IIT Bombay

Computer Programming

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Session: Digital Images and Histograms

Quick Recap

- We have seen several computational problems involving matrices
- The main challenges are
  - Representation of problem data by matrices
  - Manipulation of index values for rows and columns of matrices

Overview

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- Images are routinely stored and processed digitally
- We will study
  - The basic image representation using a matrix
  - Simple processing of a digital image to enhance the contrast

[Note: The histogram equalization technique described here, and the digital images used are directly based on a wikipedia article:

http://en.wikipedia.org/wiki/Histogram_equalization]

Digital Images

- Digital images are a collection of pixel values
  - Pixel: A Picture element. Value represents light intensity
- These are arranged in a matrix form (H x W)
- Each pixel value can be represented by
  - 1 bit (m : monochrome, 0 or 1 value, e.g. black and white)
  - 8 bits (g : grayscale, 0 black to 255 white)
  - 24 bits (c: Red, Blue, Green, each one byte)
- One can have 16 million colours!
  - Capacity of a human eye is limited to a small range from 200 to 2000 colours

Digital Images

- Information about an image in a file,
- Such a file has some header information
  - We need values of Height, Width,
  - The type of colors present
- Values for each pixel in the image, for every colour present

Digital Images

- Monochrome (grayscale) fingerprint images have small size
  - (500 x 300) bytes
- For large images, compression is necessary
  - to keep the file size within limits
  - 12 M pixel camera can produce 36 M bytes in an image
- Compression can be either lossy or lossless
- Several file formats have evolved

  raw, png, bmp, tiff, gif, jpeg, xmp
- Refer to wikipedia (Image_file_formats)

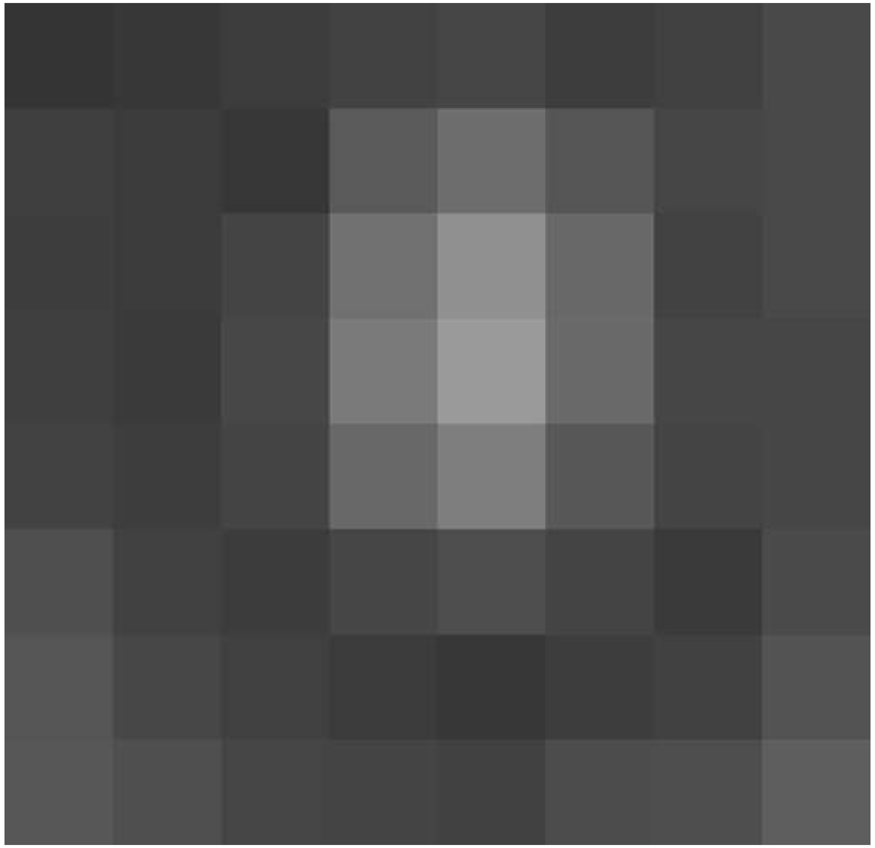
Digital Images

- Pixel values of digital images can be read in a matrix
  - Matrix elements can be processed further
- Thus each element of a matrix for a grayscale image would contain a value between 0 and 255
  - type/size short int or char (1 byte)

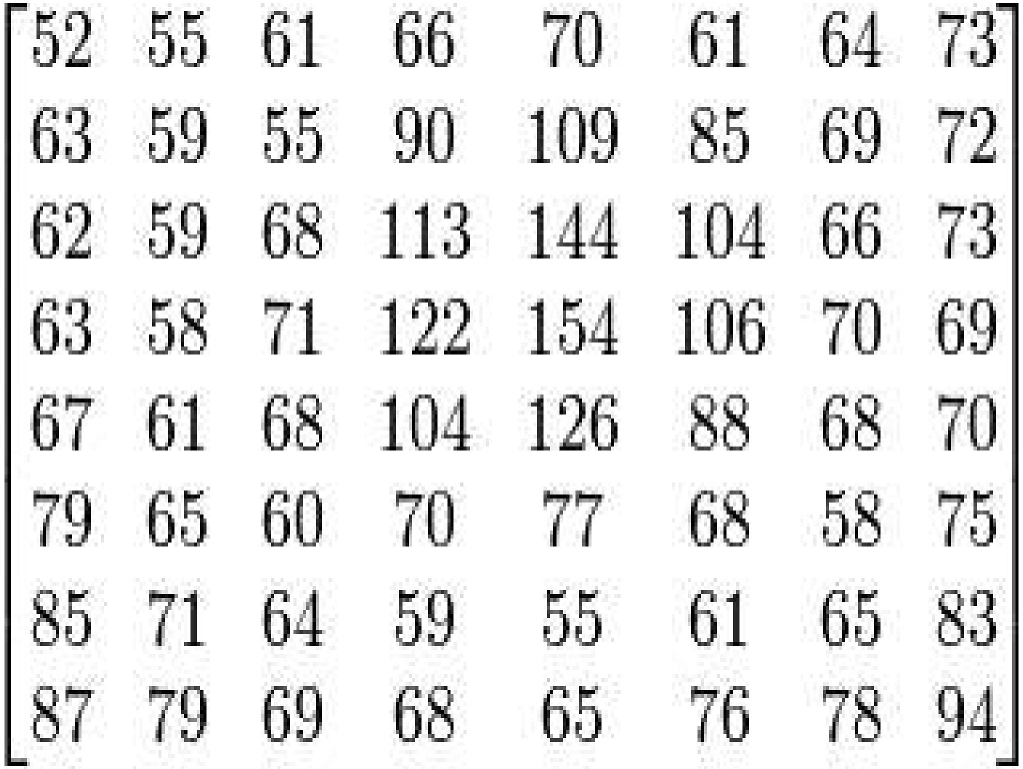
Histogram

- Histogram is a term from statistics, used to denote frequencies or count of number of times an event or incidence occurs
- In case of images, a histogram table indicates how many times a particular value occurs in the image pixels
  - For each possible value, the number of pixels in the image having that value
- Why is histogram important?

A sample image of size 8 pixel x 8 pixel

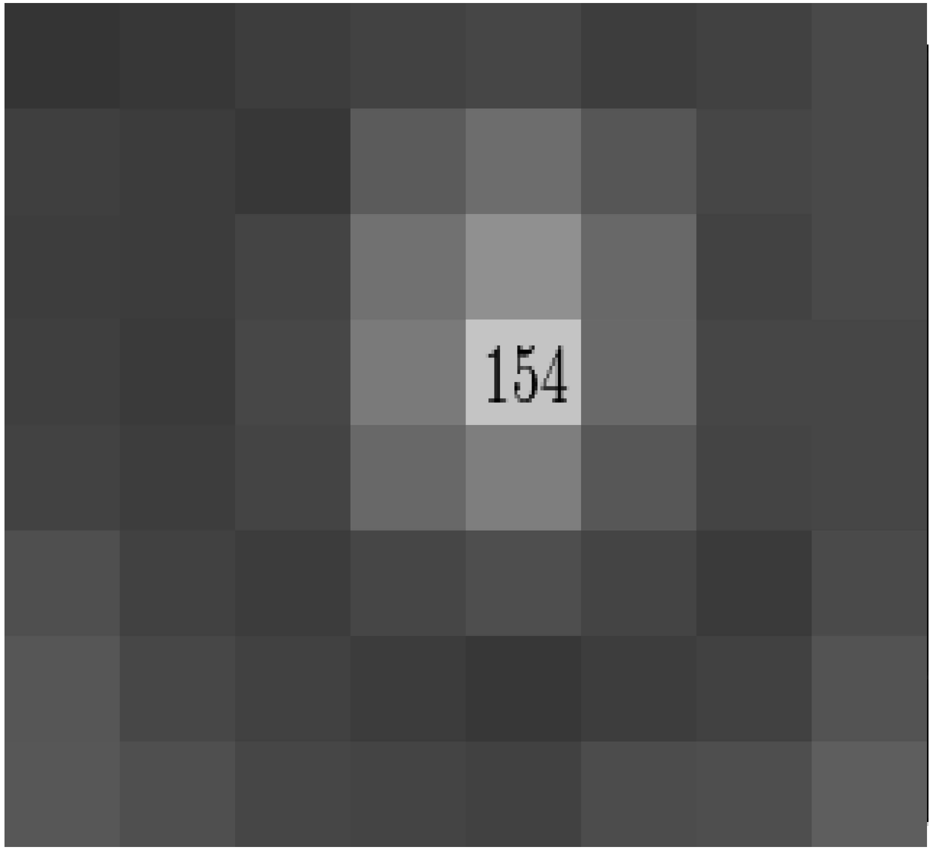


Pixel values for the image



$$\begin{bmatrix} 52 & 55 & 61 & 66 & 70 & 61 & 64 & 73 \\ 63 & 59 & 55 & 90 & 109 & 85 & 69 & 72 \\ 62 & 59 & 68 & 113 & 144 & 104 & 66 & 73 \\ 63 & 58 & 71 & 122 & 154 & 106 & 70 & 69 \\ 67 & 61 & 68 & 104 & 126 & 88 & 68 & 70 \\ 79 & 65 & 60 & 70 & 77 & 68 & 58 & 75 \\ 85 & 71 & 64 & 59 & 55 & 61 & 65 & 83 \\ 87 & 79 & 69 & 68 & 65 & 76 & 78 & 94 \end{bmatrix}$$

Pixel values for the image



Histogram values (shown for non-zero pixels)

Val	n	Val	n	Val	n	Val	n	Val	n
52	1	64	2	72	1	85	2	113	1
55	3	65	3	73	2	87	1	122	1
58	2	66	2	75	1	88	1	126	1
59	3	67	1	76	1	90	1	144	1
60	1	68	5	77	1	94	1	154	1
61	4	69	3	78	1	104	2		
62	1	70	4	79	2	106	1		
63	2	71	2	83	1	109	1		

Values are between 52 and 154. This results in inadequate contrast!

What do we wish to do?

- The histogram is concentrated in a narrow range
  - 52 to 154
- Whereas the possible values of pixels are from 0 to 255
- We can ‘stretch’ the histogram to cover all possible values
  - This is called histogram ‘equalization’
  - We will get a better contrast
- We need to ‘map’ existing pixel values to new values
  - A value ‘v’ should be mapped by a suitable function to h (v)
    [52 should be mapped to 0, 154 should be mapped to 255]
- We use the cumulative distribution function (cdf) of a histogram

Cumulative Distribution Function

V	c	V	c	V	c	V	c	V	c
52	1	64	19	72	40	85	51	113	60
55	4	65	22	73	42	87	52	122	61
58	6	66	24	75	43	88	53	126	62
59	9	67	25	76	44	90	54	144	63
60	10	68	30	77	45	94	55	154	64
61	14	69	33	78	46	104	57		
62	15	70	37	79	48	106	58		
63	17	71	39	83	49	109	59		

Histogram Equalization

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- The equalization formula to calculate new value for any existing pixel value v

$$h(v) = \mathrm{round}\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L-1)\right)$$

- “Equalization” formula for example image
  - L = 256, M = N = 8, minimum cdf is 1

$$h(v) = \mathrm{round}\left(\frac{cdf(v) - 1}{63} \times 255\right)$$

Histogram Equalization …

- For example, the cdf of 78 is 46
  - So a pixel value 78 will be ‘equalized’ using the formula:

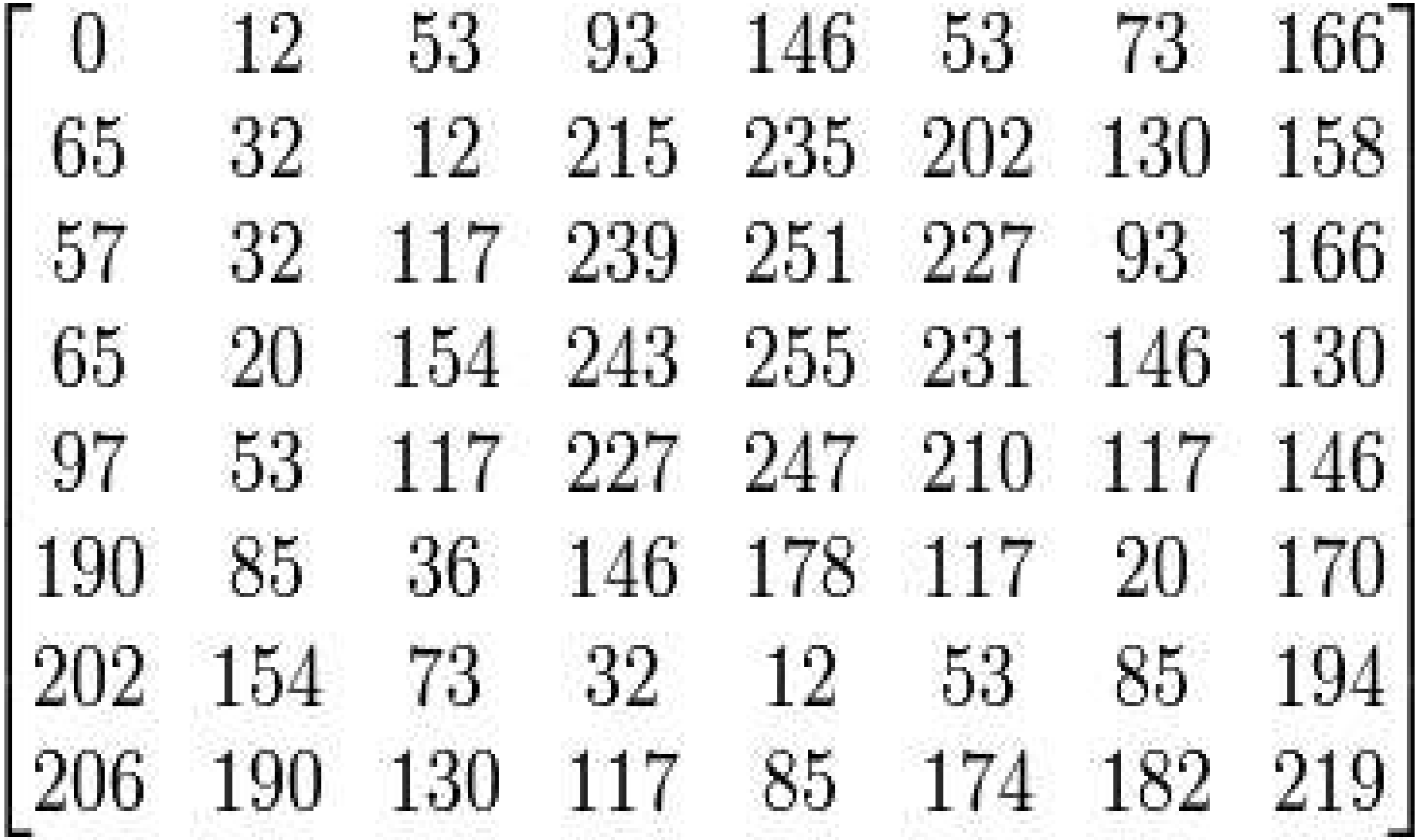
H(78) = round ((46 -1)/63) * 255) =

= round (0.714286 * 255)

= 182

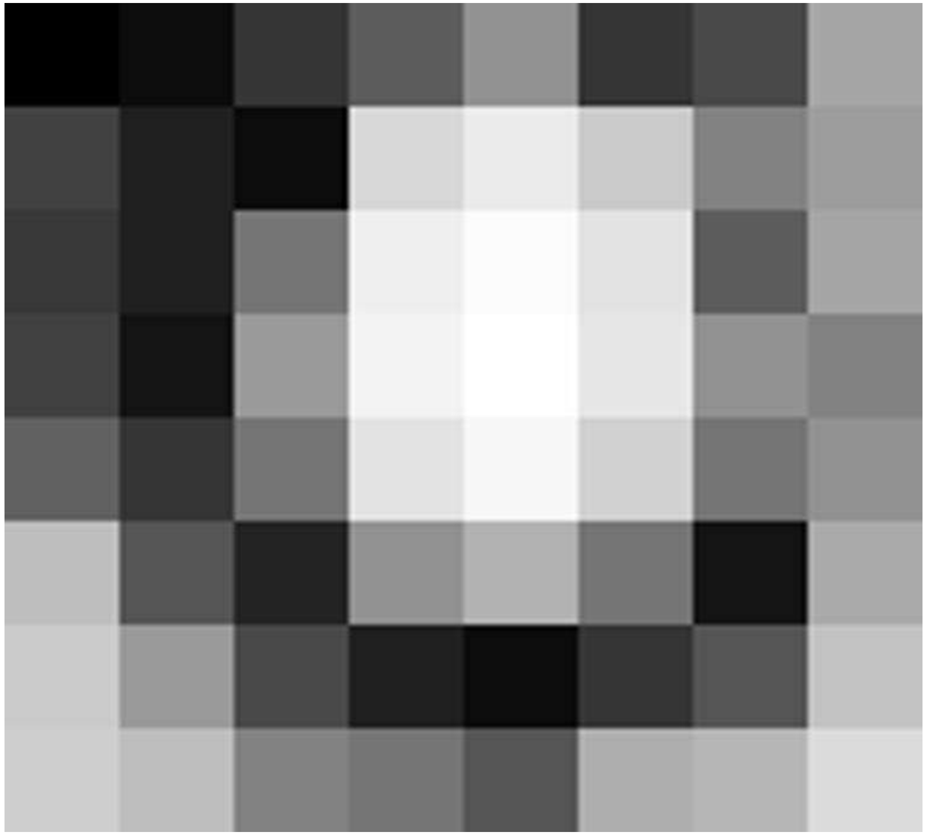
  - This will give us a new ‘equalized’ value
  - Each pixel in the image, which has a value 78, will now have this new value
- We calculate such new value for each pixel

Pixel values after histogram equalization

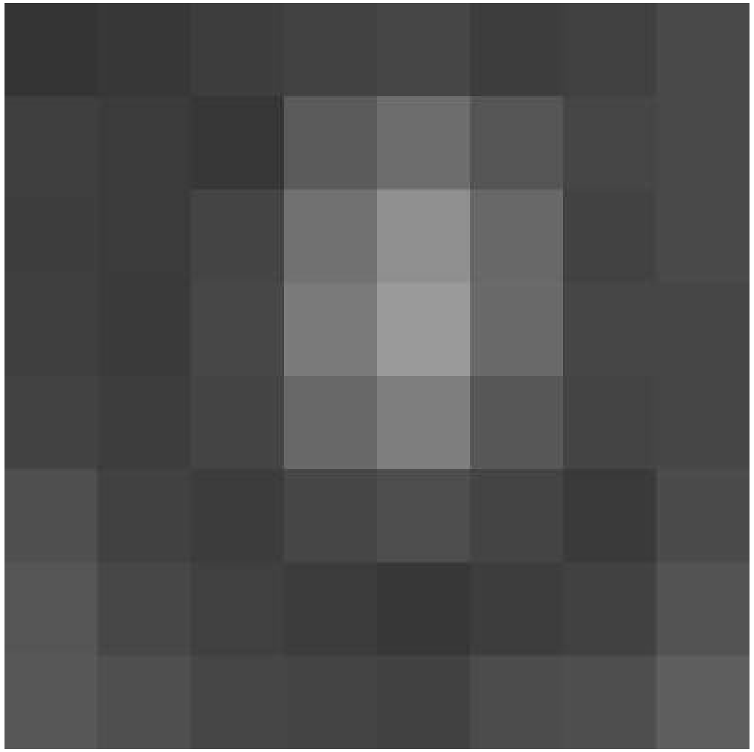


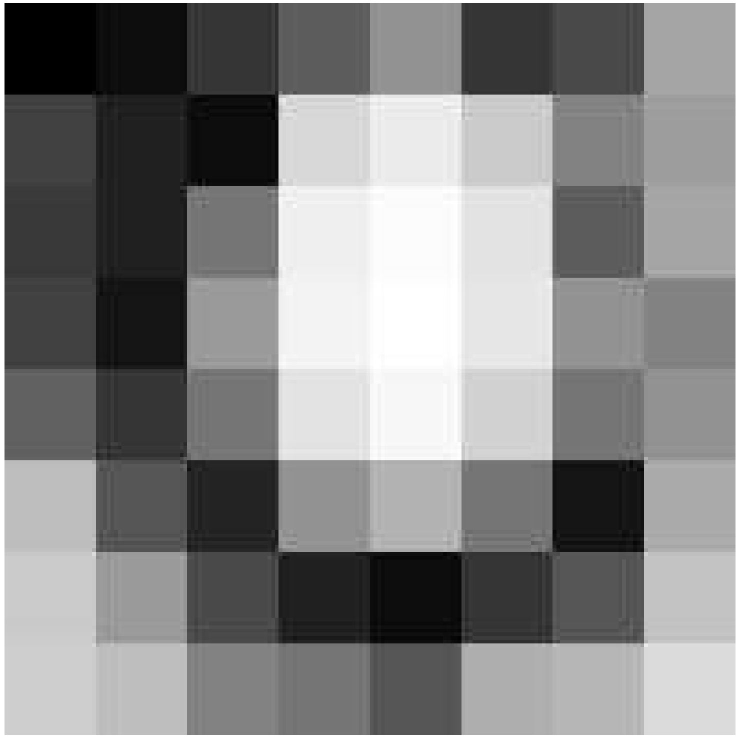
$$\begin{bmatrix} 0 & 12 & 53 & 93 & 146 & 53 & 73 & 166 \\ 65 & 32 & 12 & 215 & 235 & 202 & 130 & 158 \\ 57 & 32 & 117 & 239 & 251 & 227 & 93 & 166 \\ 65 & 20 & 154 & 243 & 255 & 231 & 146 & 130 \\ 97 & 53 & 117 & 227 & 247 & 210 & 117 & 146 \\ 190 & 85 & 36 & 146 & 178 & 117 & 20 & 170 \\ 202 & 154 & 73 & 32 & 12 & 53 & 85 & 194 \\ 206 & 190 & 130 & 117 & 85 & 174 & 182 & 219 \end{bmatrix}$$

Contrast Enhancement



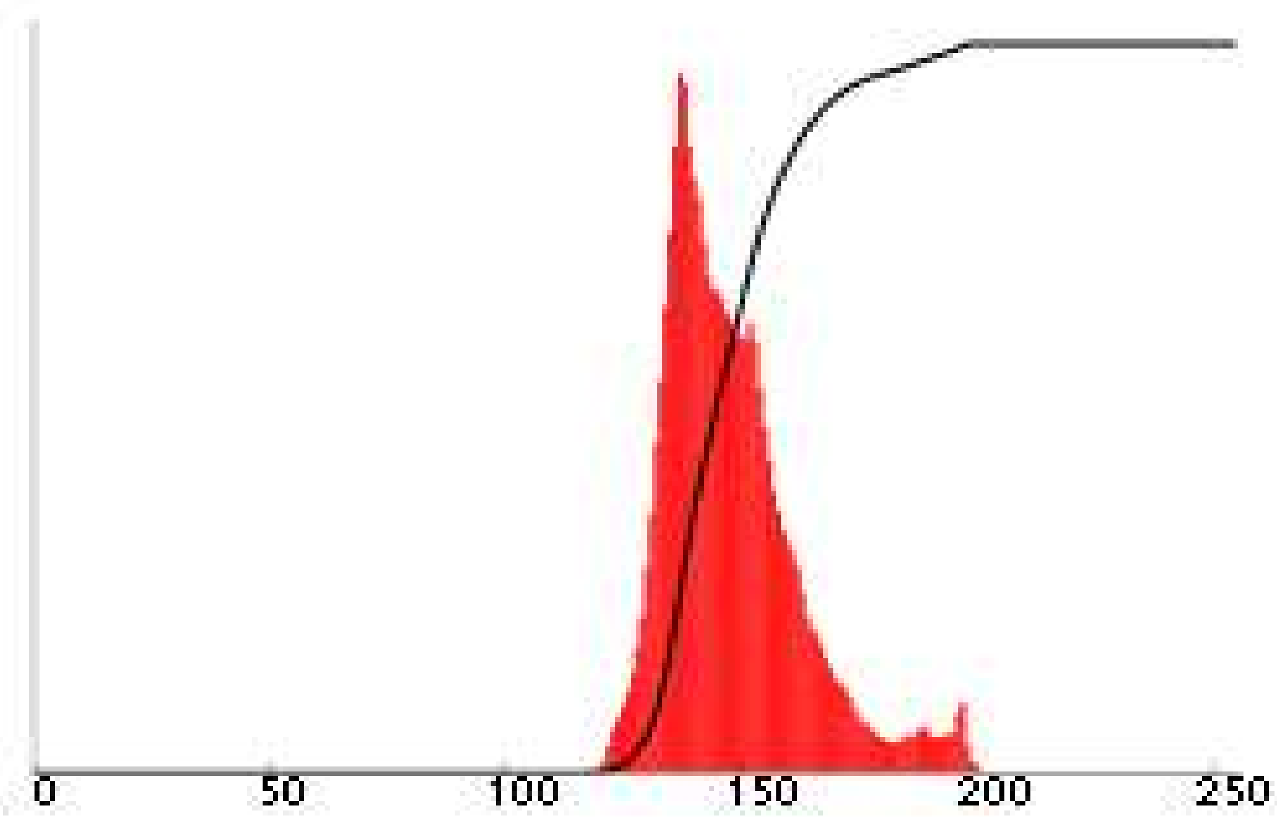
Original and new pictures for comparison



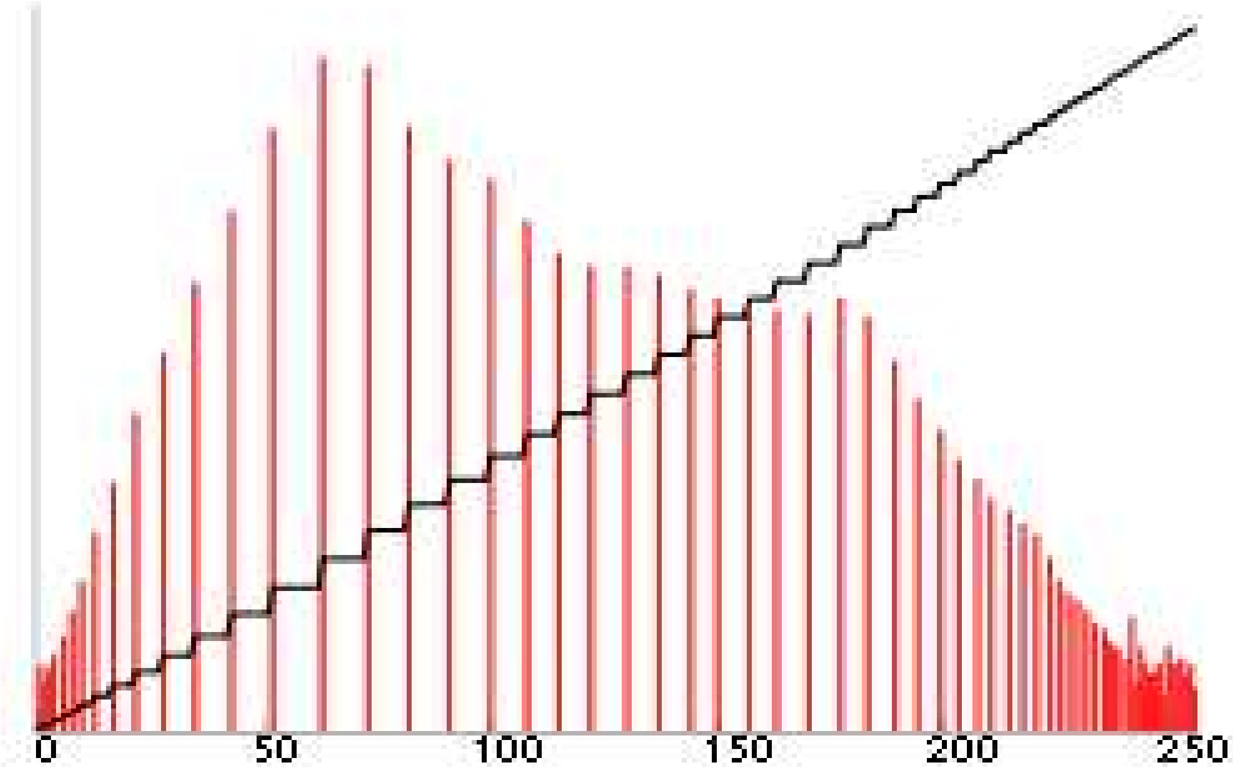


Another grayscale picture

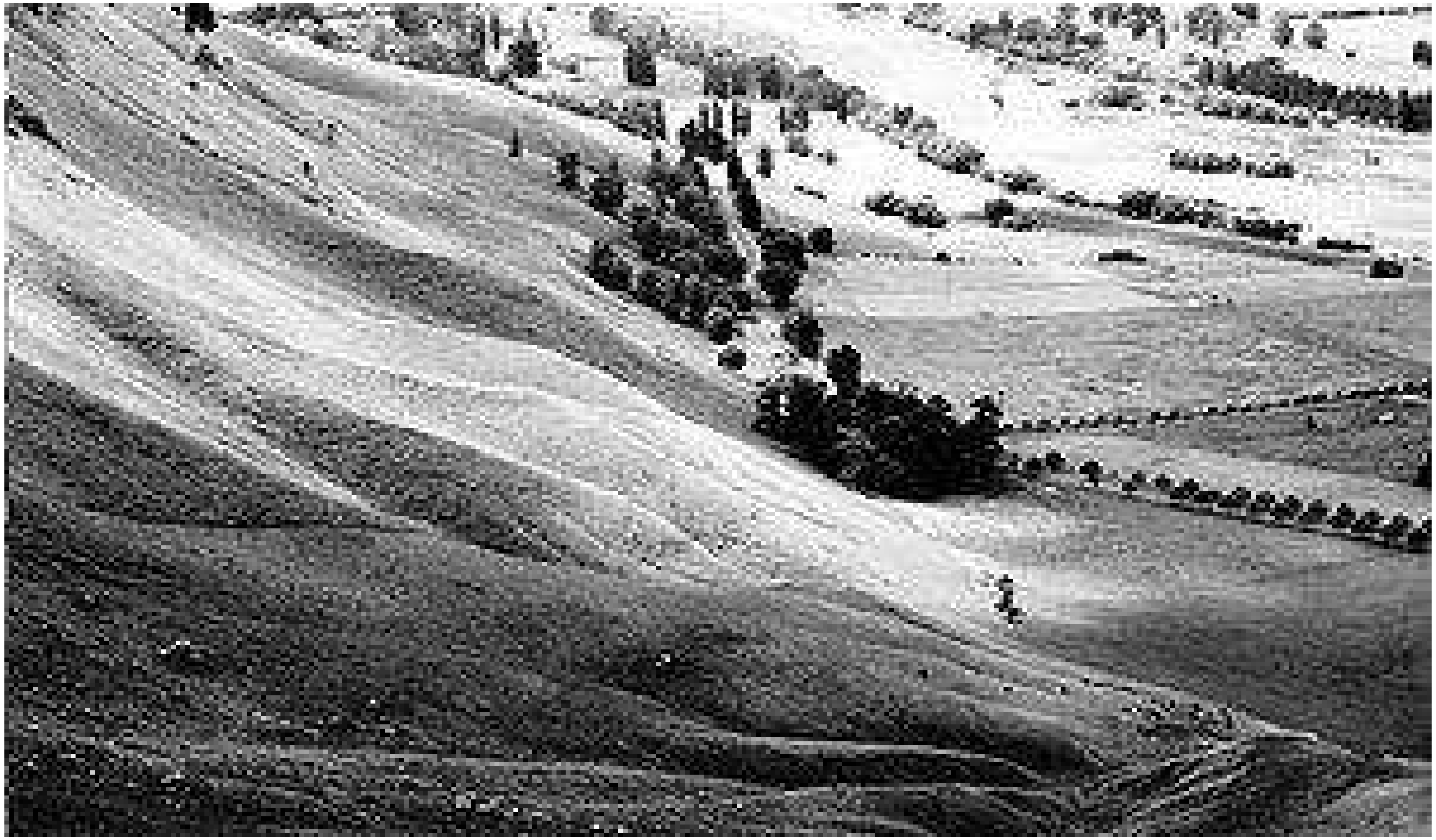
Histogram and cdf



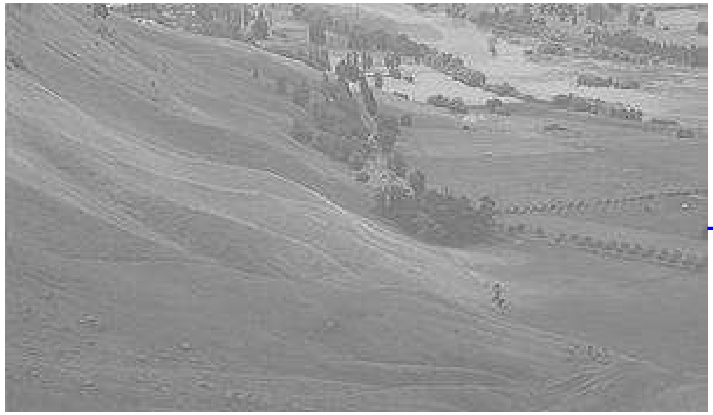
“Equalized” histogram and cdf

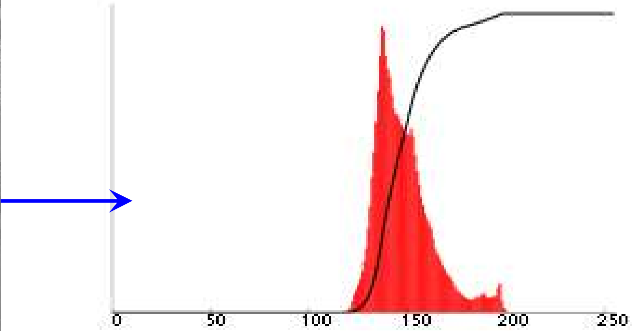


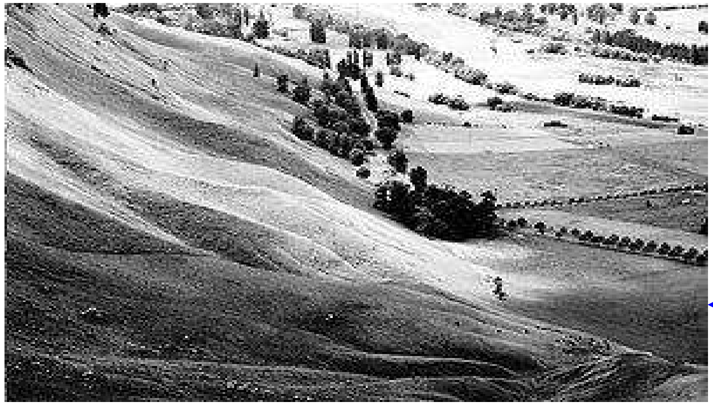
Picture with enhanced contrast

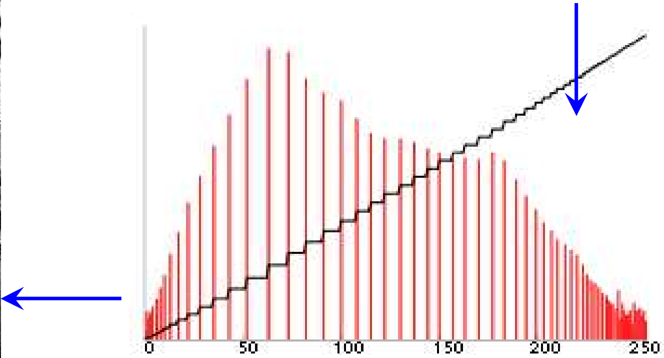


Original picture, equalization, modified picture









Summary

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- In this session, we studied digital representation of images
- Understood how matrices can be used to represent images
- We discussed
  - Histogram
  - Cumulative Distribution Function
  - Histogram equalization technique to improve contrast
- In the next session, we will use the formulae for histogram equalization, and write a program to improve image contrast