ĐẠI HỌC TÔN ĐỨC THẮNG

Ton Duc Thang University (TDTU)

Digital Image Processing

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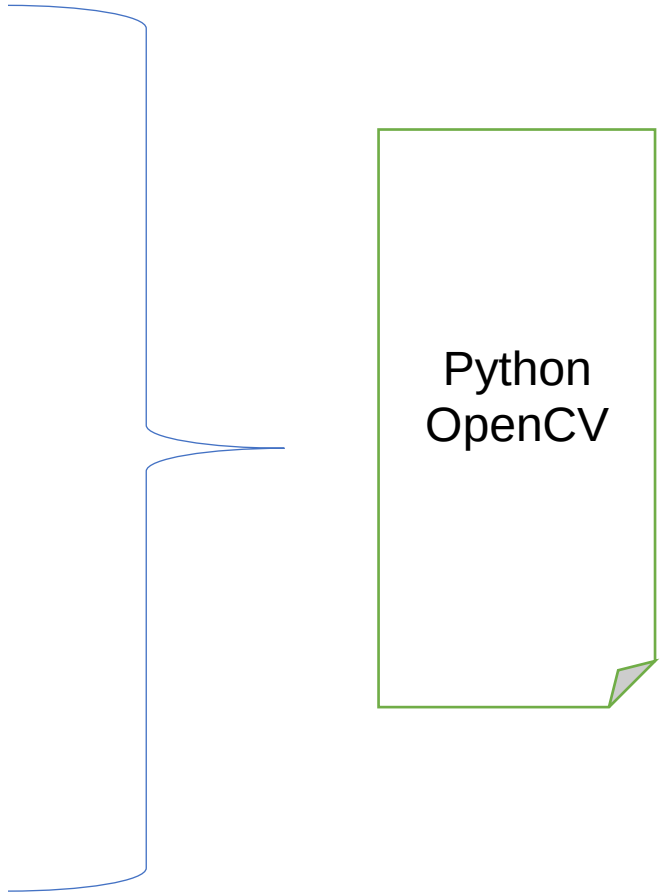
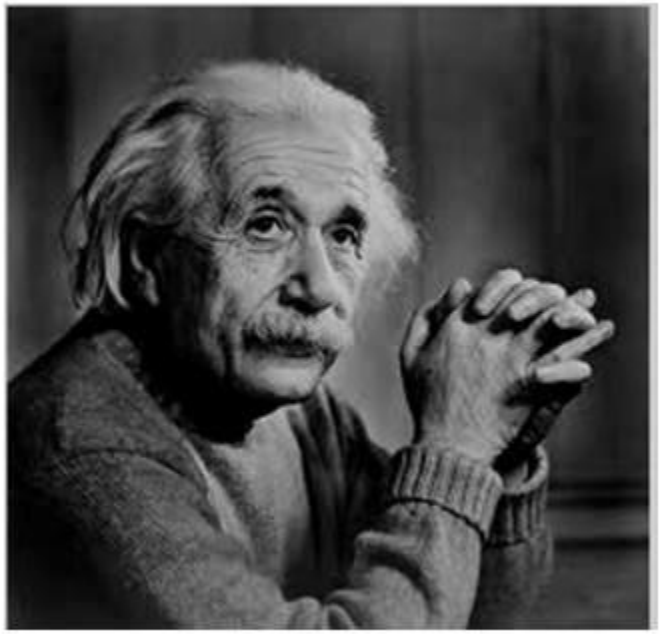
Lecture 02

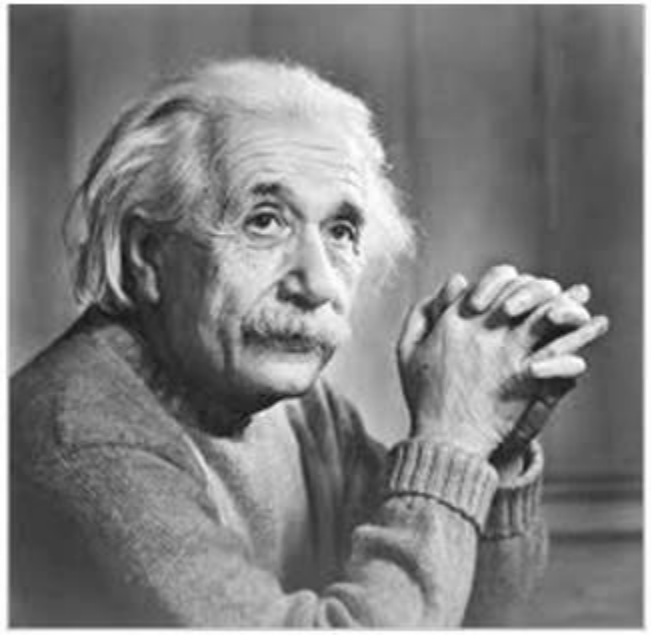
Image Enhancement

1. Brightness and contrast
2. Histogram Equalization
   - Image histogram
   - Histogram equalization techniques
   - Adaptive histogram equalization
   - Applications
3. Image fitering
   - Convolution
   - Noise removal



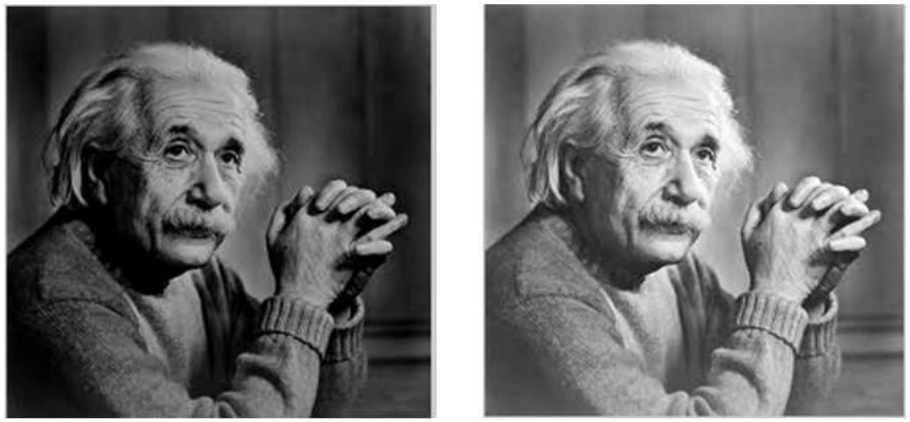
Which is brighter?





Brightness vs. Contrast

- Brightness can be defined as the amount of energy output by a source of light relative to the source we are comparing it to (Wiki)
    - Brightness is a relative term. It depends on your visual perception.

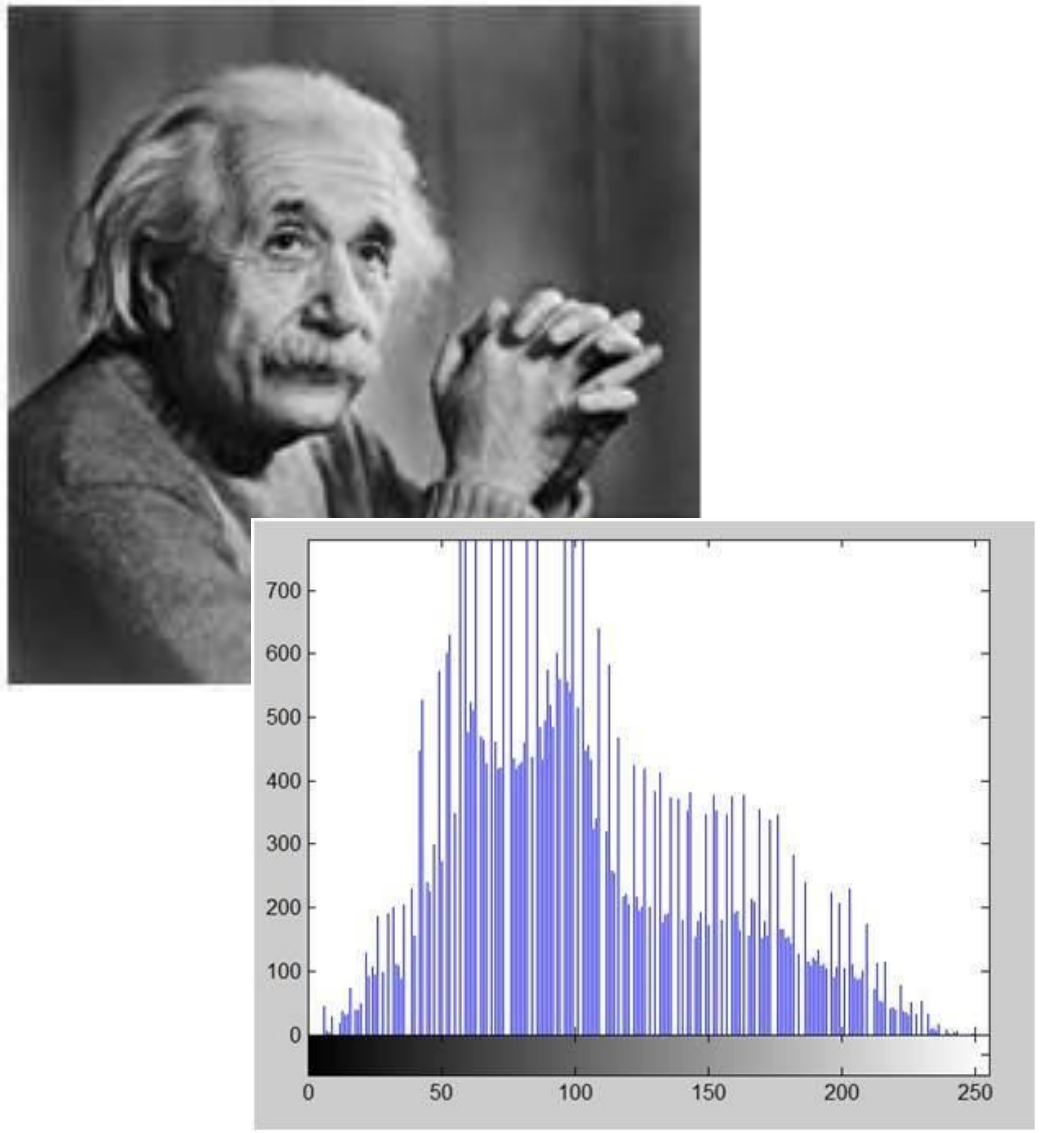


Contrast

the difference between
maximum and minimum pixel intensity
in an image.

Histogram

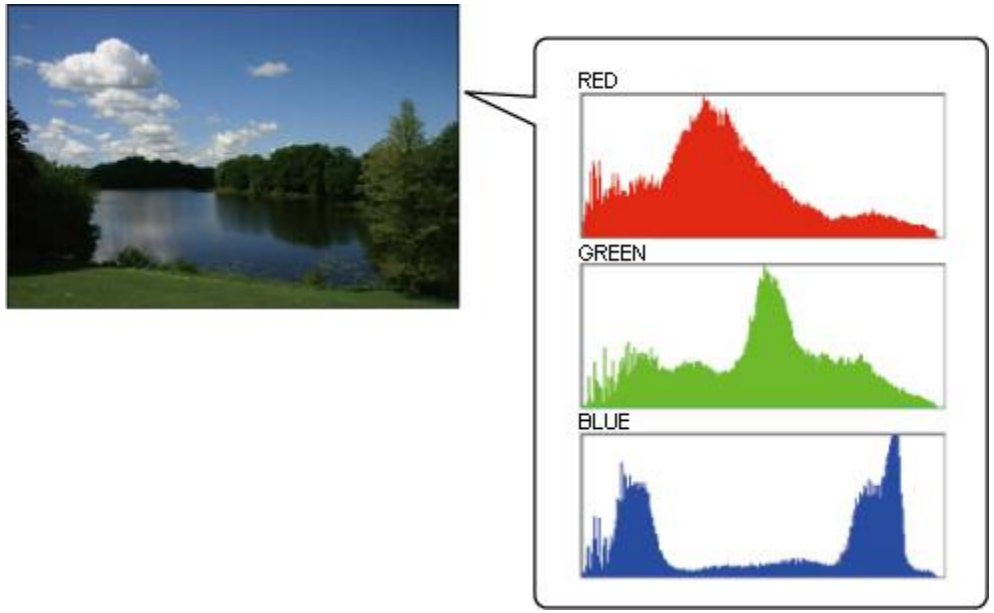
- Histograms shows frequency.
- An image histogram, shows **frequency of pixels intensity values**.
  - In an image histogram, the x axis shows the gray level intensities and the y axis shows the frequency of these intensities.

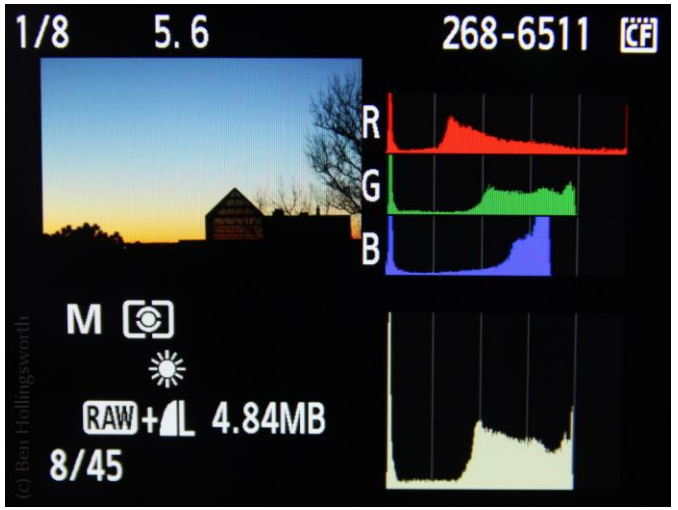


The histogram of the above picture of the Einstein would be something like this

Histogram

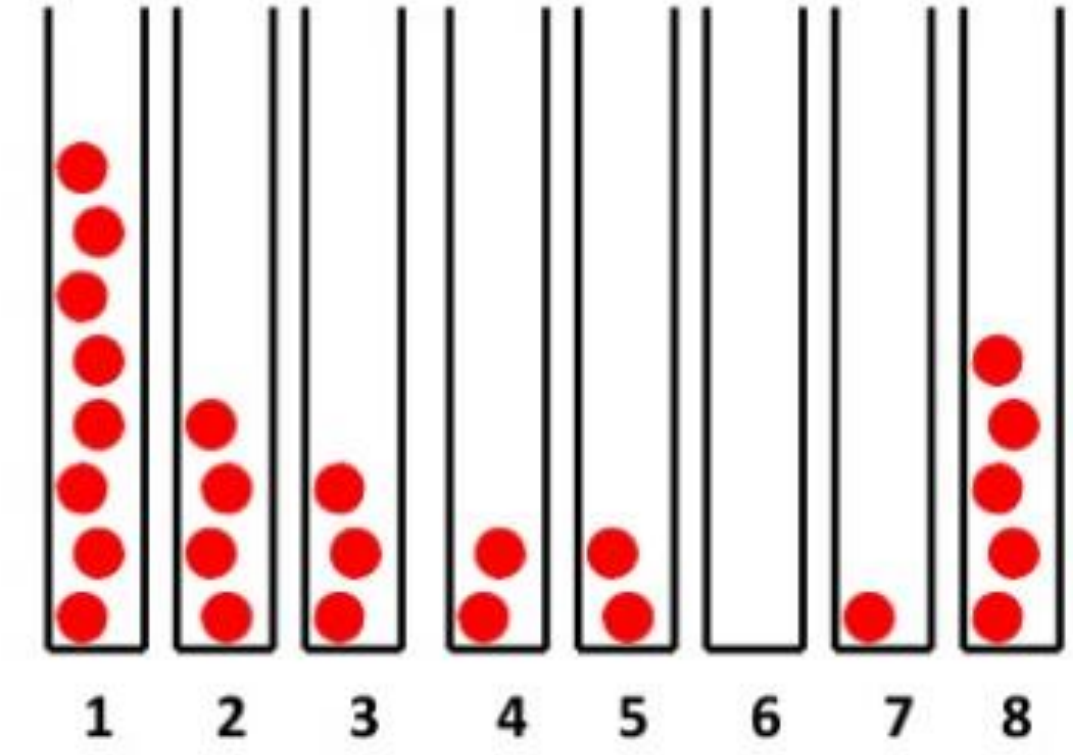
- Applications of Histograms
  - Analysis of the image.
    - We can predict about an image by just looking at its histogram. Its like looking an x ray of a bone of a body.
  - For brightness purposes
  - to equalize an image used in adjusting contrast of an image.
  - Histogram has wide use in thresholding in computer vision.



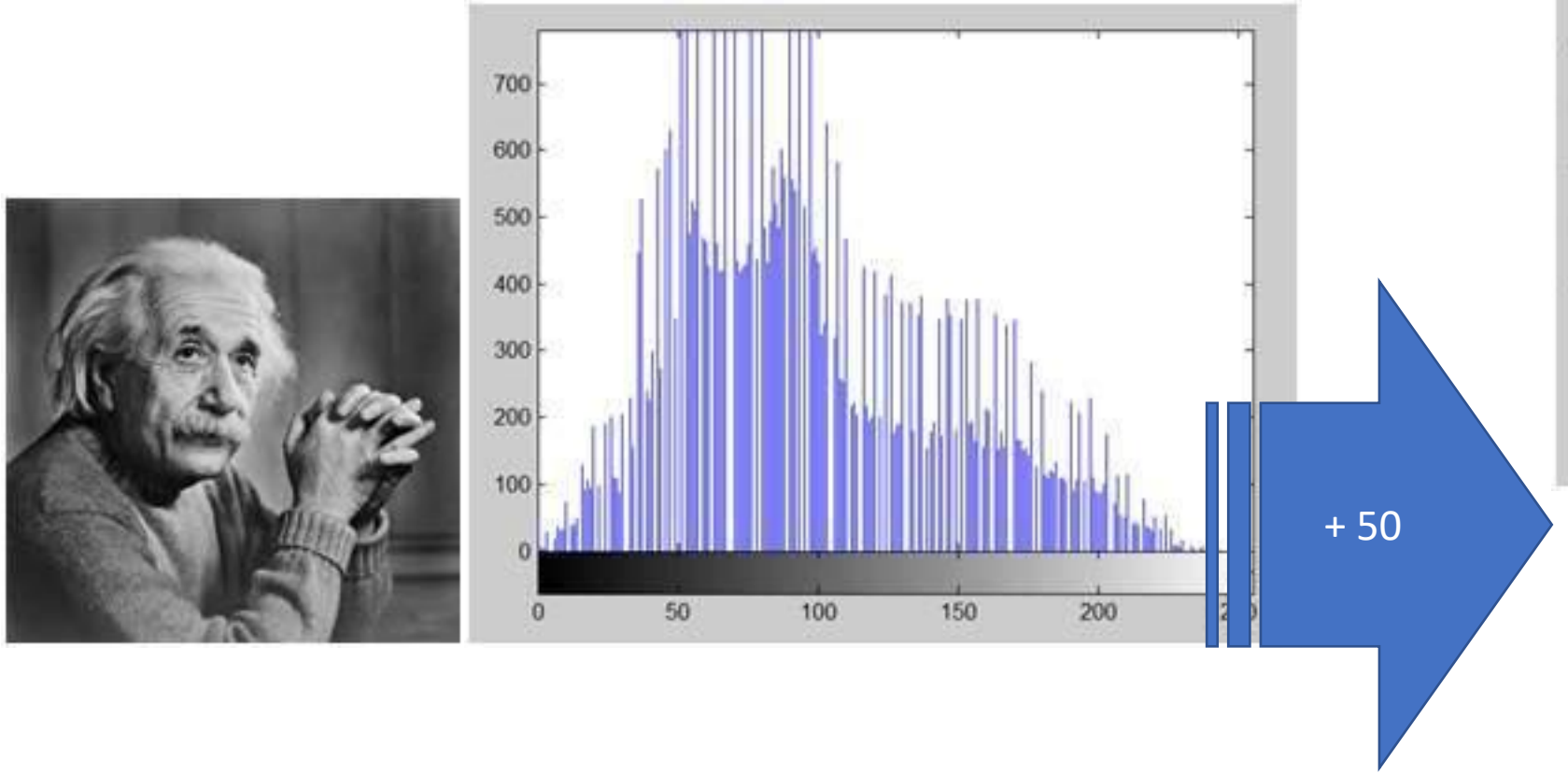


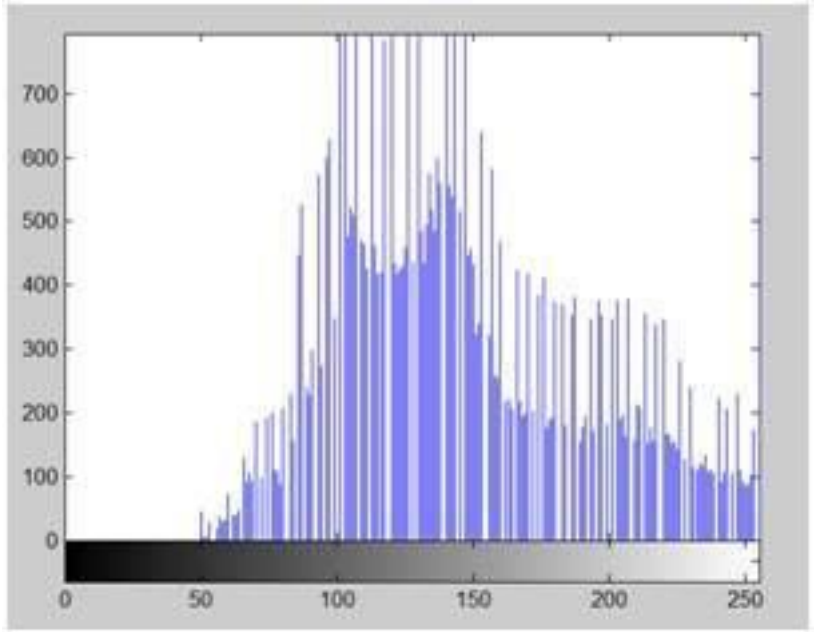
Histogram calculation

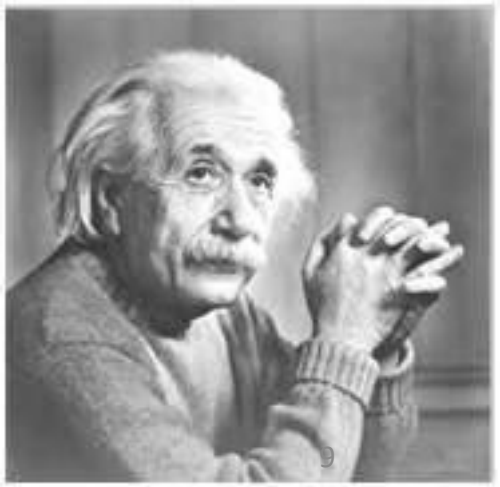
1	8	4	3	4
1	1	1	7	8
8	8	3	3	1
2	2	1	5	2
1	1	8	5	2



Brightness enhancement



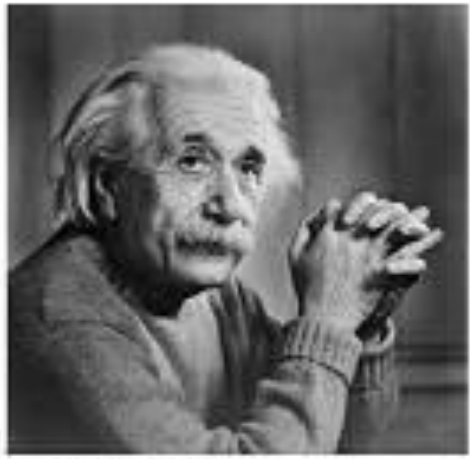




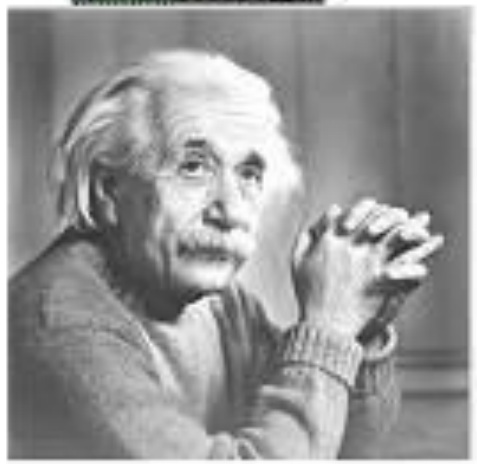
Sliding histogram

+ 50

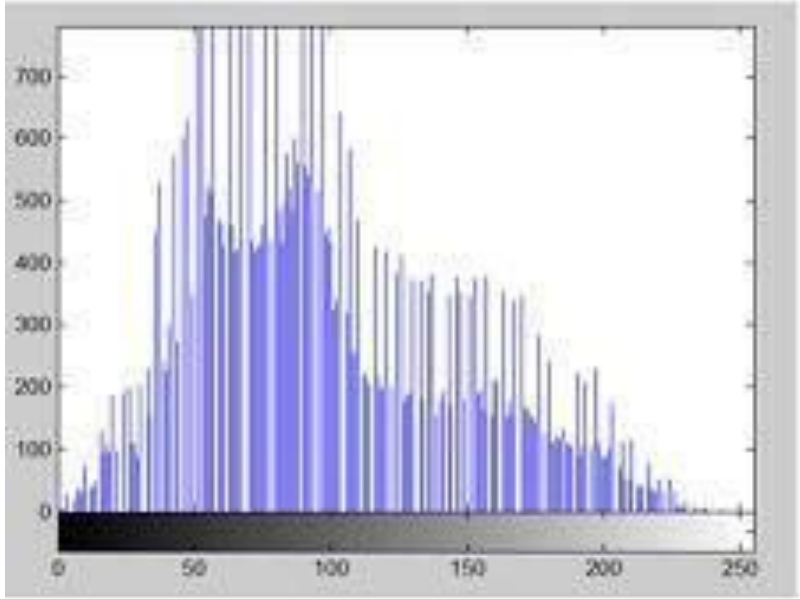
Old image



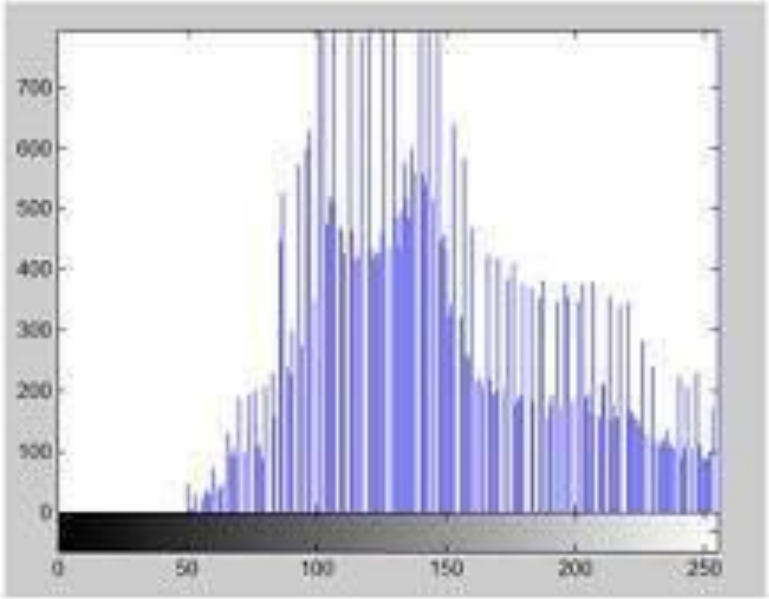
New image



Old histogram

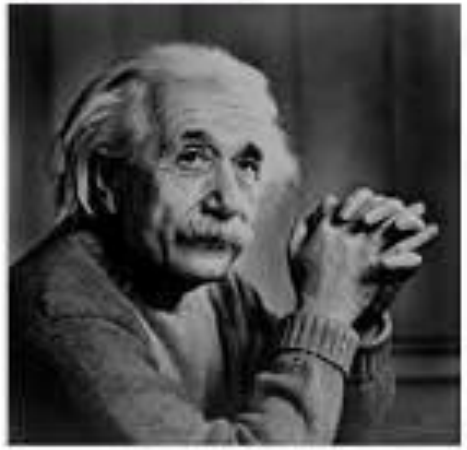


New Histogram

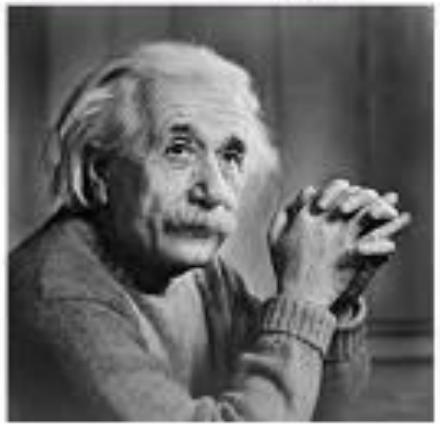


- 80

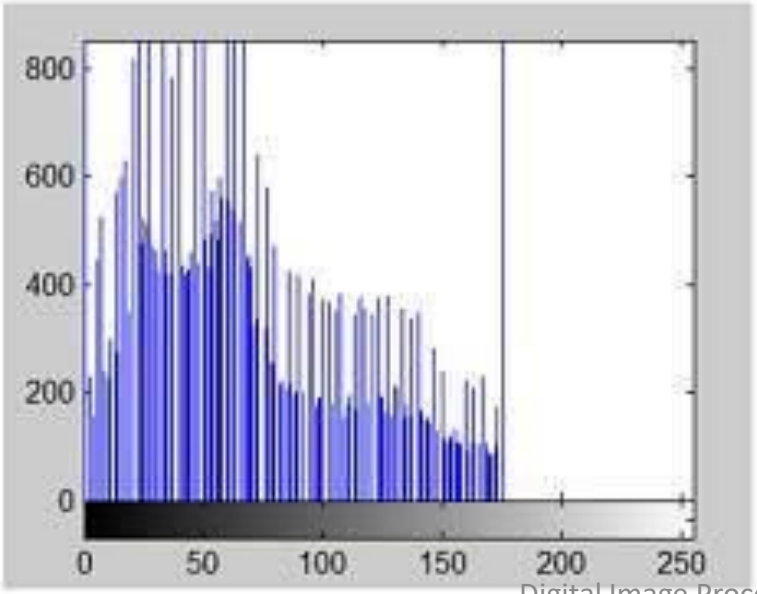
New image.



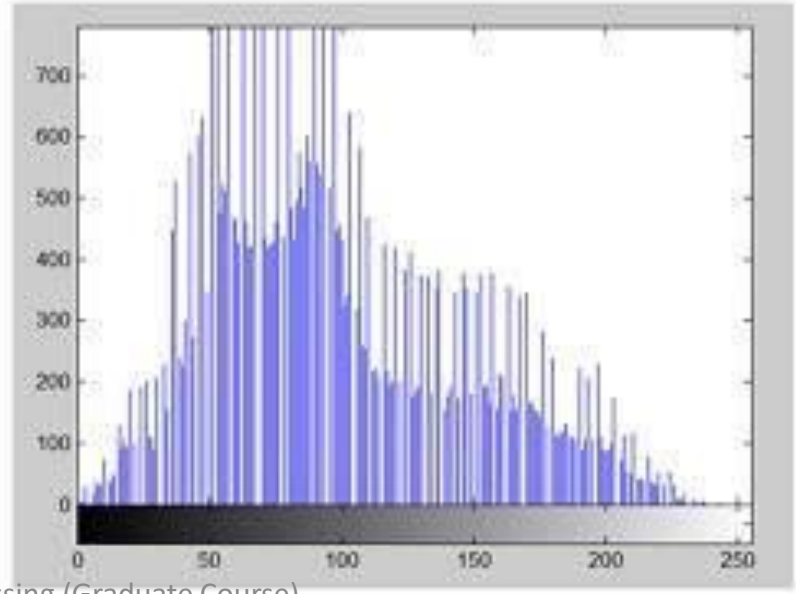
Original image.



New Histogram.



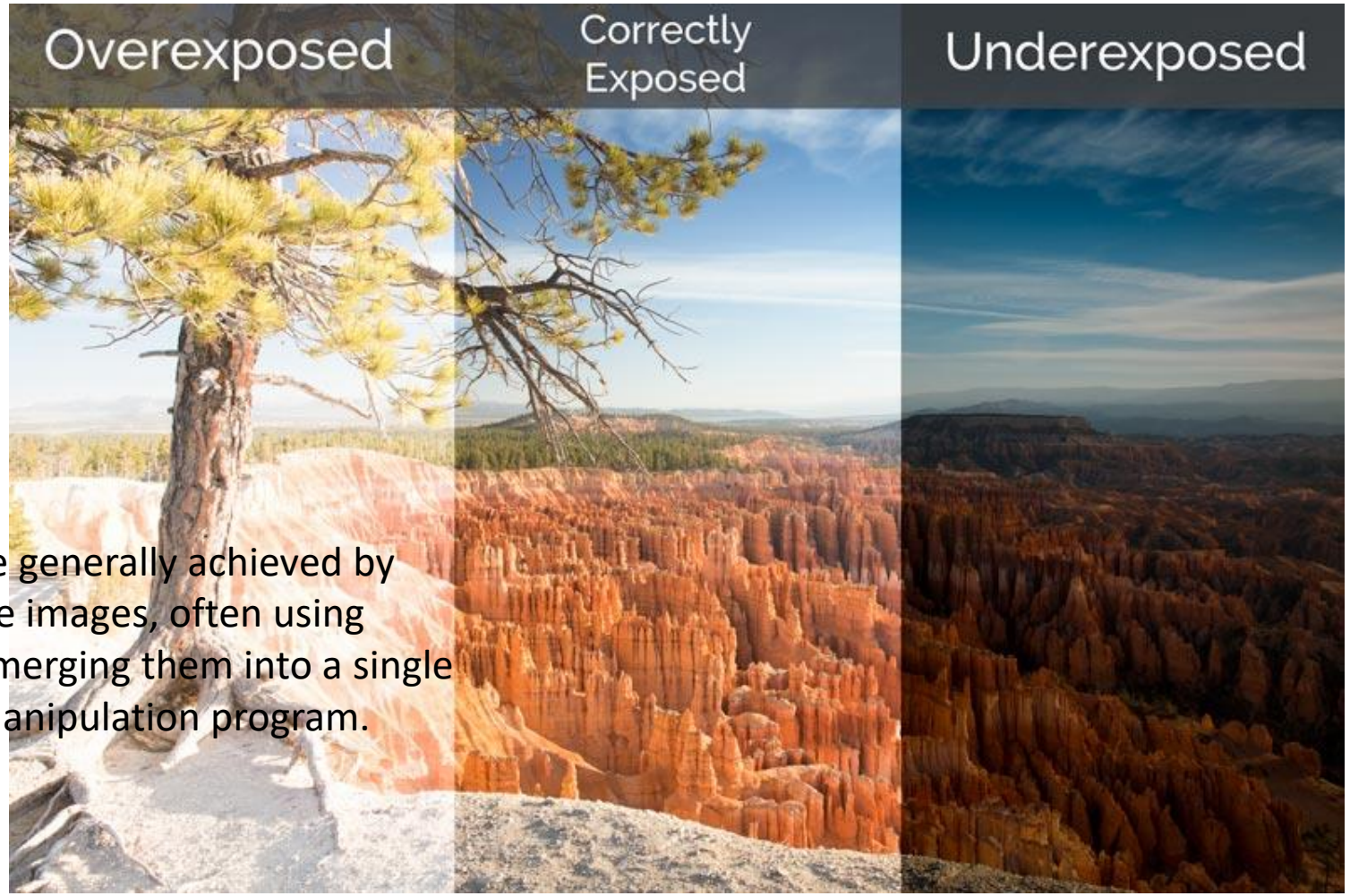
Original Histogram.



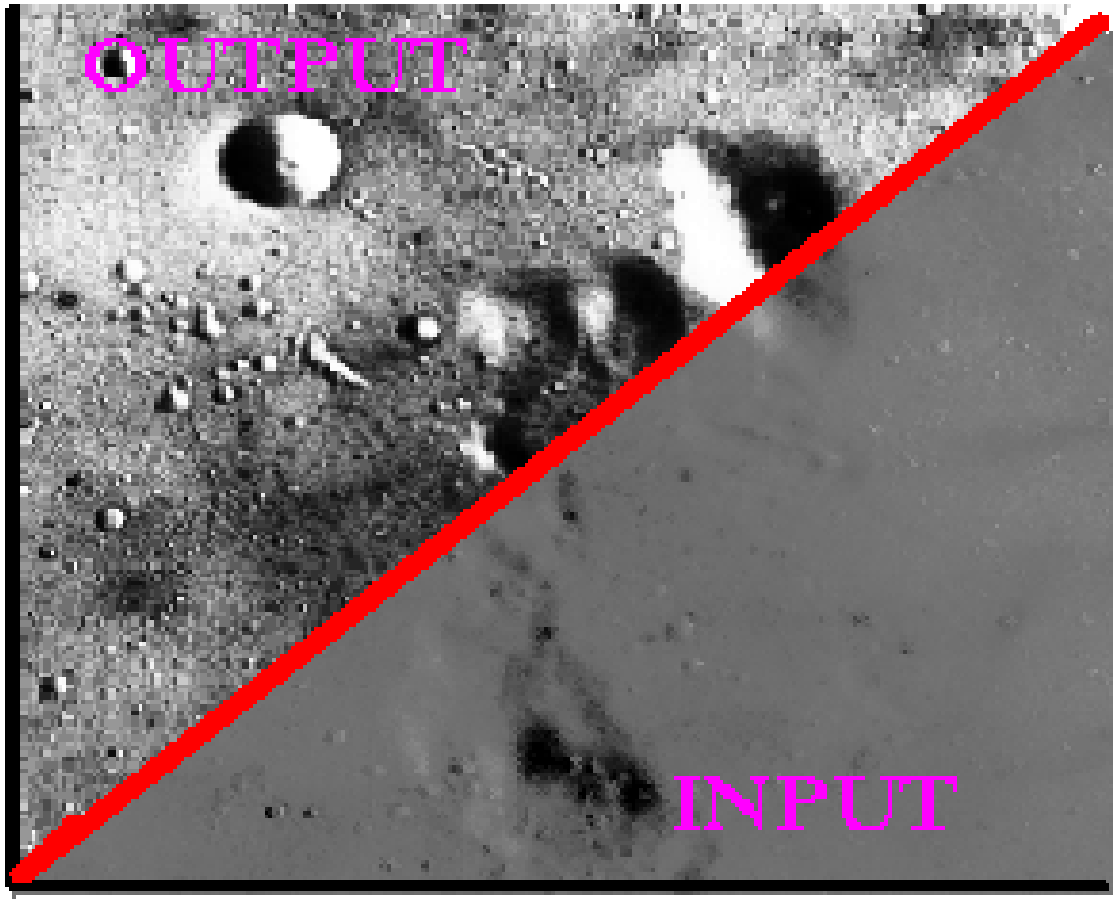
Brightness enhancement

- Exposure problem
  - Over-exposed photo
  - Under-exposed photo
  - Flash
  - RAW image
  - HDR technology

High-dynamic-range photographs are generally achieved by capturing multiple standard-exposure images, often using exposure bracketing, and then later merging them into a single HDR image, usually within a photo manipulation program.



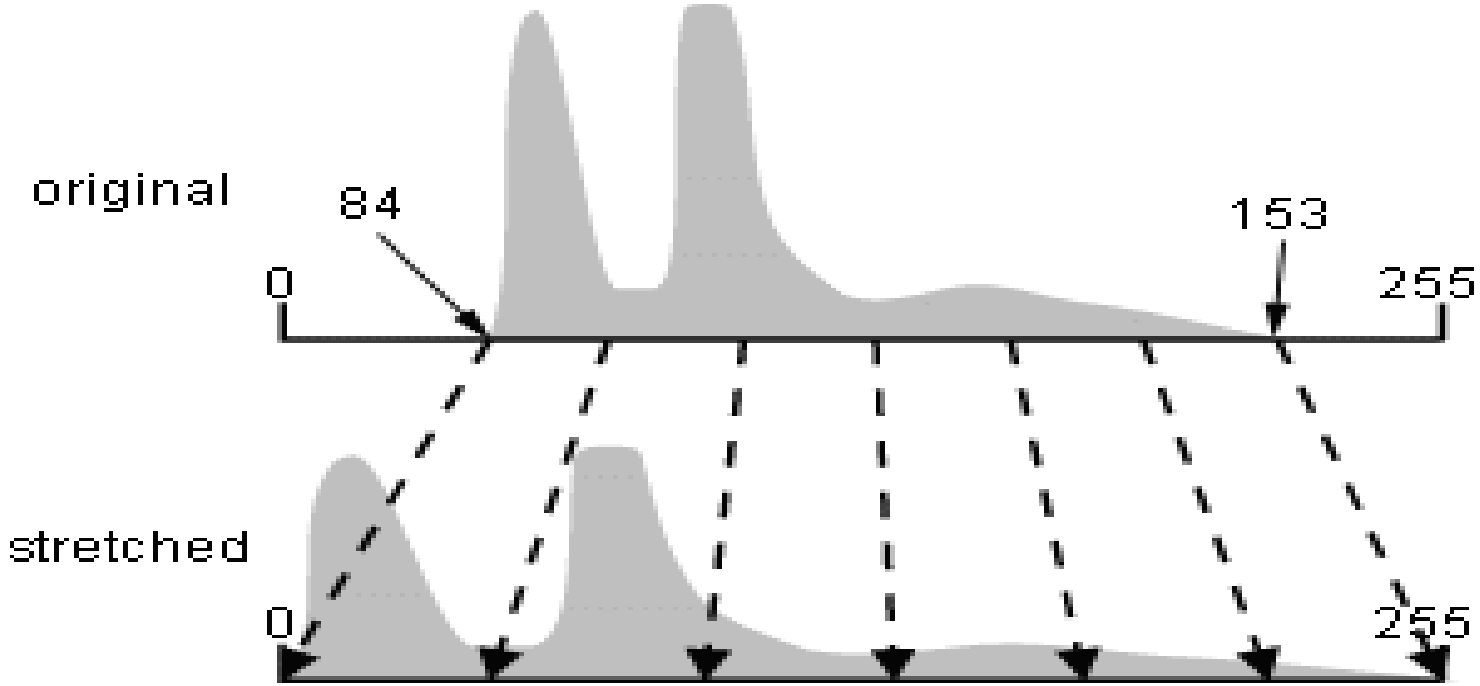
Contrast enhancement



Contrast enhancement

Histogram Stretching

Increasing the contrast of an image



Contrast enhancement

Histogram Stretching

Increasing the contrast of an image

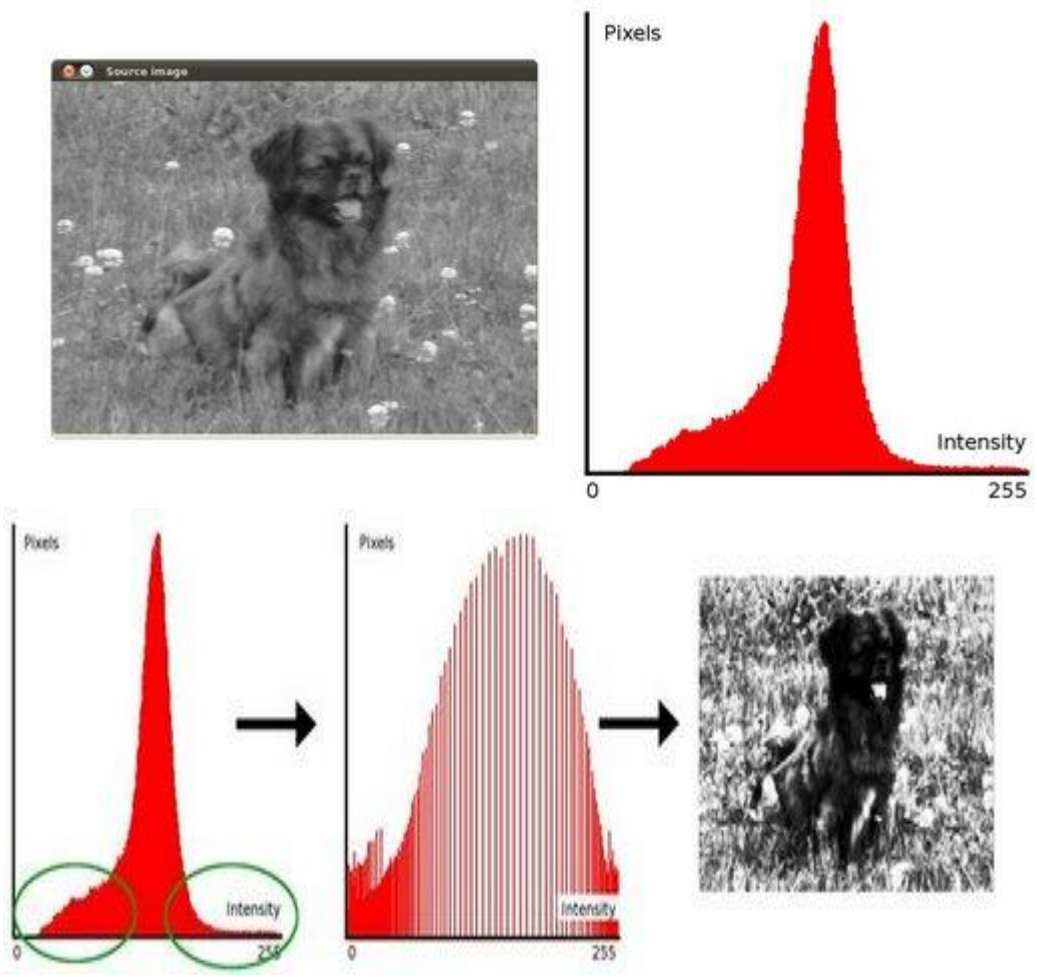
$$g(x,y) = \frac{f(x,y)-fmin}{fmax-fmin} * 2^{bpp}$$

$$g(x,y) = \frac{f(x,y)-0}{225-0} * 255$$

Contrast enhancement

Histogram Equalization

- a technique to adjust contrast levels and expand the intensity range in a digital image.
- Thus, it enhances the image which makes information extraction and further image processing easier.



Histogram Equalization

1. Convert the input image into a grayscale image
2. Find frequency of occurrence for each pixel value i.e. histogram of an image (values lie in the range [0, 255] for any grayscale image)
3. Calculate Cumulative frequency of all pixel values
4. Divide the cumulative frequencies by total number of pixels and multiply them by maximum graycount (pixel value) in the image

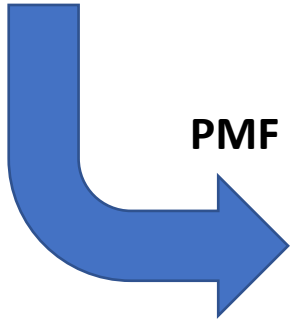
For example, consider an image having total 25 pixels having 8 distinct pixel values. All the steps have been applied to the histogram of the original image.

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Cumulative frequency	0	0	0	$\frac{6}{25}$	$\frac{20}{25}$	$\frac{25}{25}$	$\frac{25}{25}$	$\frac{25}{25}$
Result of multiplication	0	0	0	2	6	7	7	7

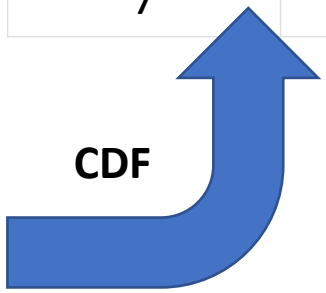
PMF – Probability mass function
CDF = Cumulative density function

1	2	7	5	6
7	2	3	4	5
0	1	5	7	3
1	2	5	6	7
6	1	0	3	4

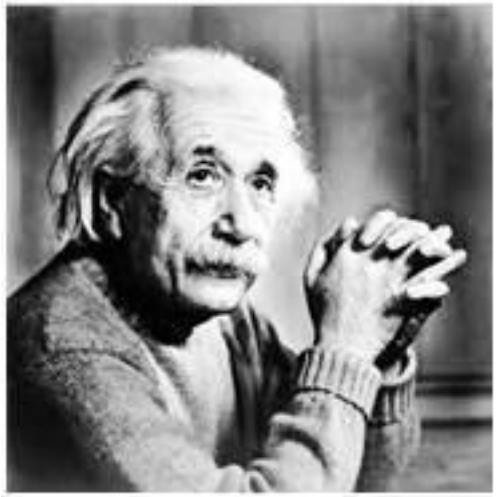
Image pixel values

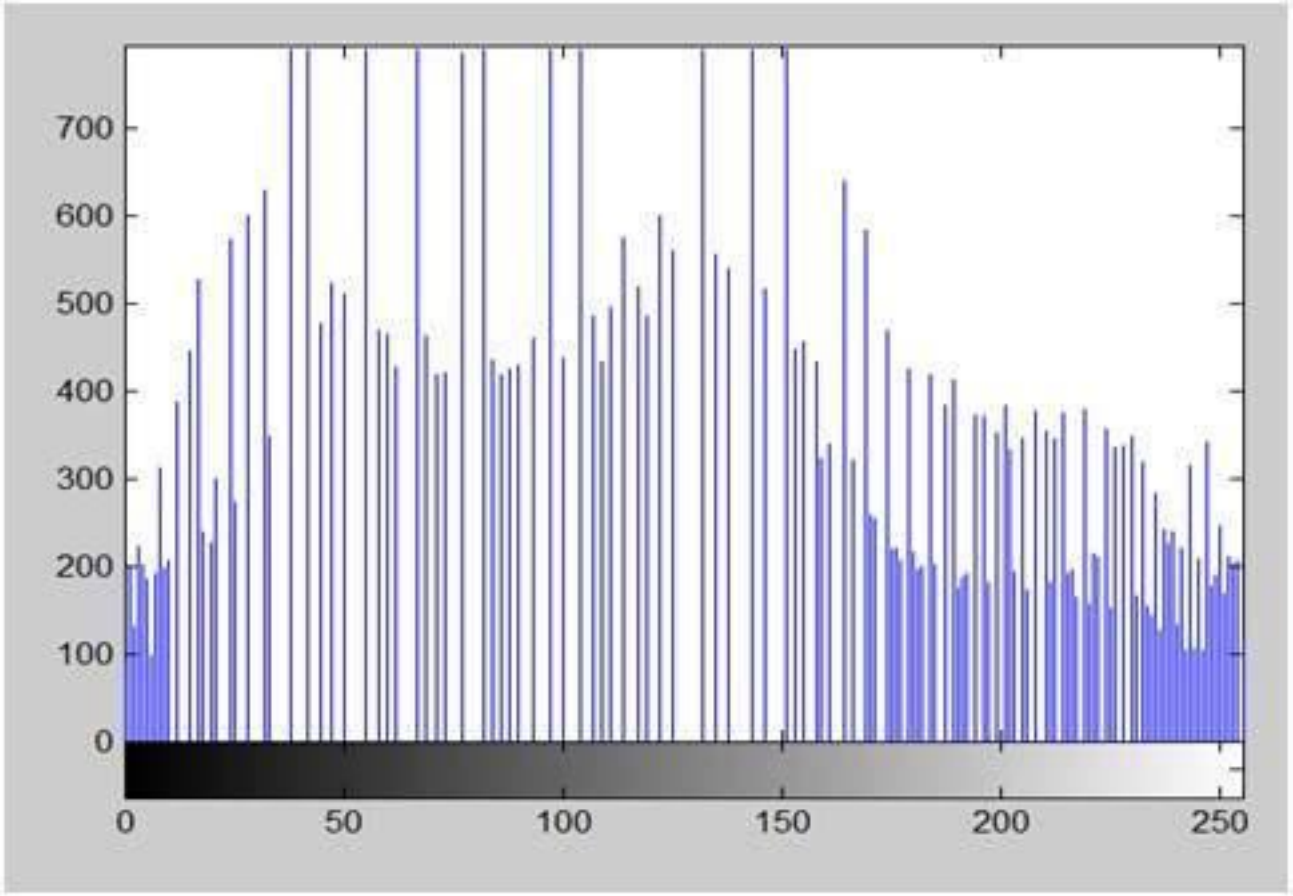


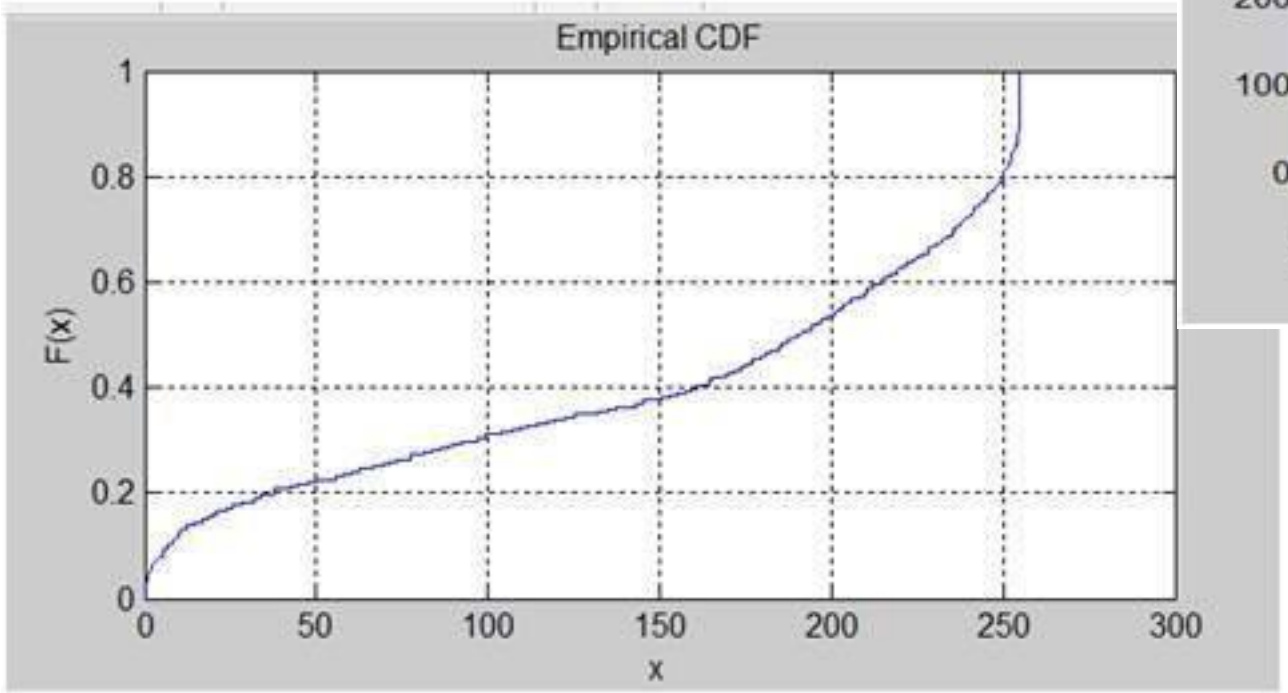
Pixel	Count	P
0	2	2/25
1	4	4/25
2	3	3/25
3	3	3/25
4	2	2/25
5	4	4/25
6	3	3/25
7	4	4/25



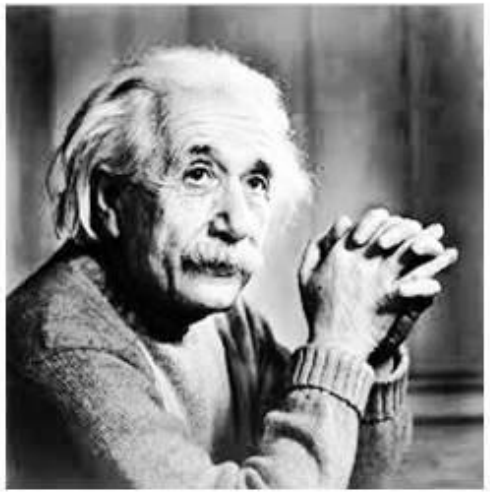
Gray Level Value	CDF	CDF * (Levels-1) = CDF*7
0	0.11	0
1	0.22	1
2	0.55	3
3	0.66	4
4	0.77	5
5	0.88	6
6	0.99	6
7	1	7



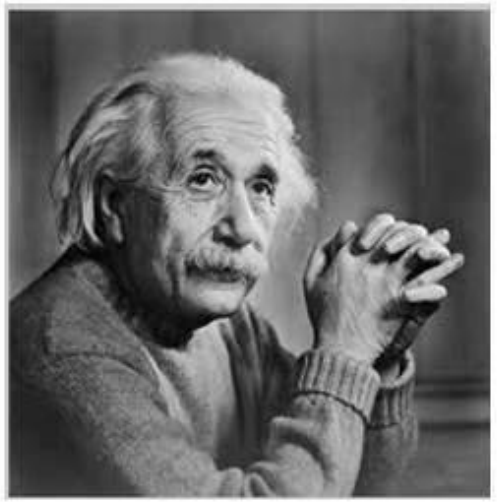

700
600
500
400
300
200
100
0
0
50
100
150
200
250


Empirical CDF
F(x)
x
0
0.2
0.4
0.6
0.8
1
0
50
100
150
200
250
300

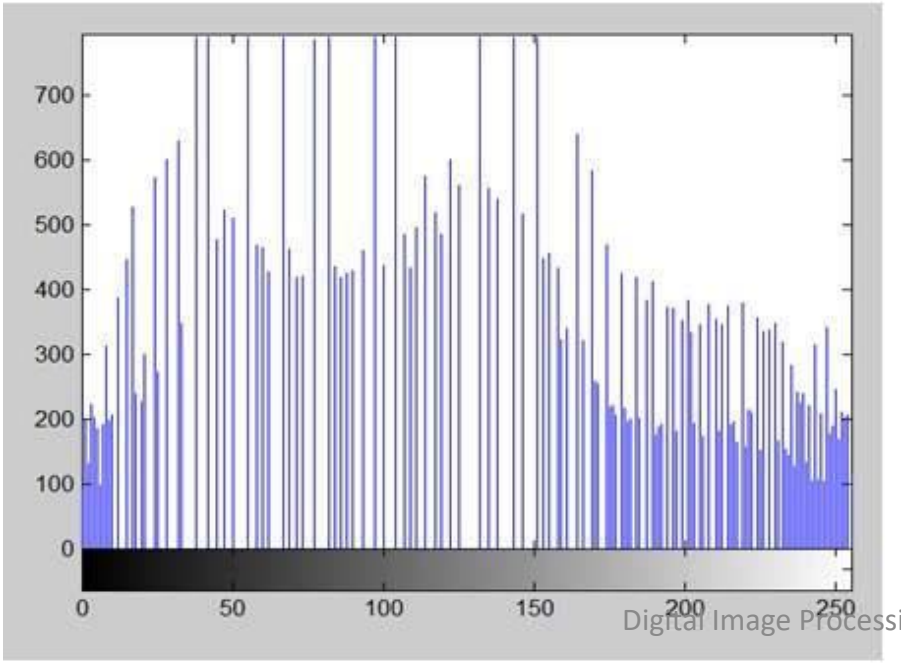
New Image



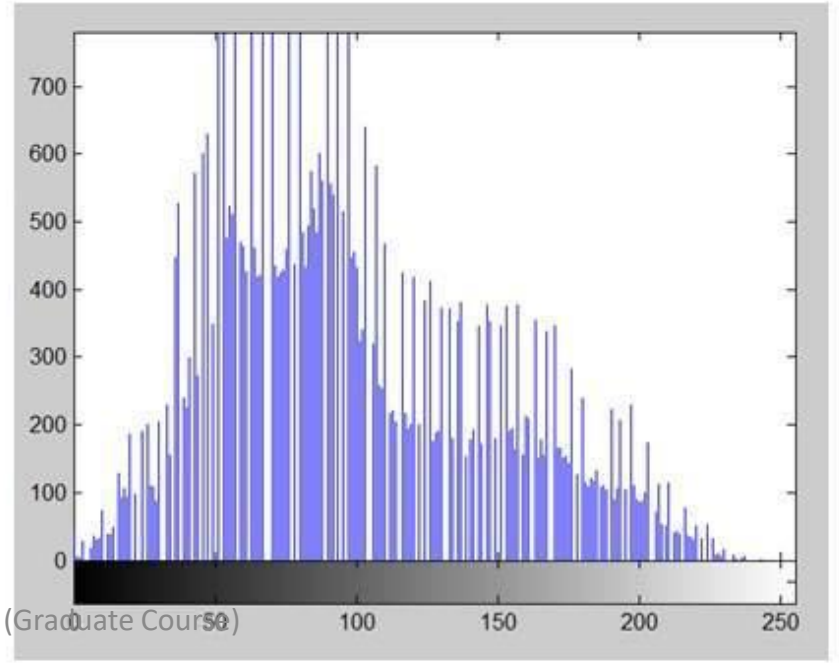
Old image



New Histogram



Old Histogram



Example

(a)

0	1	3	4
1	2	2	3
1	3	4	4
3	2	5	2

(b)

i	$\hat{h}_i$	$\hat{C}_i$	$7\hat{C}_i$
0	1/16	1/16	0
1	3/16	4/16	2
2	4/16	8/16	4
3	4/16	12/16	5
4	3/16	15/16	7
5	1/16	16/16	7
6	0/16	16/16	7
7	0/16	16/16	7

(c)

0	2	5	7
2	4	4	5
2	5	7	7
5	4	7	4

(d)

i	$\hat{h}_i$
0	1/16
1	0/16
2	3/16
3	0/16
4	4/16
5	4/16
6	0/16
7	4/16

Figure 5.9. Numerical example of histogram equalization: (a) a 3-bit image, (b) normalized histogram and CDF, (c) the equalized image, and (d) histogram of the result.

Exercise

N Bit?

1	8	4	3	4
1	1	1	7	8
8	8	3	3	1
2	2	1	5	2
1	1	8	5	2

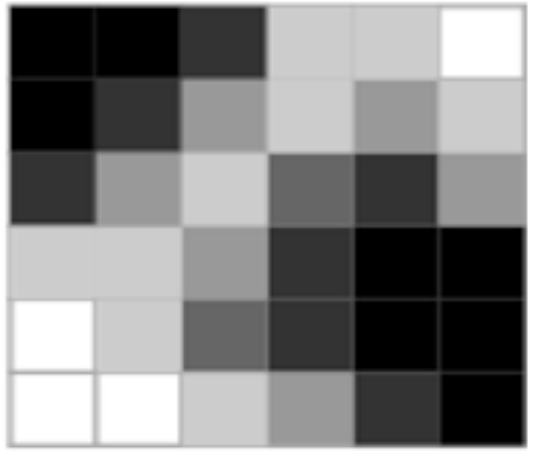
8 Bit?

$$\begin{bmatrix} 52 & 55 & 61 & 66 & 70 & 61 & 66 & 70 \\ 62 & 60 & 54 & 90 & 108 & 85 & 67 & 71 \\ 63 & 65 & 66 & 110 & 140 & 104 & 63 & 72 \\ 64 & 70 & 70 & 120 & 152 & 106 & 71 & 69 \\ 67 & 75 & 68 & 106 & 124 & 88 & 68 & 68 \\ 68 & 80 & 60 & 72 & 77 & 66 & 58 & 75 \\ 69 & 85 & 64 & 58 & 55 & 61 & 65 & 83 \\ 70 & 90 & 69 & 68 & 65 & 72 & 78 & 90 \end{bmatrix}$$

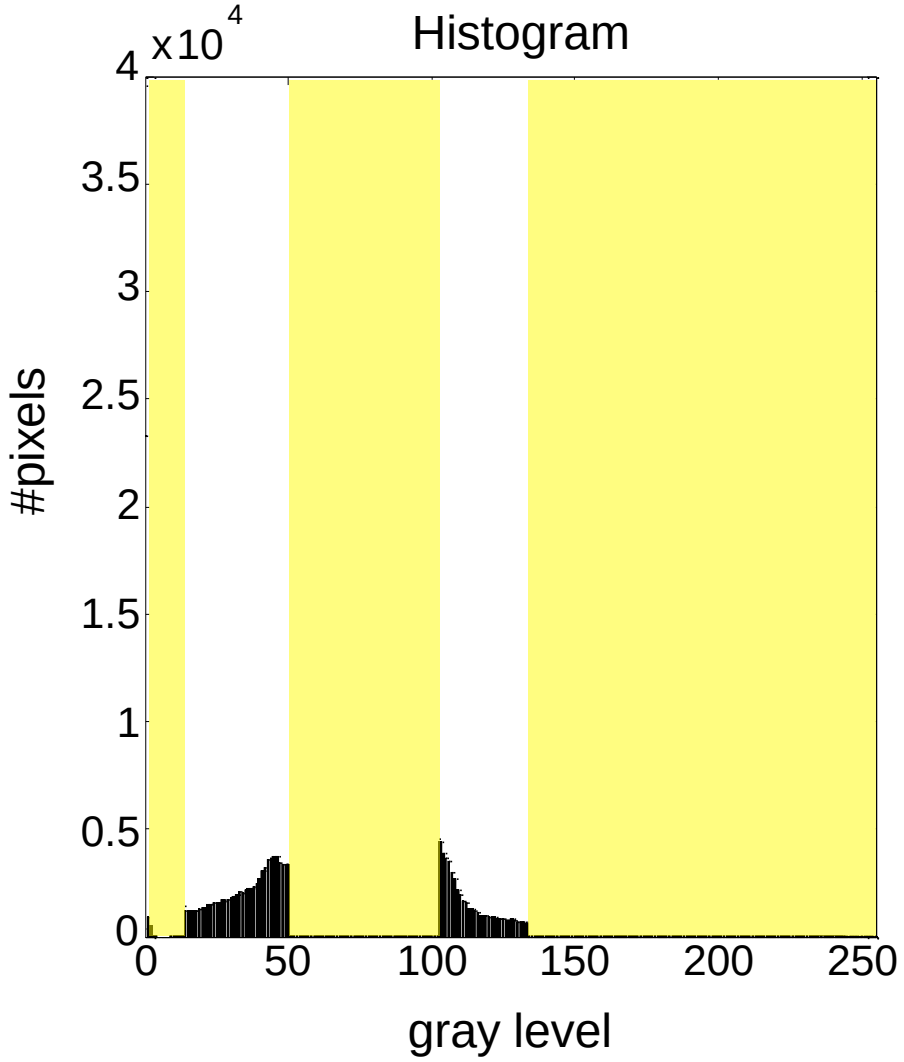
Exercise

Histogram Equalization

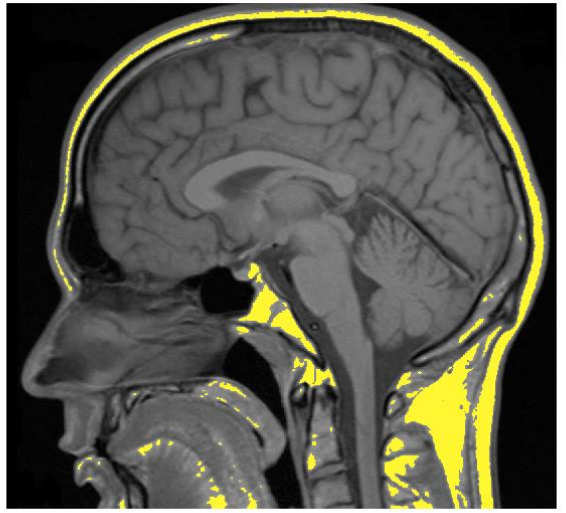
0	0	1	4	4	5
0	1	3	4	3	4
1	2	4	2	1	3
4	4	3	1	0	0
5	4	2	1	0	0
5	5	4	3	1	0



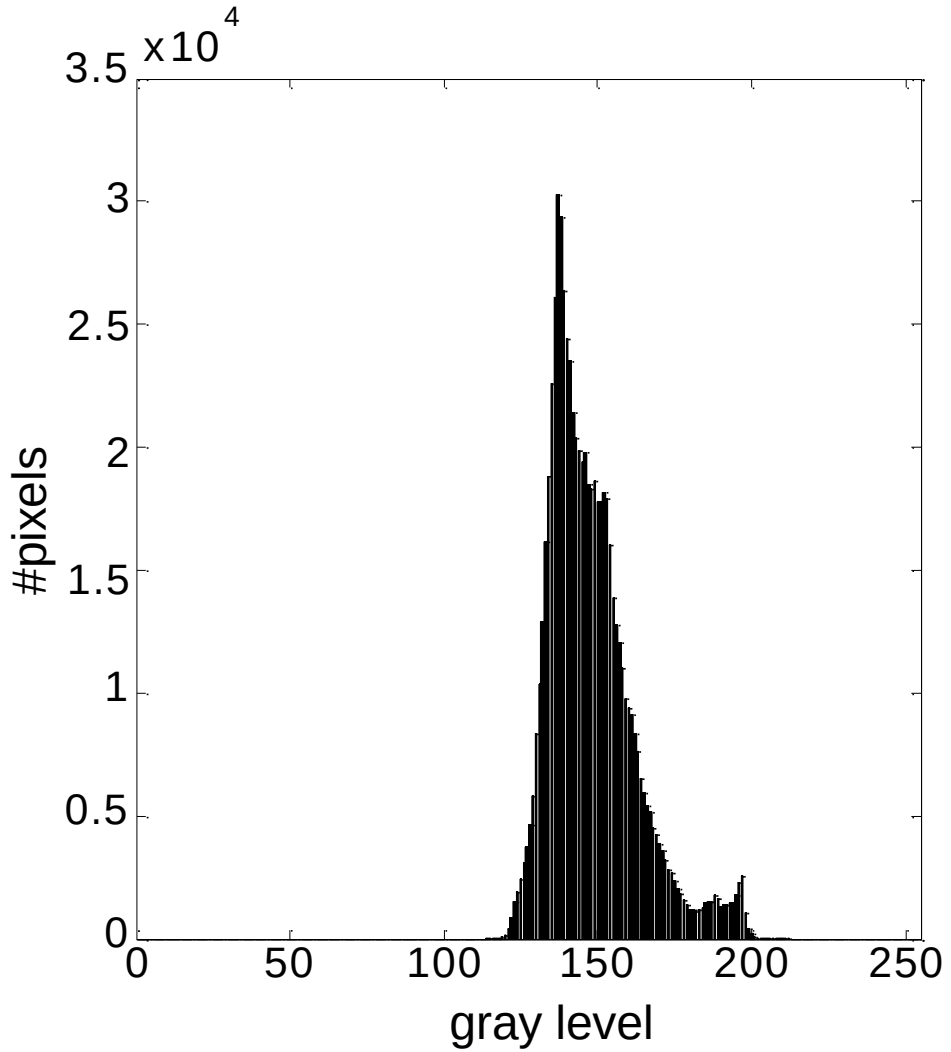
Gray level histograms



Brain image



Gray level histograms



Bay image

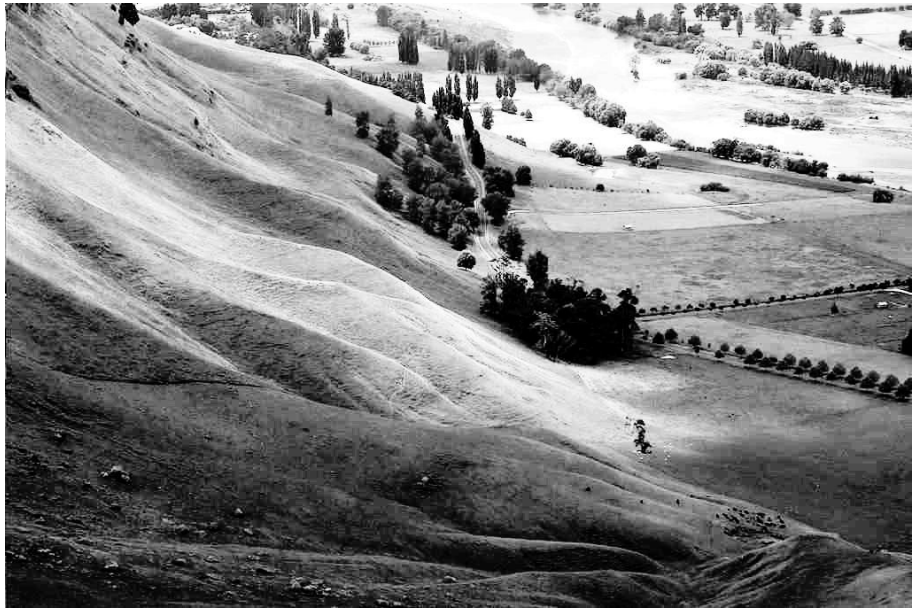
Gray level histogram in viewfinder

Gray level histograms

- To measure a histogram:
  - For B-bit image, initialize 2^B counters with 0
  - Loop over all pixels x,y
  - When encountering gray level $f[x,y]=i$, increment counter $\#i$
- Normalized histogram can be thought of as an estimate of the probability distribution of the continuous signal amplitude
- Use fewer, larger bins to trade off amplitude resolution against sample size.

Histogram equalization example

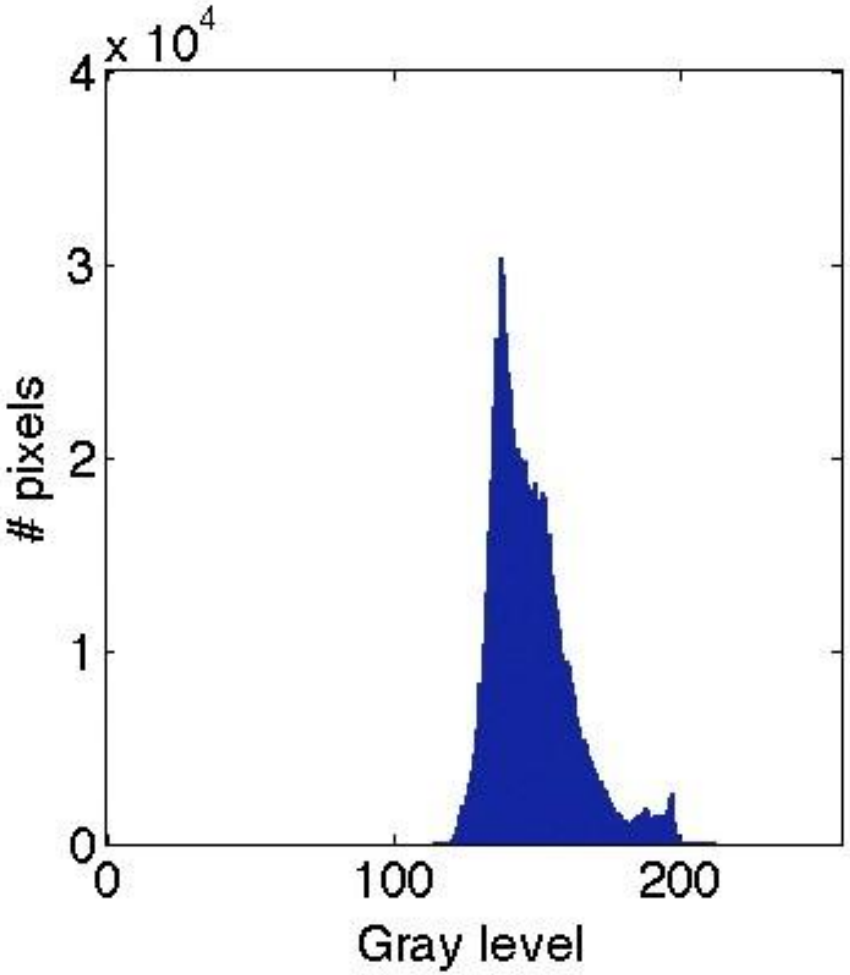
Original image *Bay*



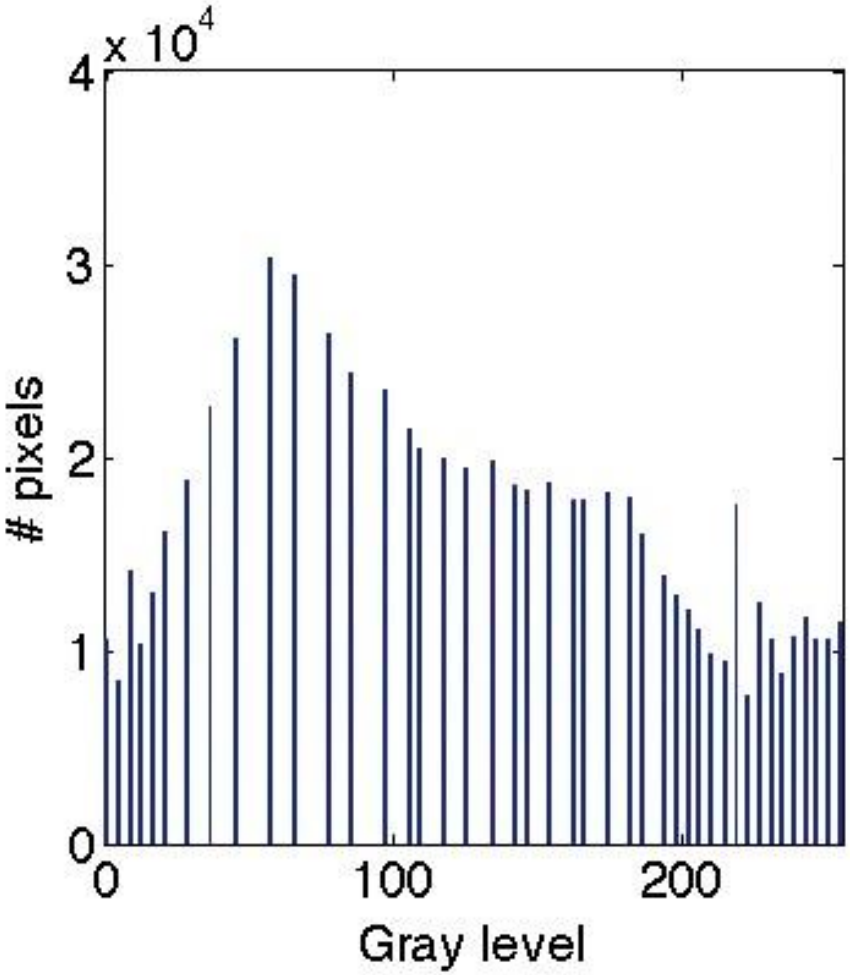
... after histogram equalization

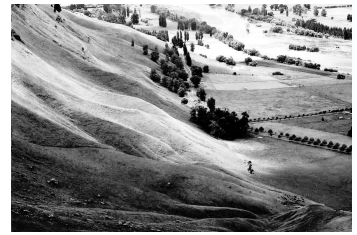
Histogram equalization example

Original image *Bay*

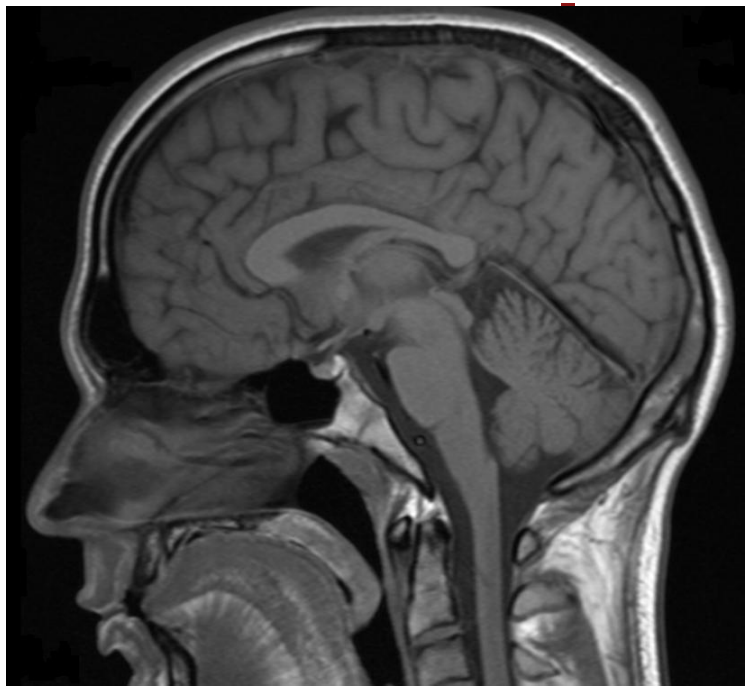


. . . after histogram equalization

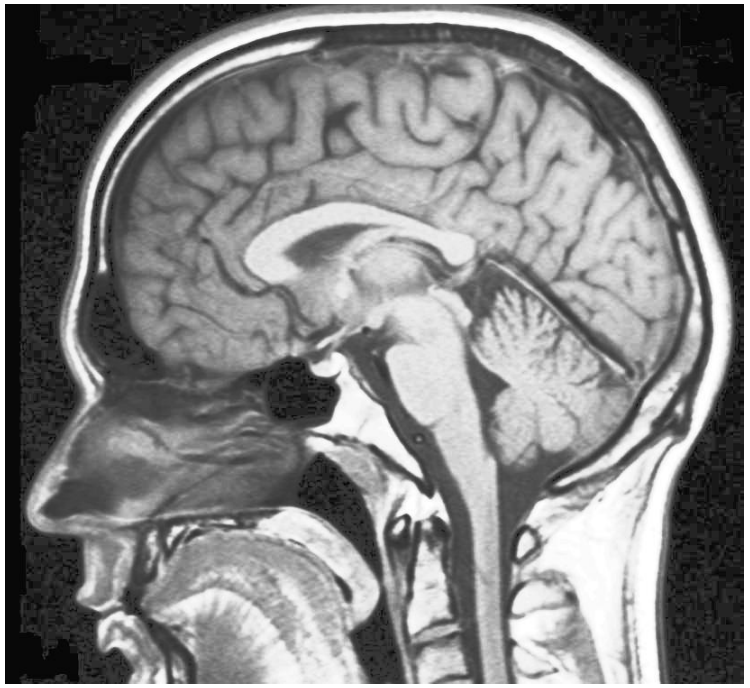




Histogram equalization



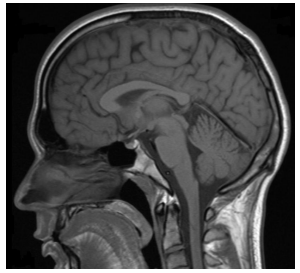
Original image *Brain*

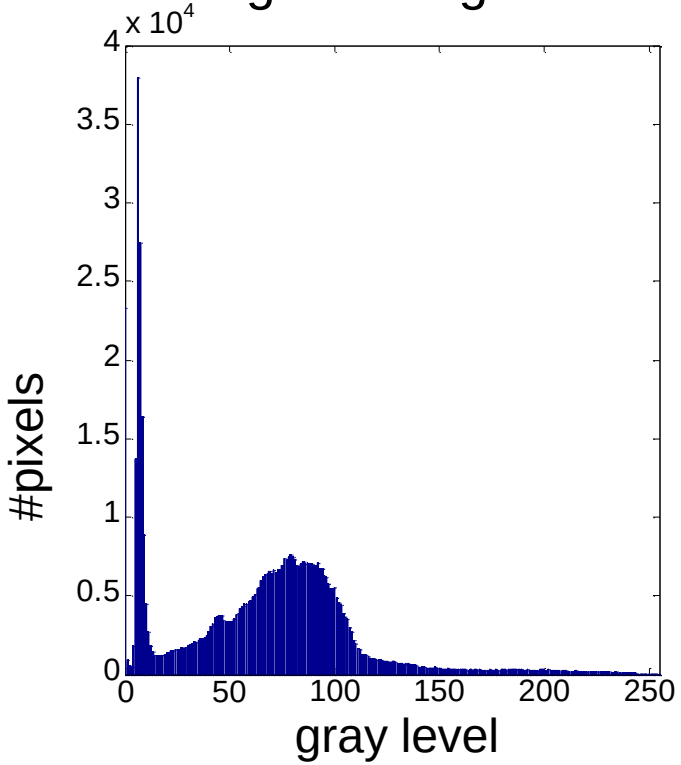


... after histogram equalization

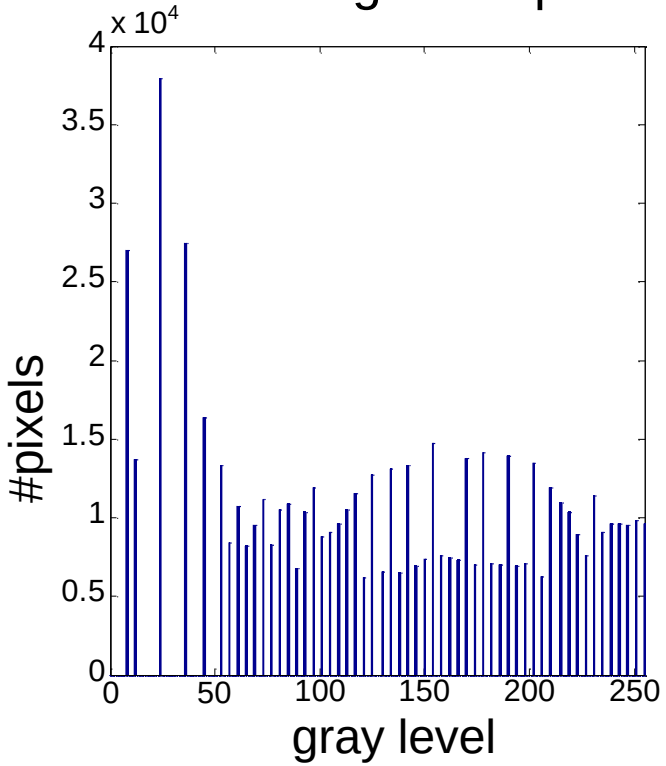
Histogram equalization example

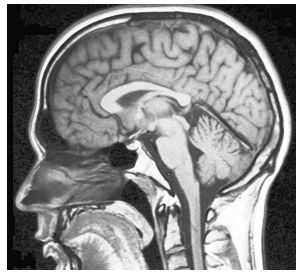
Original image *Brain*





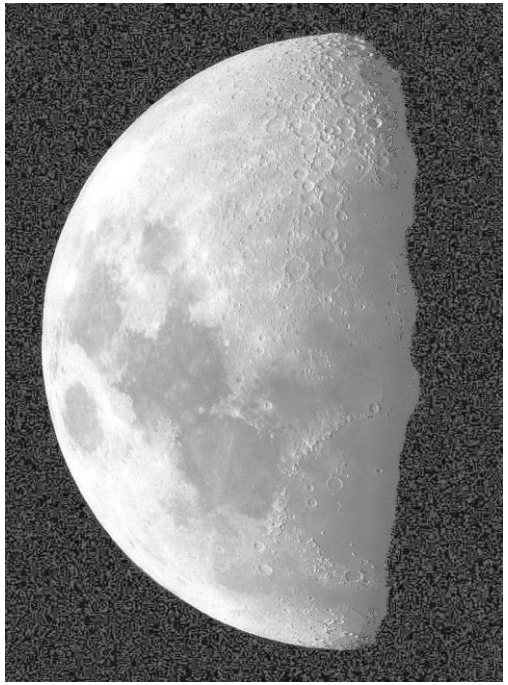
. . . after histogram equalization





Histogram equalization

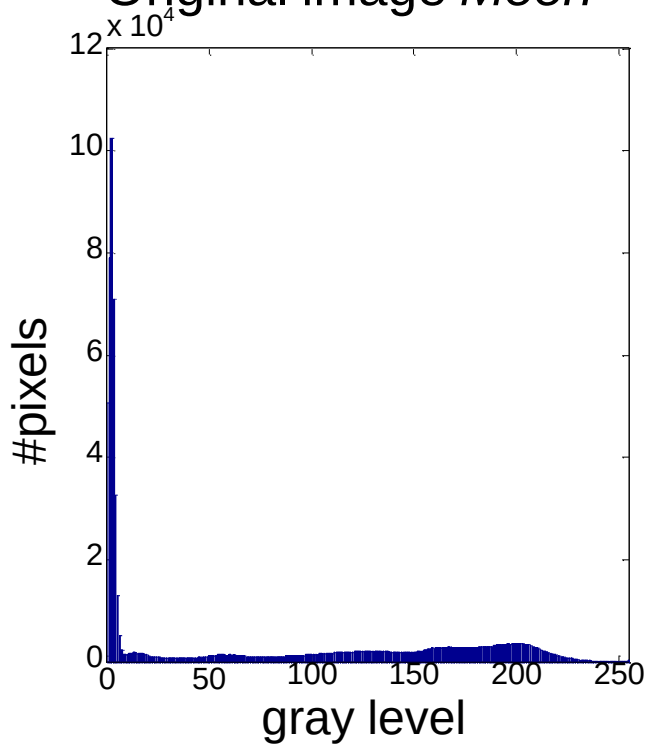
Original image *Moon*



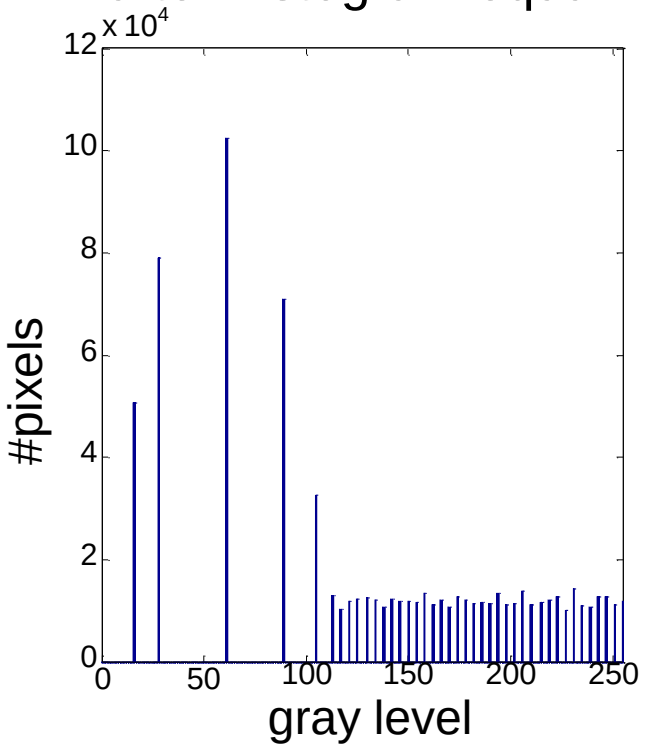
... after histogram equalization

Histogram equalization example

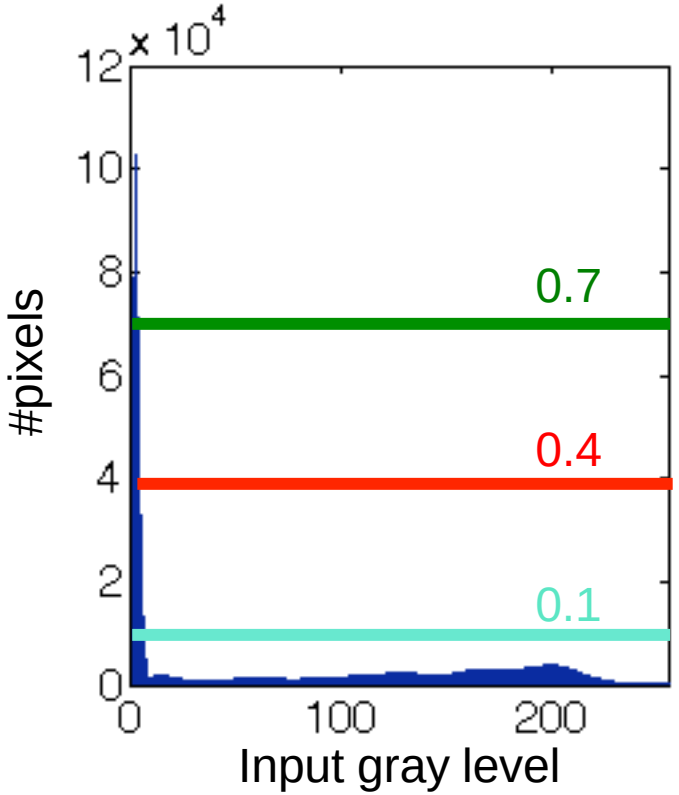
Original image *Moon*

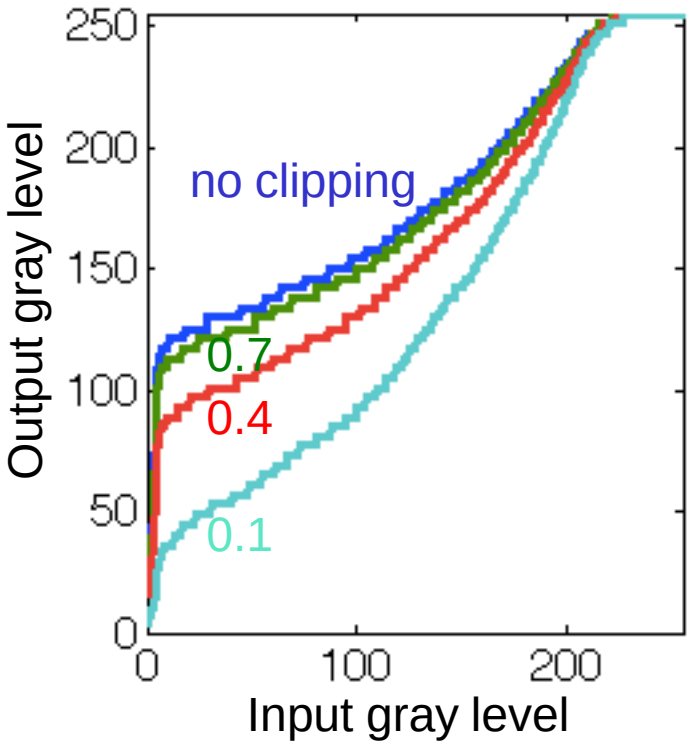


. . . after histogram equalization



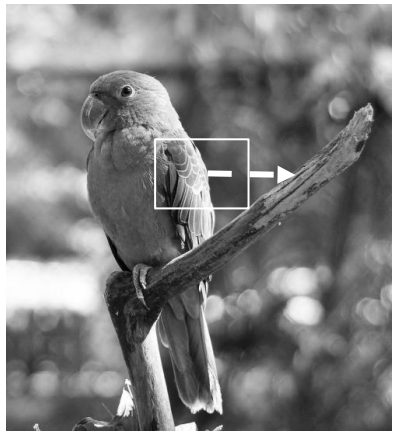
Contrast-limited histogram



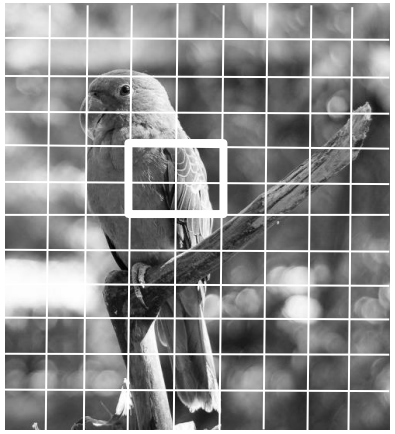


Adaptive histogram equalization

- Histogram equalization based on a histogram obtained from a portion of the image



Sliding window approach:
different histogram (and mapping) for every pixel



Tiling approach:
subdivide into overlapping regions, mitigate blocking effect by smooth blending between neighboring tiles

- Limit contrast expansion in flat regions of the image, e.g., by clipping histogram values.
  ("Contrast-limited adaptive histogram equalization")

[Pizer, Amburn et al. 1987]

Adaptive histogram equalization

Original image
Parrot

Global histogram equalization

Adaptive histogram equalization, 8x8 tiles

Adaptive histogram equalization, 16x16 tiles

Adaptive histogram equalization

Original image
Dental Xray

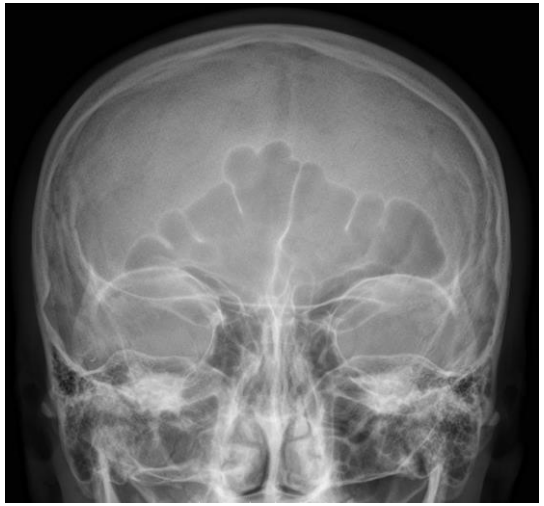
Global histogram equalization

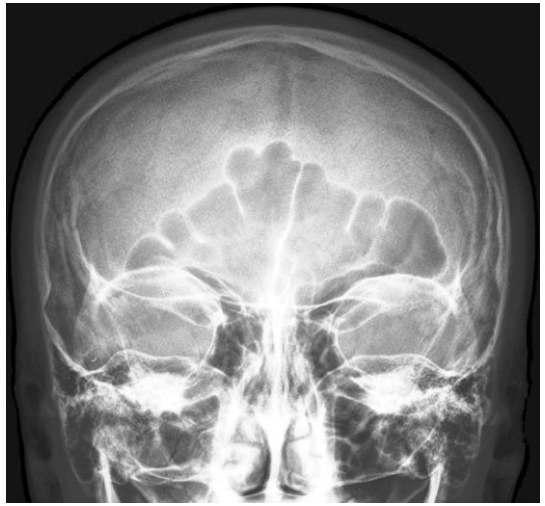
Adaptive histogram equalization, 8x8 tiles

Adaptive histogram equalization, 16x16 tiles

Adaptive histogram equalization

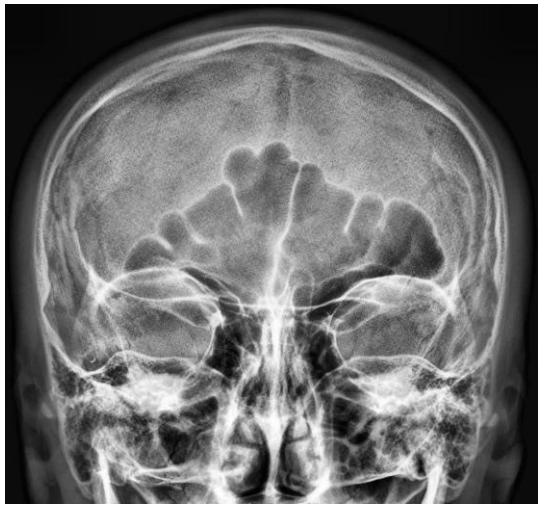
Original image
Skull Xray

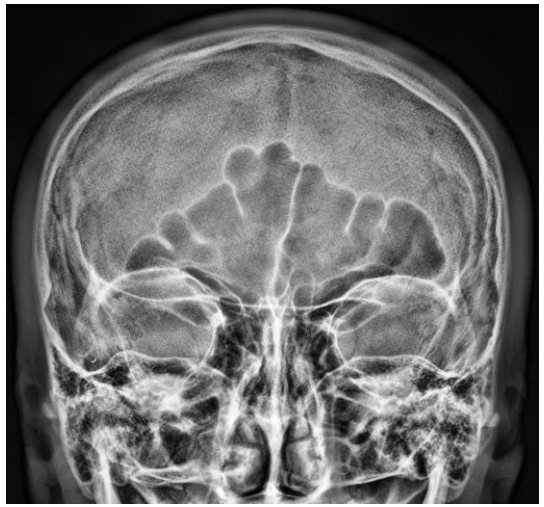




Global histogram equalization

Adaptive histogram equalization, 8x8 tiles





Adaptive histogram equalization, 16x16 tiles