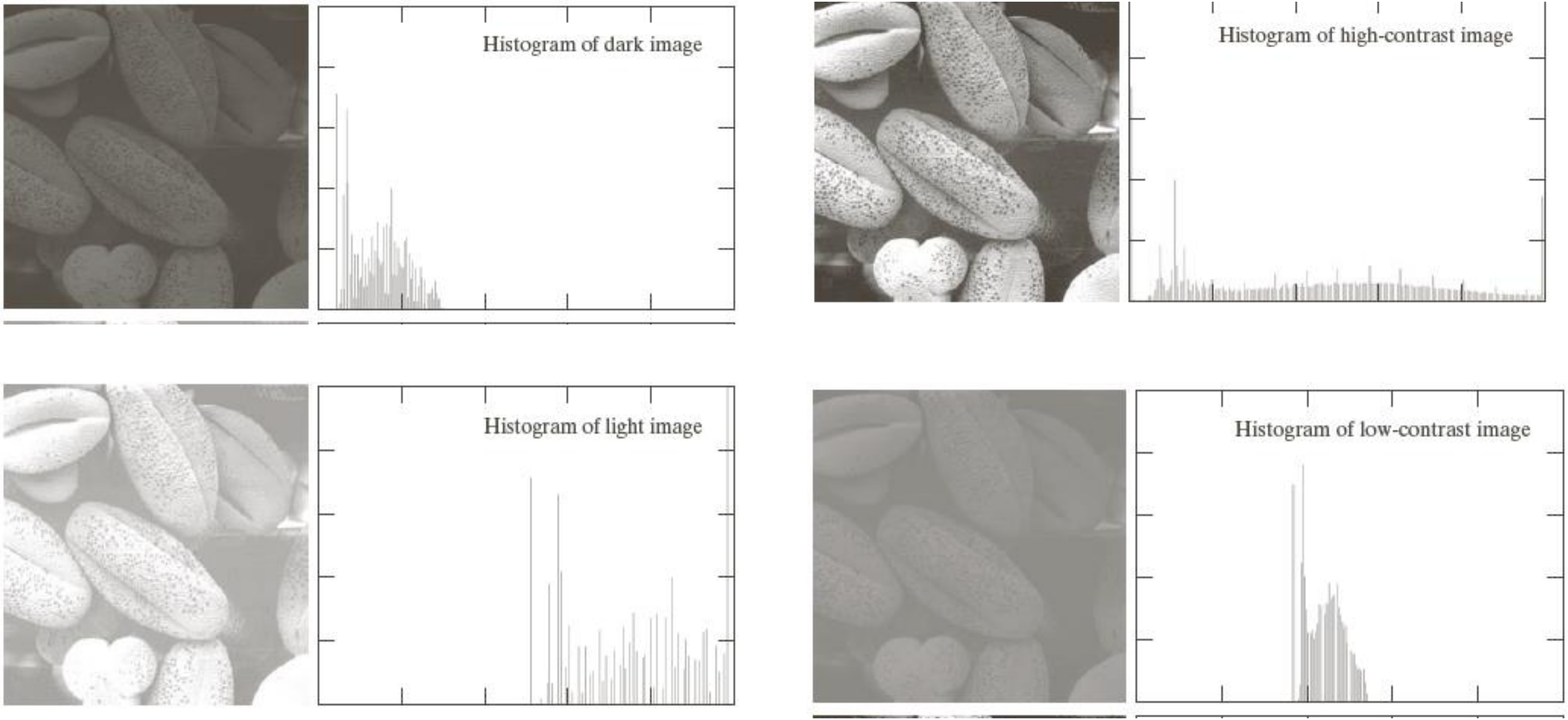
Histograms and Contrast



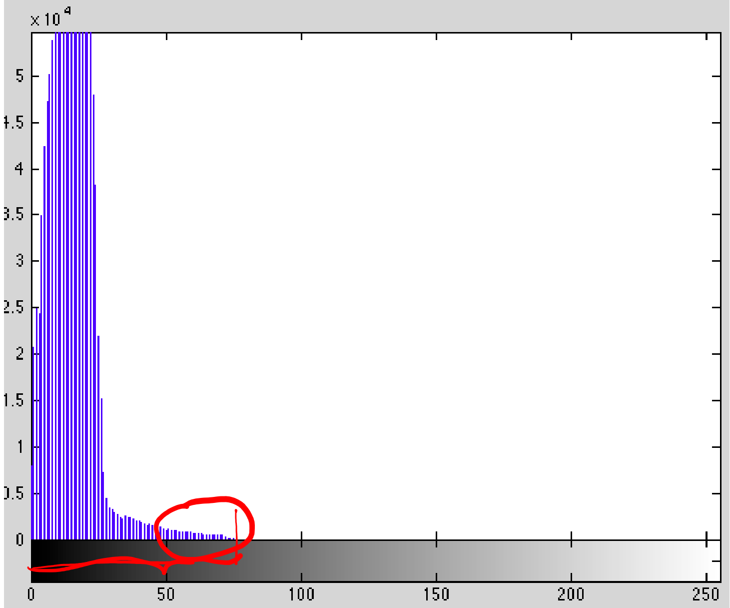


$$\text{Contrast} = \left[\frac{I_{max} - I_{min}}{I_{max} + I_{min}}\right]$$

Histograms and Contrast

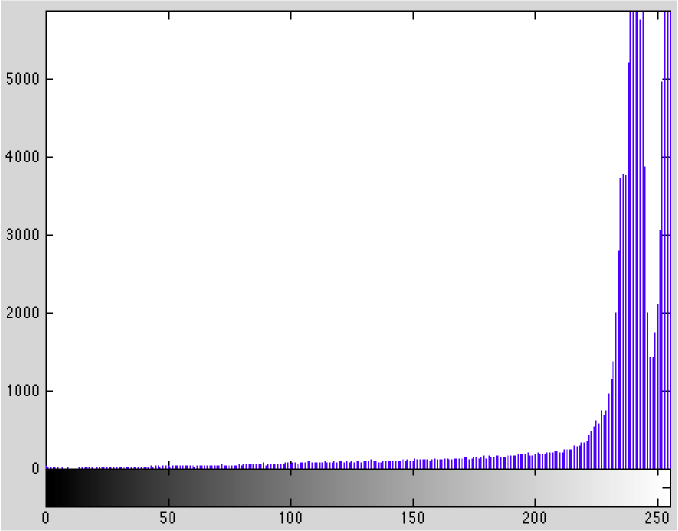


Histograms



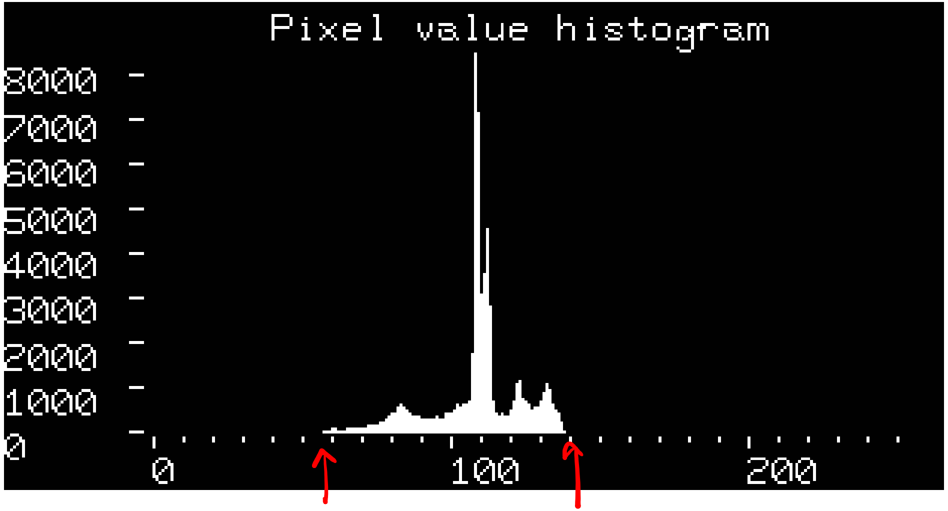
Under exposure

Histograms



Over exposure

A low-contrast image and its histogram



Contrast Stretching

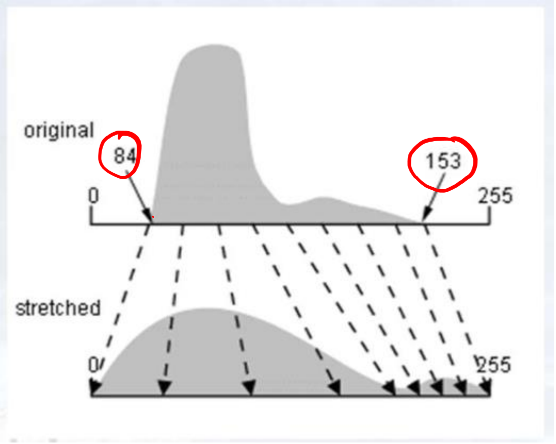
$$f_{\text{ac}}(a) = a_{\min} + (a - a_{\text{low}}) \cdot \frac{a_{\max} - a_{\min}}{a_{\text{high}} - a_{\text{low}}}$$

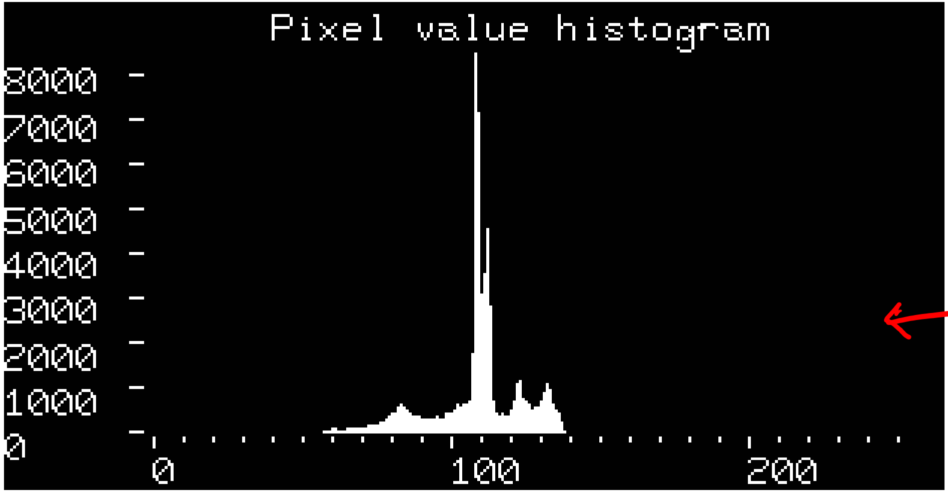
Contrast Stretching

$$f_{ac}(a) = a_{\min} + (a - a_{\text{low}}) \cdot \frac{a_{\max} - a_{\min}}{a_{\text{high}} - a_{\text{low}}}$$

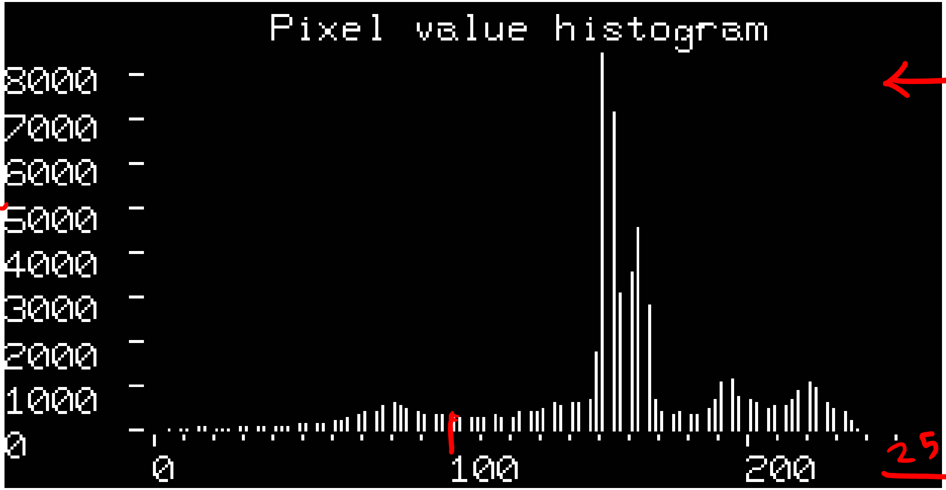
If a_{min} = 0 and a_{max} = 255

$$f_{ac}(a) = (a - a_{\text{low}}) \cdot \frac{255}{a_{\text{high}} - a_{\text{low}}}$$




Pixel value histogram
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200

ount


Pixel value histogram
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200

255

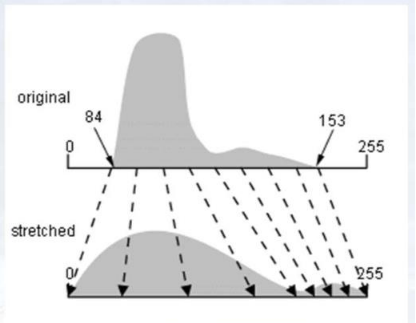
Contrast Stretching

Suppose we have a single pixel with intensity 255 in the original intensity range.
What happens ?

$$f_{ac}(a) = a_{min} + (a - a_{low}) \cdot \frac{a_{max} - a_{min}}{a_{high} - a_{low}}$$

If a_{min} = 0 and a_{max} = 255

$$f_{ac}(a) = (a - a_{low}) \cdot \frac{255}{a_{high} - a_{low}}$$

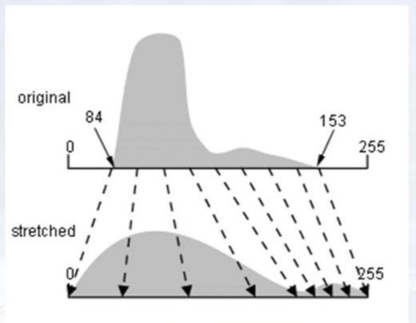


Contrast Stretching

$$f_{ac}(a) = a_{\min} + (a - a_{\text{low}}) \cdot \frac{a_{\max} - a_{\min}}{a_{\text{high}} - a_{\text{low}}}$$

If a_{min} = 0 and a_{max} = 255

$$f_{ac}(a) = (a - a_{\text{low}}) \cdot \frac{255}{a_{\text{high}} - a_{\text{low}}}$$



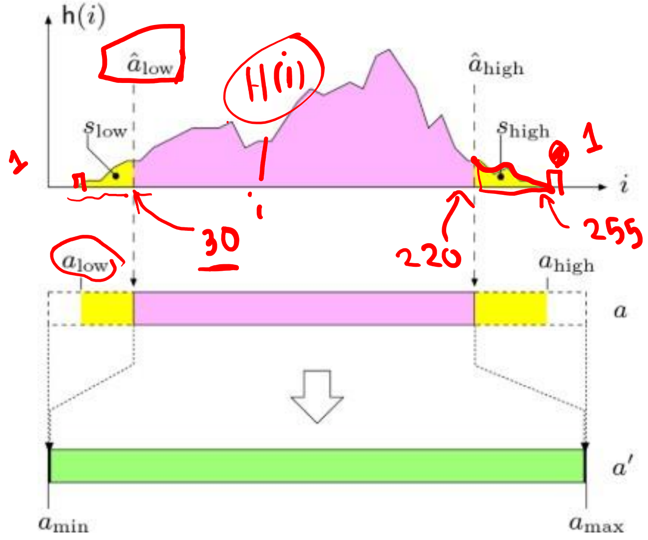
Suppose we have a single pixel with intensity 0 in the original intensity range.
What happens ?

Contrast Stretching ver. 2

H: 0 1 … 255

$M \times N \times 0.3$

N, M, M.N



$$\boxed{\hat{a}_{low}} = \min\{\, i \mid \mathsf{H}(i) \geq M \cdot N \cdot s_{low} \}$$

5% → 0.05
3% → 0.03

$$\hat{a}_{high} = \max\{\, i \mid \mathsf{H}(i) \leq M \cdot N \cdot (\cancel{1 - s_{high}}) \}$$

s_{high}

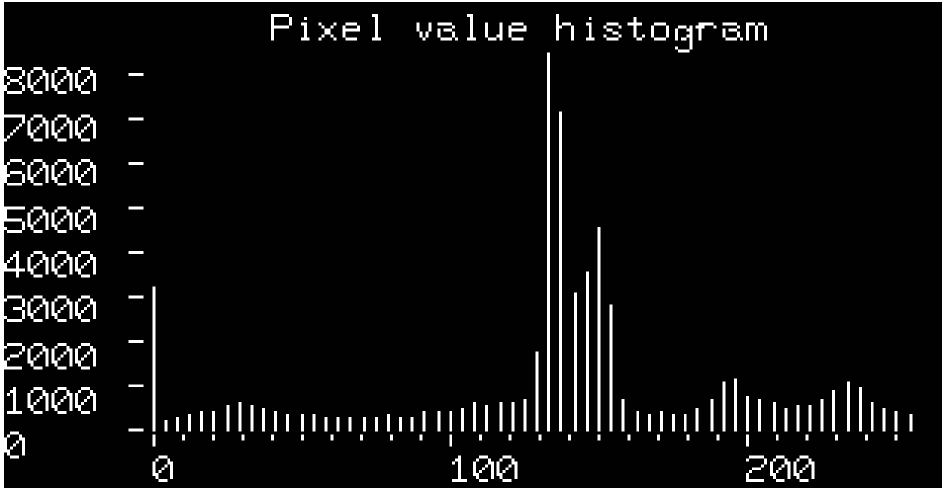
$$f_{mac}(a) = \begin{cases} a_{min} & \text{for } a \leq \hat{a}_{low} \\ a_{min} + (a - \hat{a}_{low}) \cdot \dfrac{a_{max} - a_{min}}{\hat{a}_{high} - \hat{a}_{low}} & \text{for } \hat{a}_{low} < a < \hat{a}_{high} \\ a_{max} & \text{for } a \geq \hat{a}_{high} \end{cases}$$

0

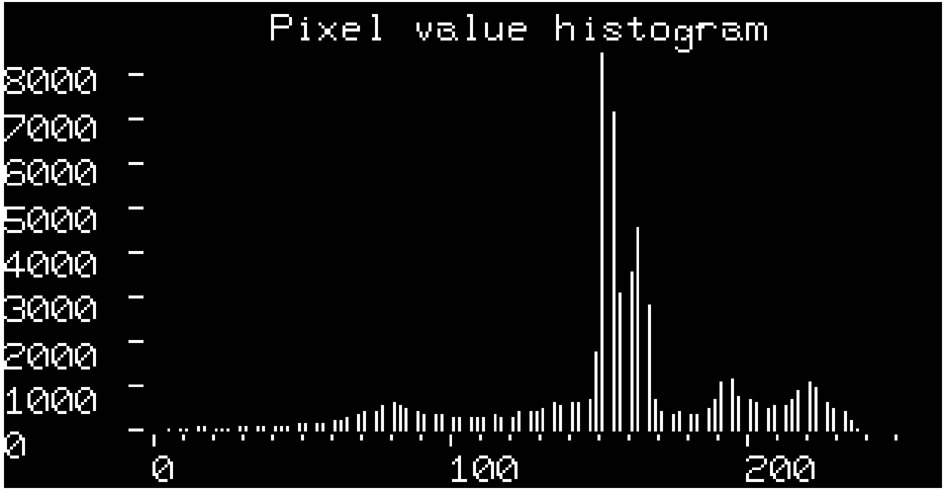
255

s_{low} s_{high}

Ver. 2

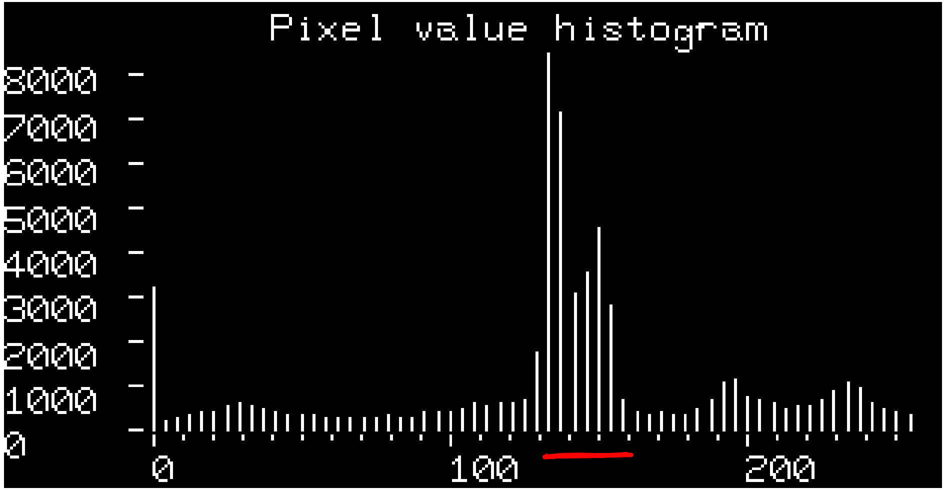

Pixel value histogram
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200

Ver 1


Pixel value histogram
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200

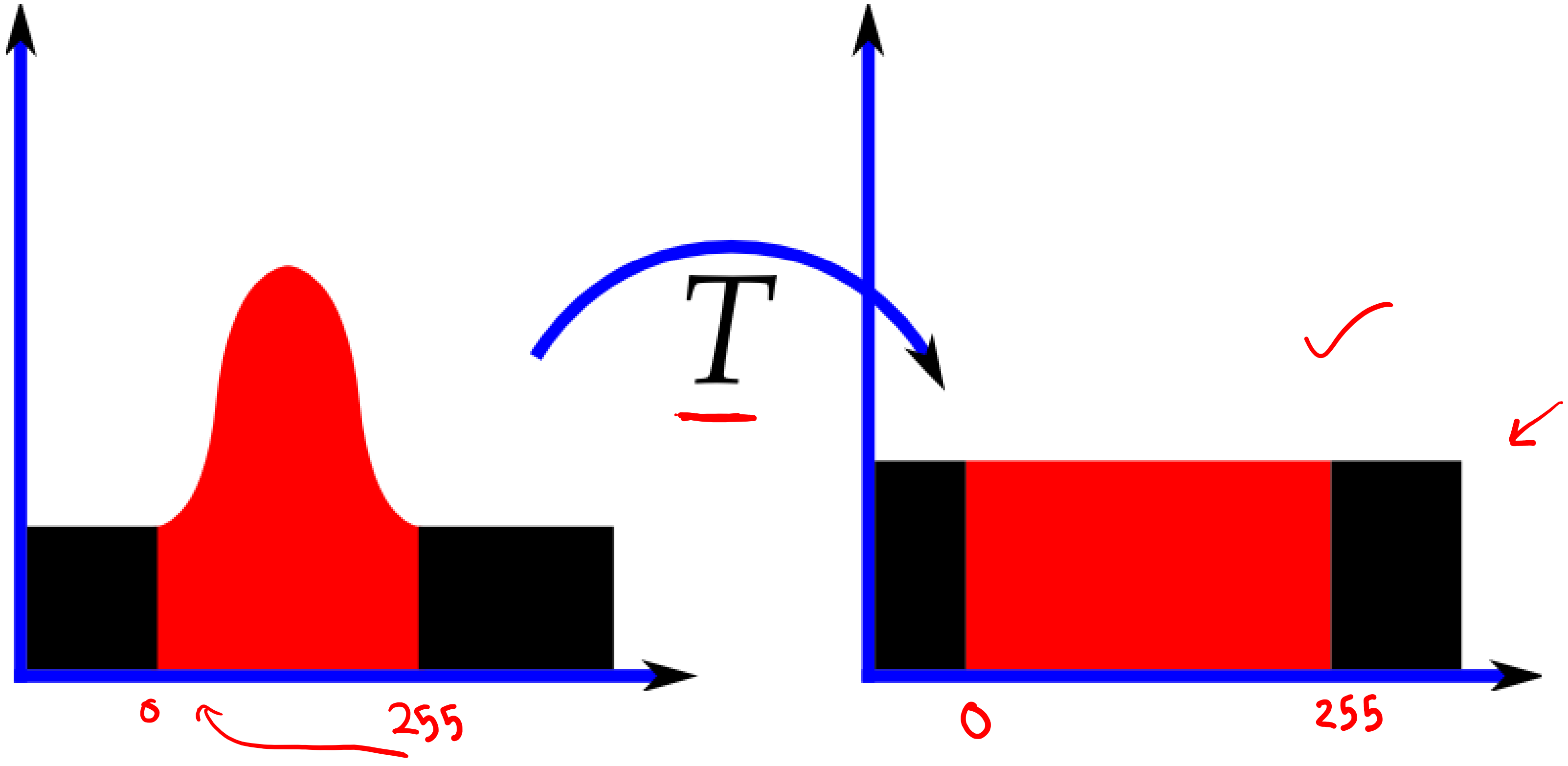
Are all intensities well represented ?

Ver. 2

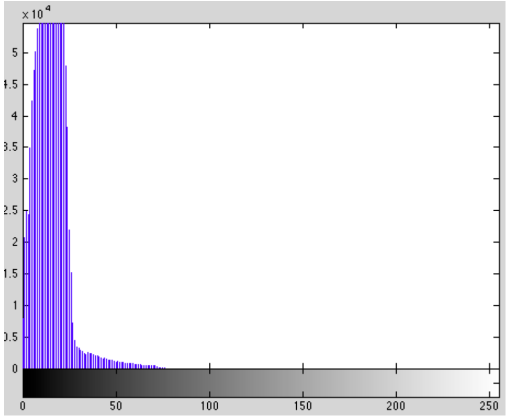


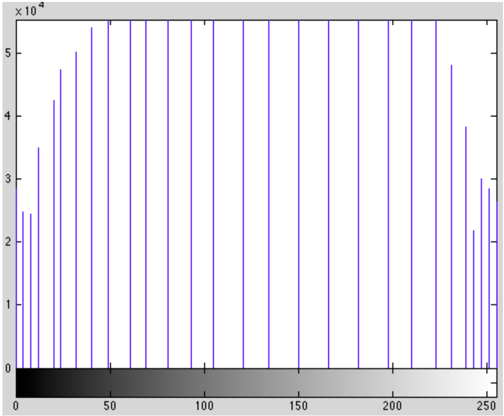
ALL INTENSITIES

Histogram Equalization



Histogram Equalization





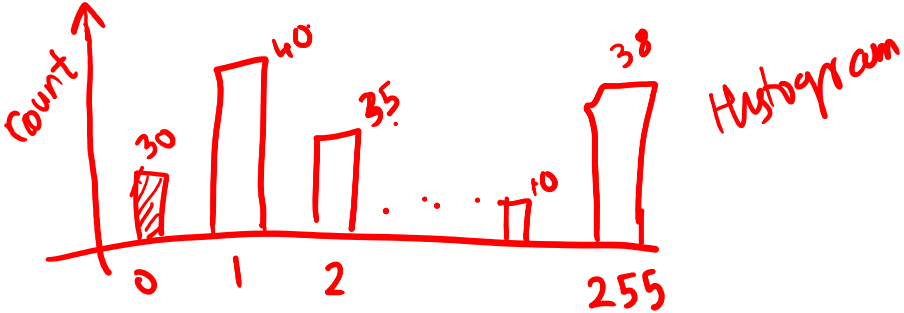
The issue with contrast stretching

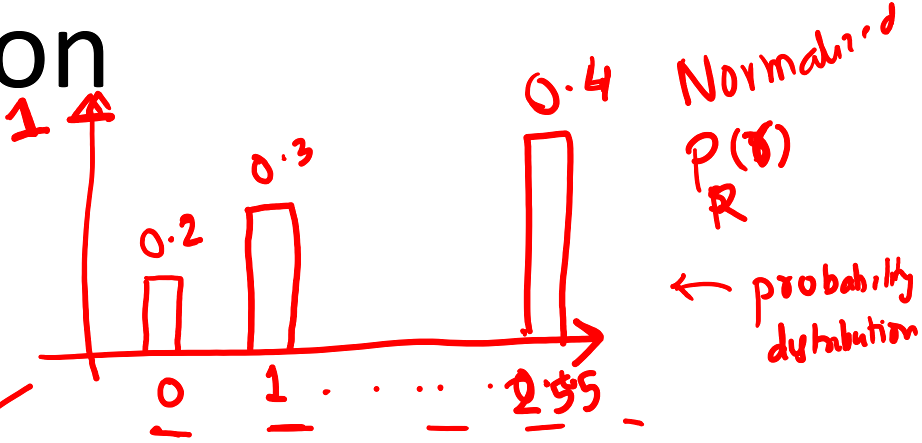
$$f_{\mathrm{ac}}(a) = a_{\min} + (a - a_{\mathrm{low}}) \cdot \frac{a_{\max} - a_{\min}}{a_{\mathrm{high}} - a_{\mathrm{low}}}$$

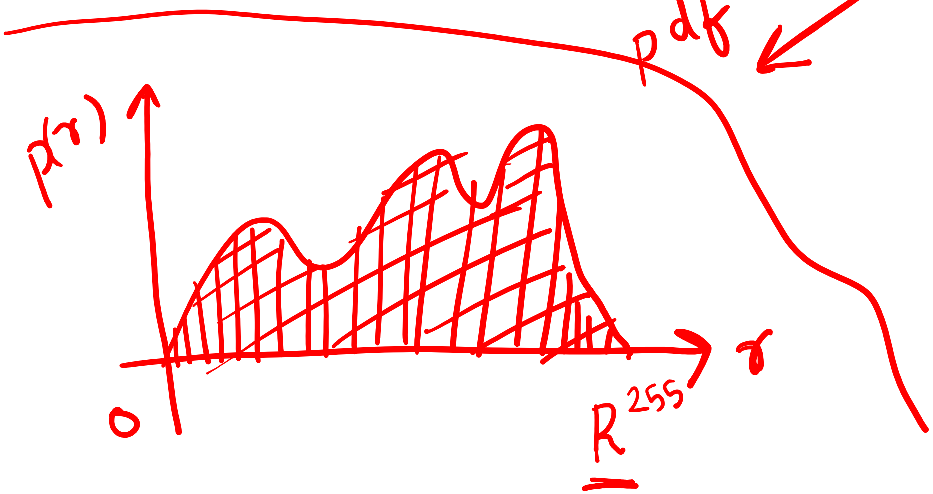
If a_{min} = 0 and a_{max} = 255

$$f_{\mathrm{ac}}(a) = (a - a_{\mathrm{low}}) \cdot \frac{255}{a_{\mathrm{high}} - a_{\mathrm{low}}}$$

Histogram Equalization



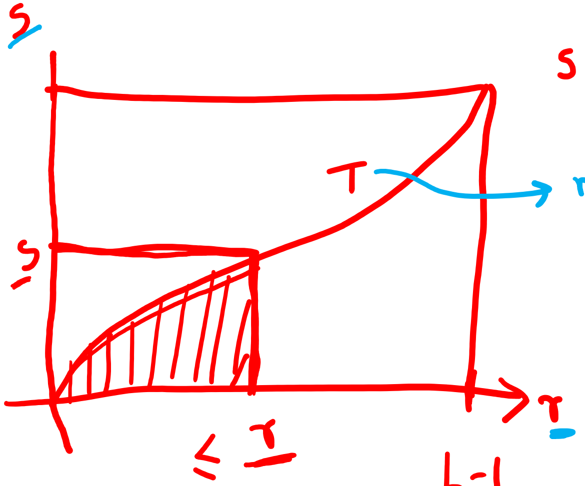




$$\int_{-\infty}^{\infty} P_R(r) = 1$$

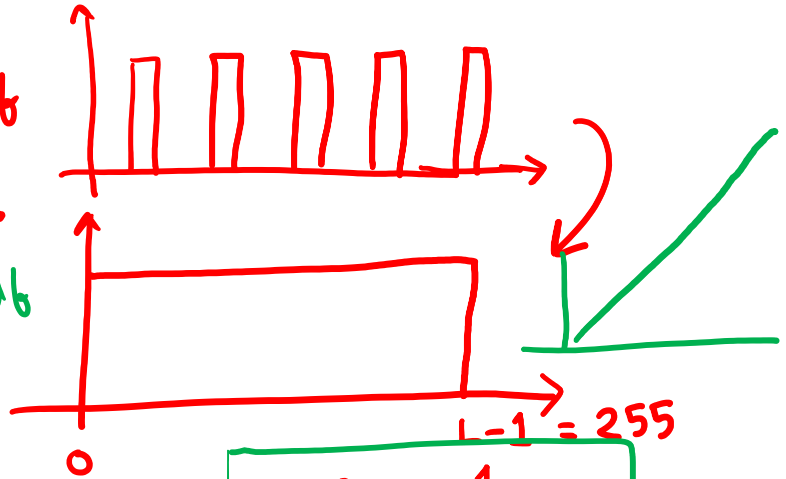
$$\int_{0}^{255} P_R(r) = 1$$

Histogram Equalization



$s = T(r)$

$L = \#$ of bits / levels



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

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

$$\boxed{p_S(s) = p_R(r)\,\frac{dr}{ds}}$$

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

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

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

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

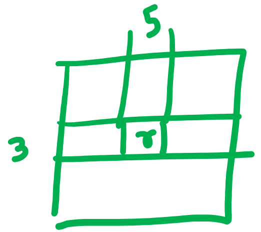
Leibniz formula

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

Histogram Equalization

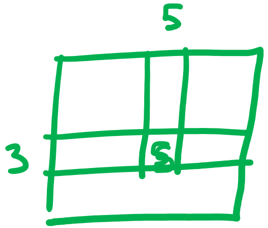
$$\boxed{p_s(s) = \frac{1}{L-1}}$$

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



digital equivalent

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



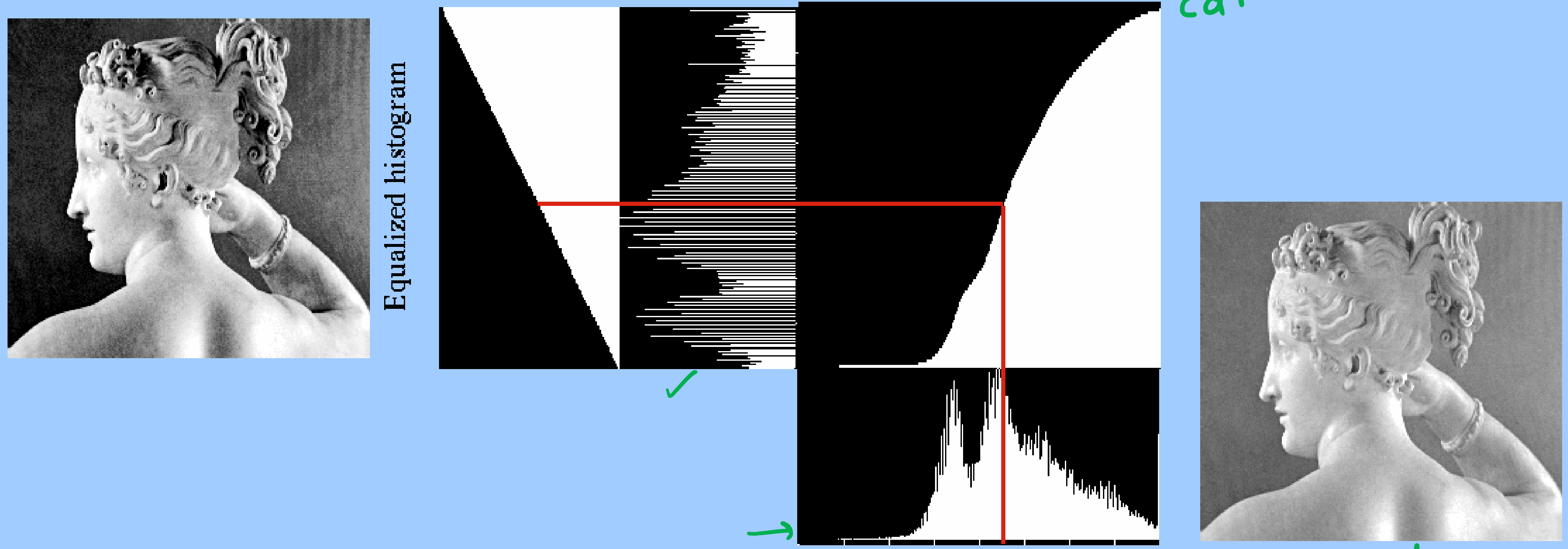
Histogram Equalization

Contrast Stretching

Histogram Equalization

cdf pdf

cdf



Histogram of original image

original image

References

- GW Chapter – 3.3.1 to 3.3.3

- Transformations of Random Variables
  - http://www.randomservices.org/random/dist/Transformations.html
  - Section 1 of http://www.cs.cmu.edu/~minx/transform.pdf
  - Leibnitz Integration Rule :
    https://en.wikipedia.org/wiki/Leibniz_integral_rule#Alternative_derivation
  - Univariate transformation of a random variable

Scribe Group

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20171205
20171208
2018101002
2018101003
2018101005

Mini Quiz 1 Link

https://forms.office.com/Pages/ResponsePage.aspx?id=vDsaA3zPK06W7IZ1VVQKHNFN1LYrWjxAktM68Sb-hiFUOEdKVElEOU8xTjNZTjNCUDFRTjhHQ09BNC4u