DATA ANALYSIS AND VISUALIZATION

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IMAGE PROCESSING

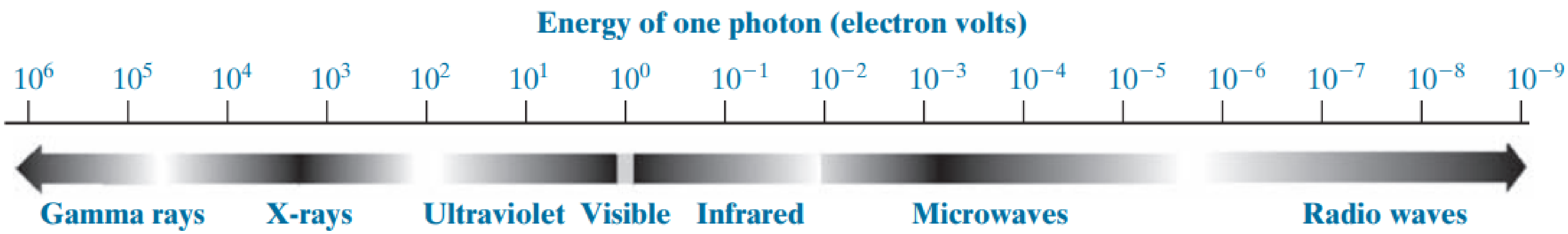
INTRODUCTION

WHAT IS IMAGE?

- It is defined as a two-dimensional function, **F(x,y)**,
  - where x and y are spatial coordinates.
  - the amplitude of **F** at any pair of coordinates (x,y) is called the **intensity** of that image at that point.
- When x,y, and amplitude values of **F** are finite, we call it a **digital image**.

IMAGE SOURCES

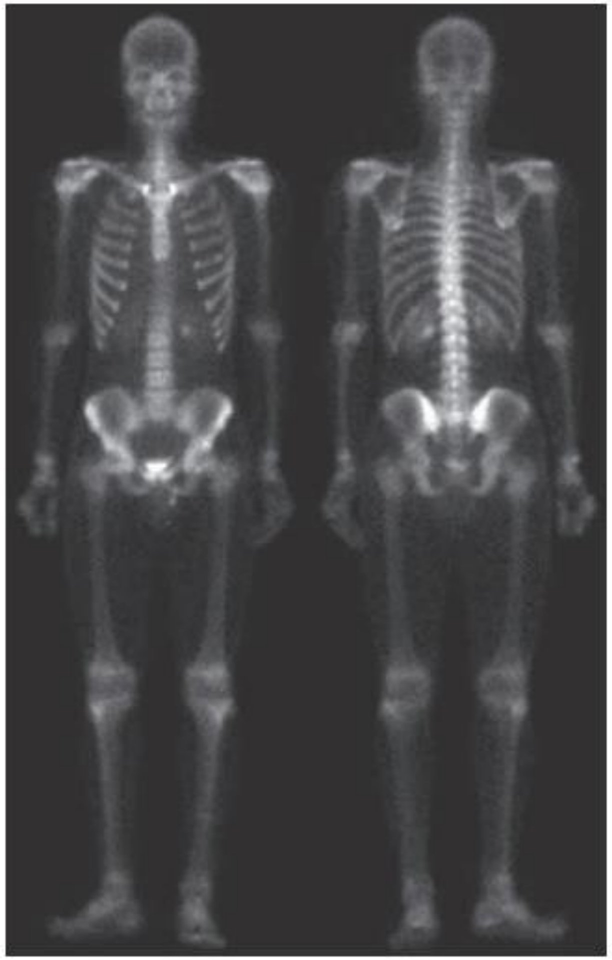
- The principal energy source for images in use today is the electromagnetic energy spectrum



- Synthetic images, used for modeling and visualization, are generated by computer

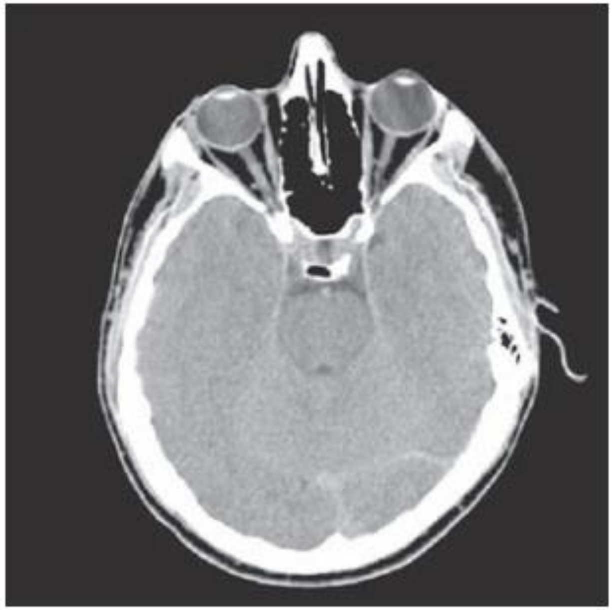
GAMMA RAYS IMAGING

- Bone Scan
- Pet Scan



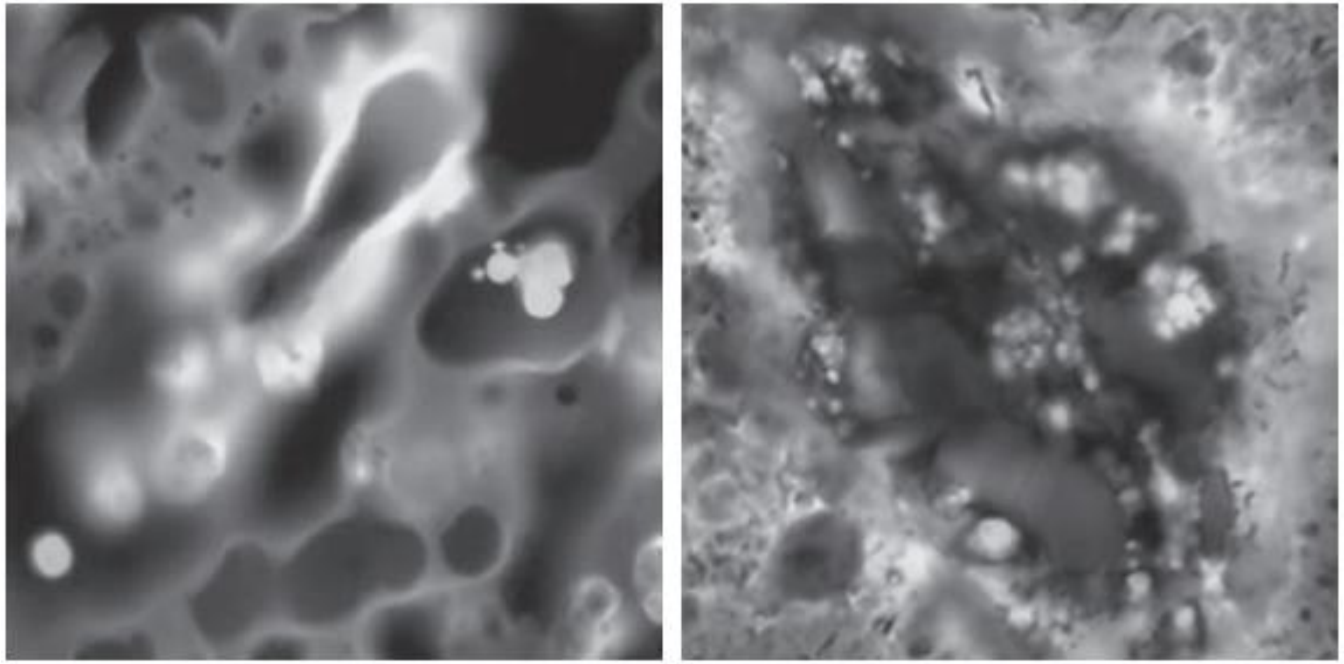
X-RAY IMAGING

- Chest X Ray
- Head CT Scan



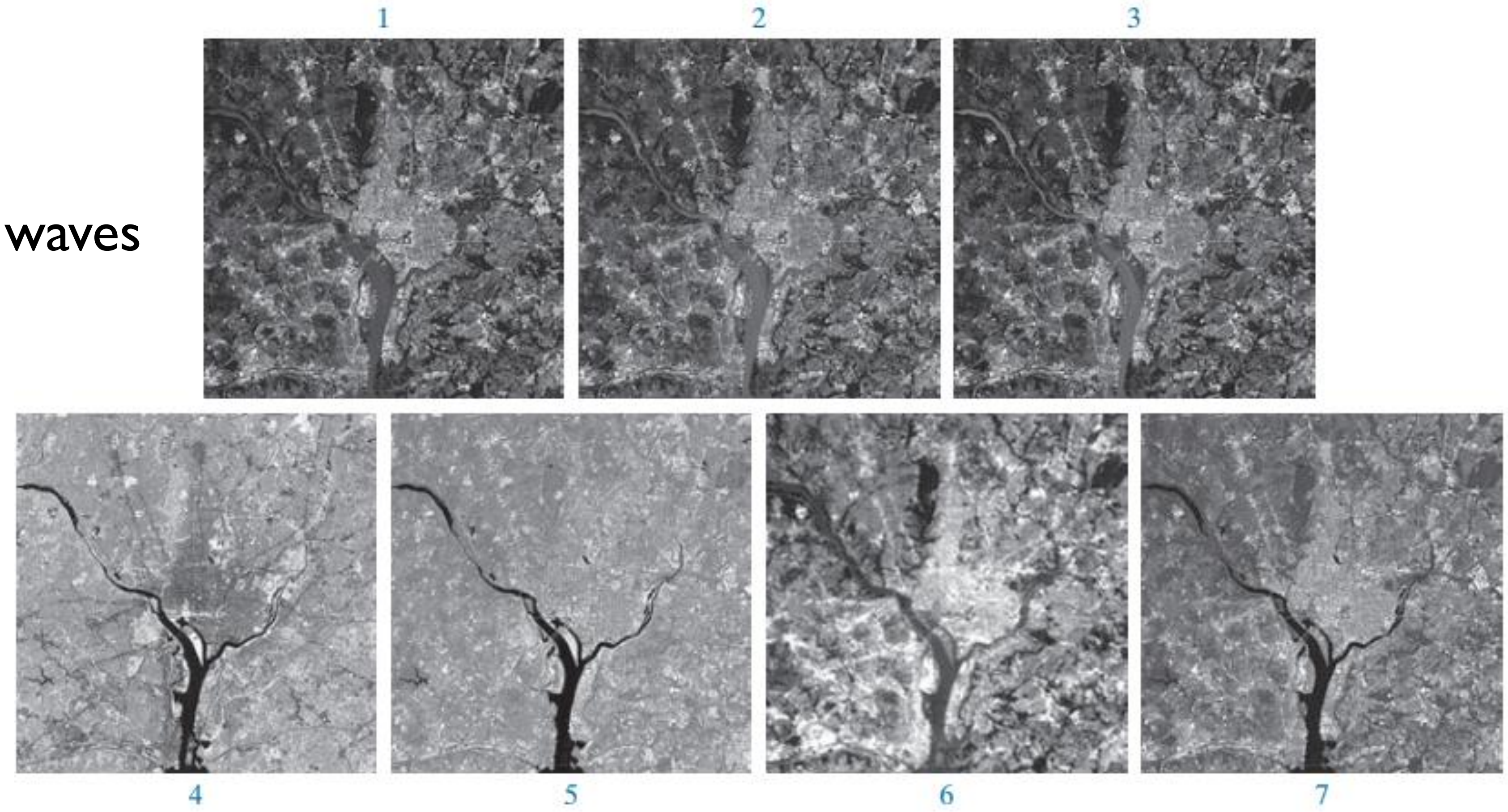
ULTRAVIOLET IMAGING

- Fluorescence microscopy

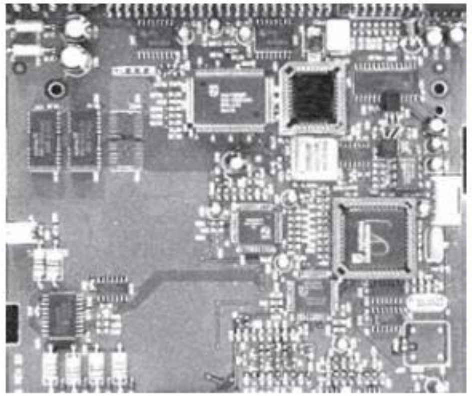


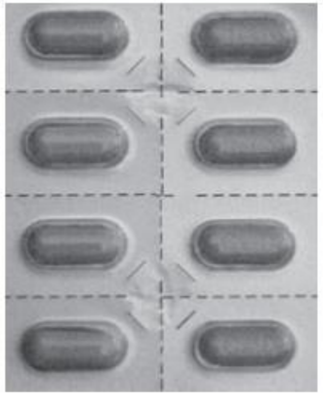
SATELLITE IMAGES

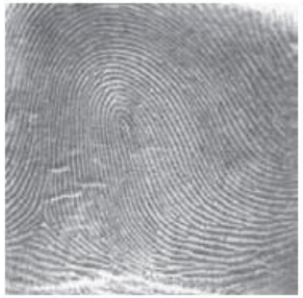
Captured using different waves



IMAGES OF VISIBLE SPECTRUM

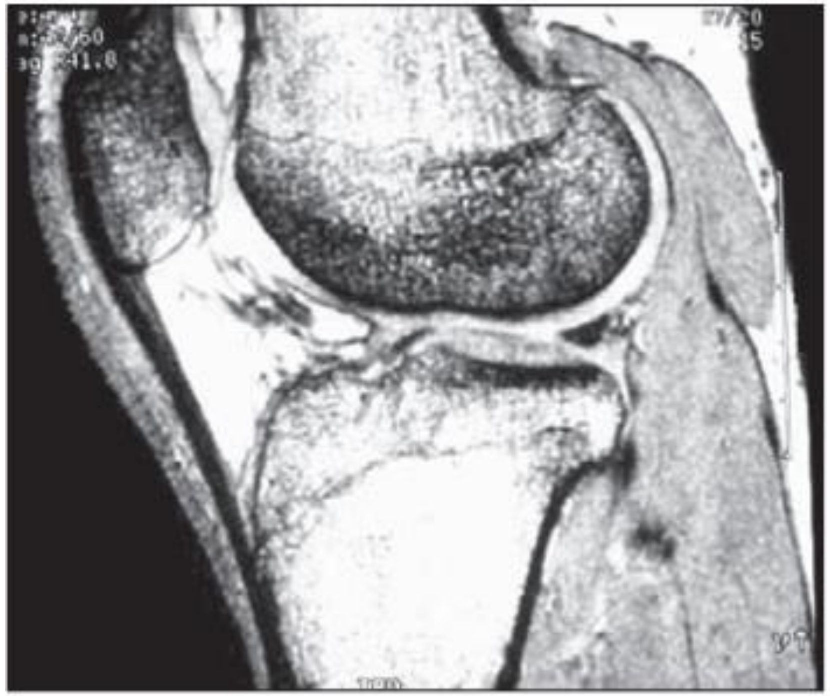




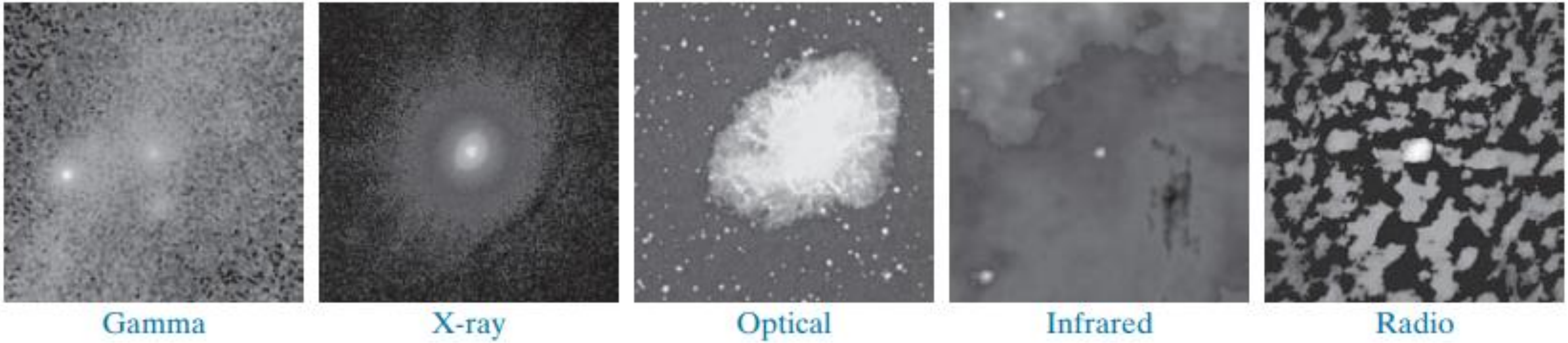


IMAGING IN THE RADIO BAND

- MRI Scans (Knee, Spine)



SPACE IMAGES



- Same star is captures using different waves.

ULTRASOUND IMAGING

- Thyroid and muscle layer

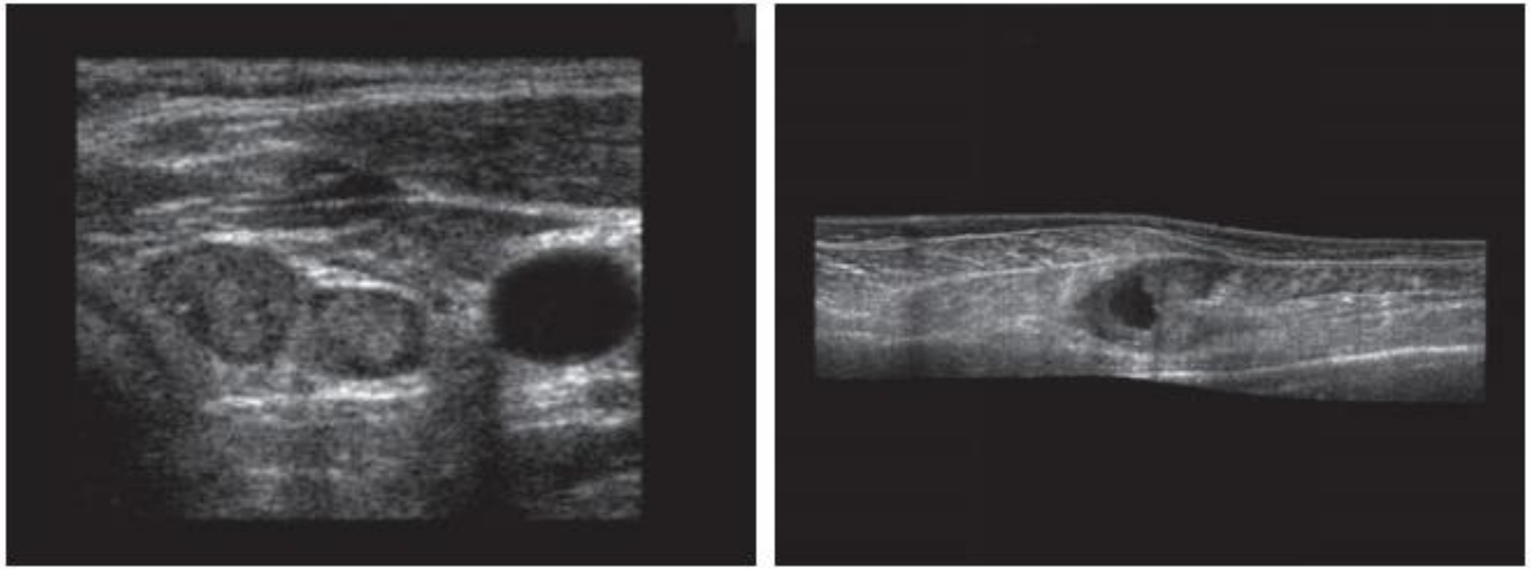
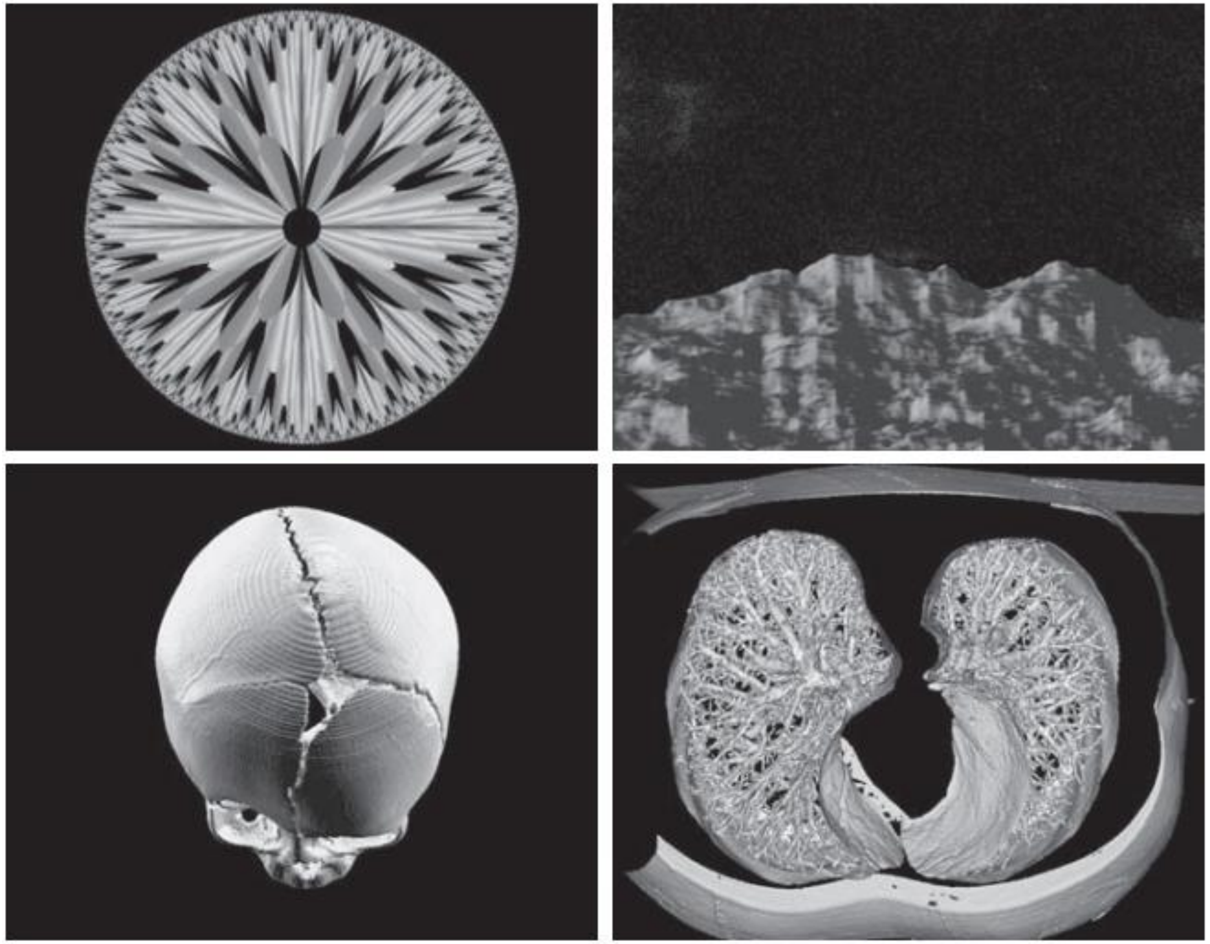


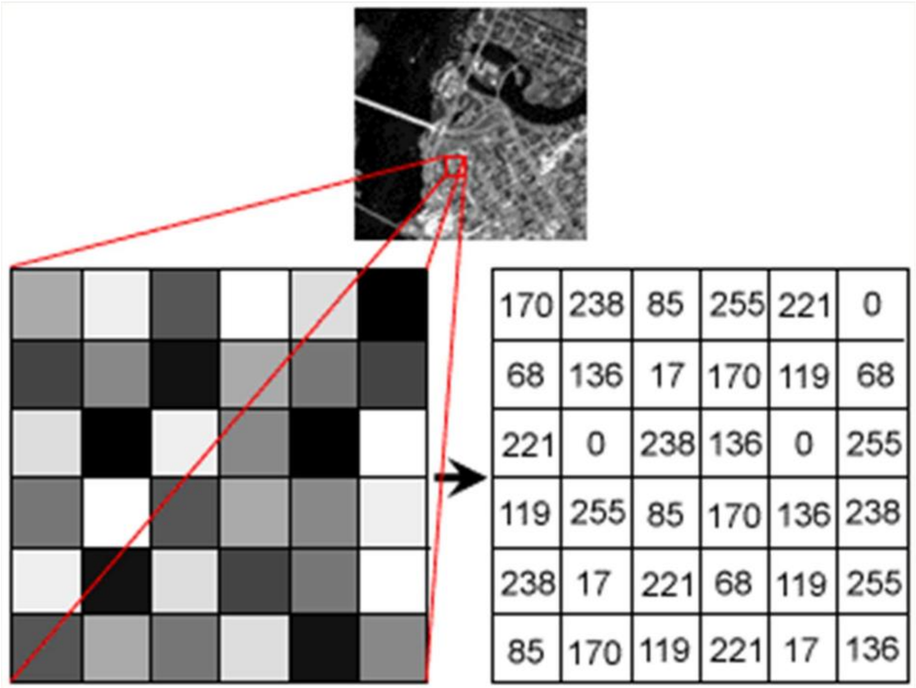
IMAGE GENERATION BY COMPUTER

- Patterns
- 3D modeling



PIXEL

- A digital image is composed of a finite number of elements, each of which has a particular location and value.
- These elements are called picture elements, image elements, pels, and pixels



STEPS OF IMAGE PROCESSING

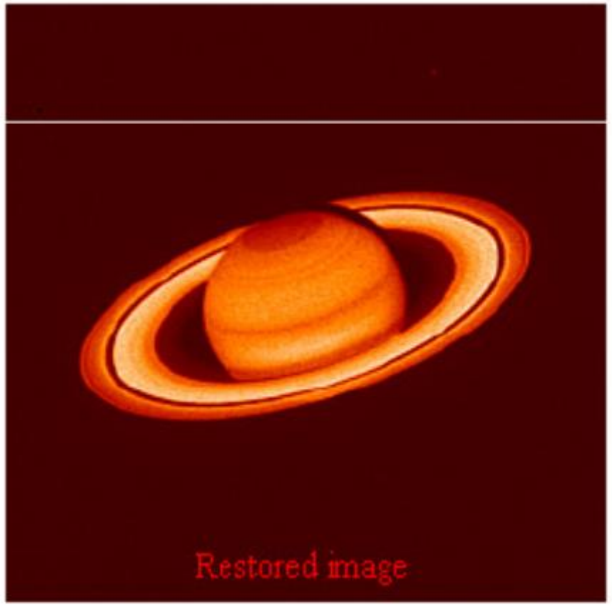
- Image acquisition
- Image enhancement
- Image restoration
- Color image processing
- Wavelets
- Compression
- Morphing
- Segmentation
- Feature extraction
- Image pattern classification

EXAMPLES

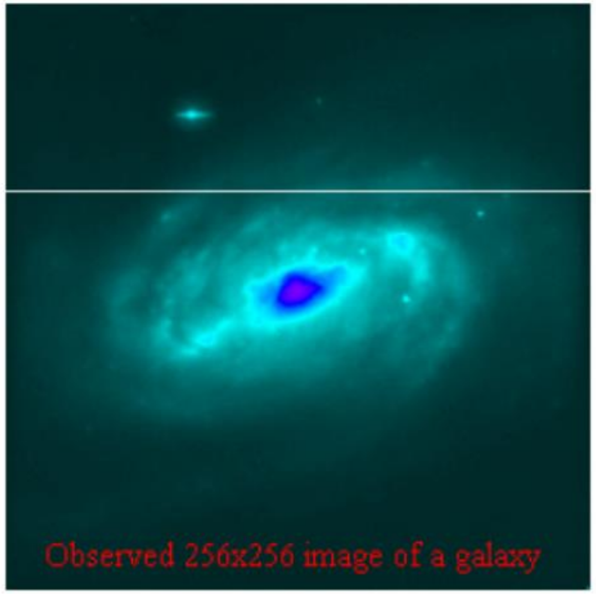
- Image Enhancement

RESTORATION

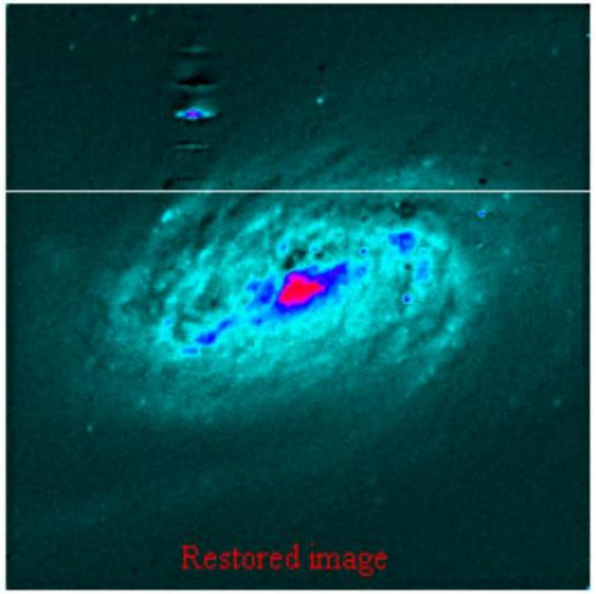
Observed image of Saturn



Restored image



Observed 256x256 image of a galaxy

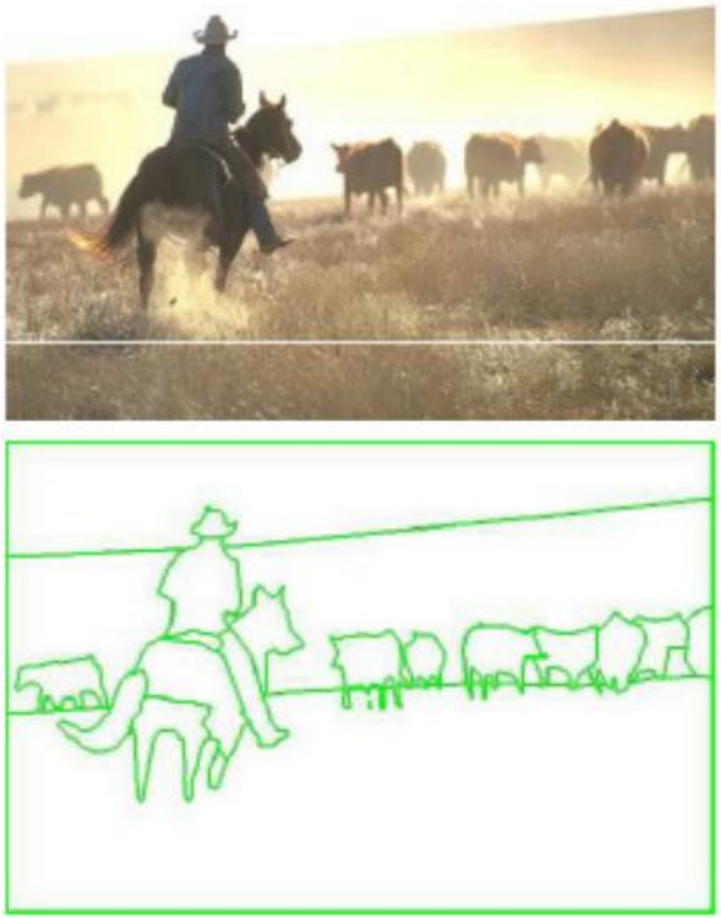


Restored image

RESTORATION

Original Image Degraded Image Restored Image[16]

SEGMENTATION



WHY IMAGE PROCESSING

- To facilitate storage and transmission
  - Compression, quality
  - Prepare images for display or printing
- Enhancement and restoration
  - Noise removal, quality, sharpness
- Extract information from images
  - Image understanding
  - Comparison of images to find changes

RESOLUTION

- Resolution is a common term used with images
- The resolution can be defined in many ways.
  - Pixel resolution,
  - Spatial resolution,
  - Intensity resolution,
  - Spectral resolution.

SPATIAL RESOLUTION

- Defined as the smallest observable/identifiable detail in an image
- Spatial resolution refers to clarity
- For image clarity comparison, images have to be of the same size
- As spatial resolution reduces, image size also reduces

- Different devices, different measure
  - Dots per inch (DPI) - usually used in monitors.
  - Lines per inch (LPI) - usually used in laser printers.
  - Pixels per inch (PPI) is measure for different devices such as tablets , Mobile phones etc.

PIXEL RESOLUTION

- Resolution refers to the number of pixels in an image.
- Resolution is sometimes identified by
  - The width and height of the image as well as
  - The total number of pixels in the image
- An image that is 2048 pixels wide and 1536 pixels high (2048 x 1536) contains 3,145,728 pixels (or 3.1 Megapixels).

RESOLUTION UNITS

- Resolution is the number of pixels in a linear Resolution inch (i.e. pixels per inch or ppi).
- The more pixels per inch (ppi), the higher your image resolution will be.
- Resolution of an image display device or Resolution printing device is described in dots per inch (dpi).

HOW DOES RESOLUTION PLAY OUT ON COMPUTER SCREEN

- If your monitor is set to 800 x 600 and
- You open up an image that is 640 x 480
- It will only fill up a part of your screen.

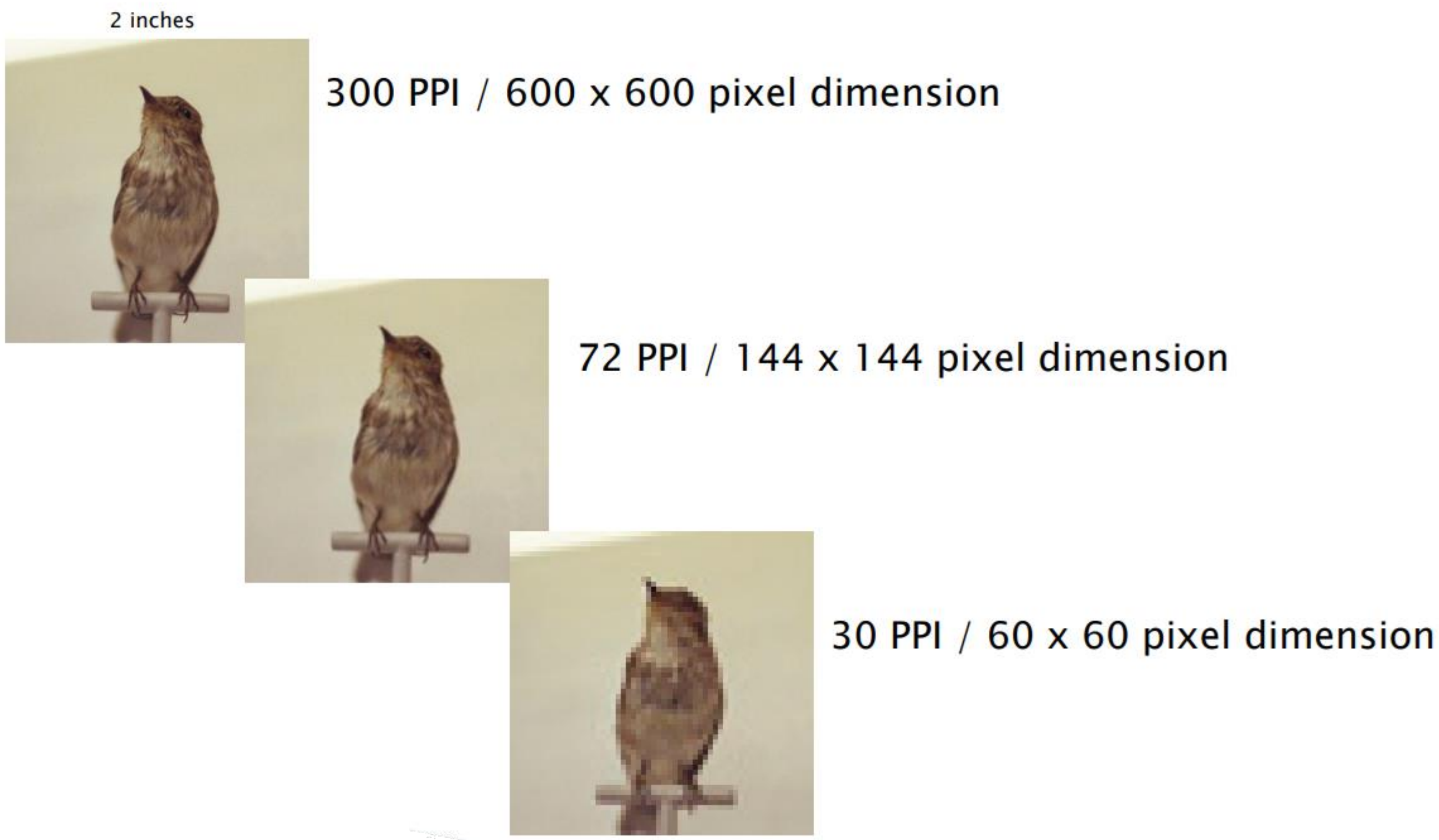
- What if you open up an image that is 2048 x 1536?

- You will find yourself moving the slider bar around to see all the different parts of the image.

PRINTING SIZE

- You have a 640 x 480 image and
- You want to print it at 200 dpi (dots or pixels per inch).
- What will be the size of the printed image?
- 640 / 200 = 3.2 and
- 480 / 200 = 2.4
- So, the size of the printed image is 3.2" x 2.4”

IMAGES AT DIFFERENT RESOLUTION



CHARACTER SCANNER AT DIFFERENT RESOLUTIONS

INTENSITY RESOLUTION

- Intensity/gray-level resolution can be defined as the smallest identifiable change in intensity level.
- image size constant at 452 X 374 pixels
- Decrasing the gray-level resolution of a digital image may result in what is known as false contouring

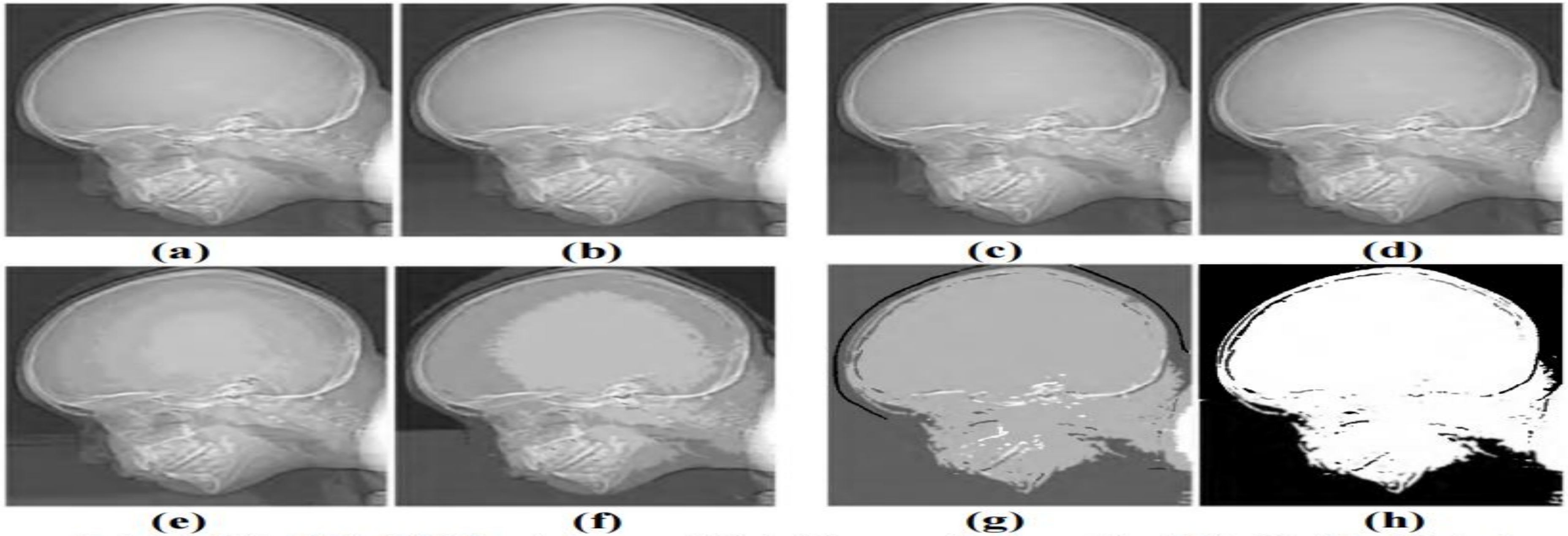


Figure 2.6 (a) 452×374, 256-level image. (b)-(h) Image displayed in 128, 64, 32, 16, 8, 4, and 2 gray levels, while keeping the spatial resolution constant.

BIT DEPTH

- The number of bits used to define a pixel.

- The greater the bit depth, the greater the number of tones that can be represented.
- For example, an image with a bit depth of 1 has pixels with two possible values.
- An image with a bit depth of 8 has 2^8, or 256, possible values.

TYPES OF IMAGES

- Binary Images
- Gray-scale images
- Color images

1 BIT IMAGE/BINARY

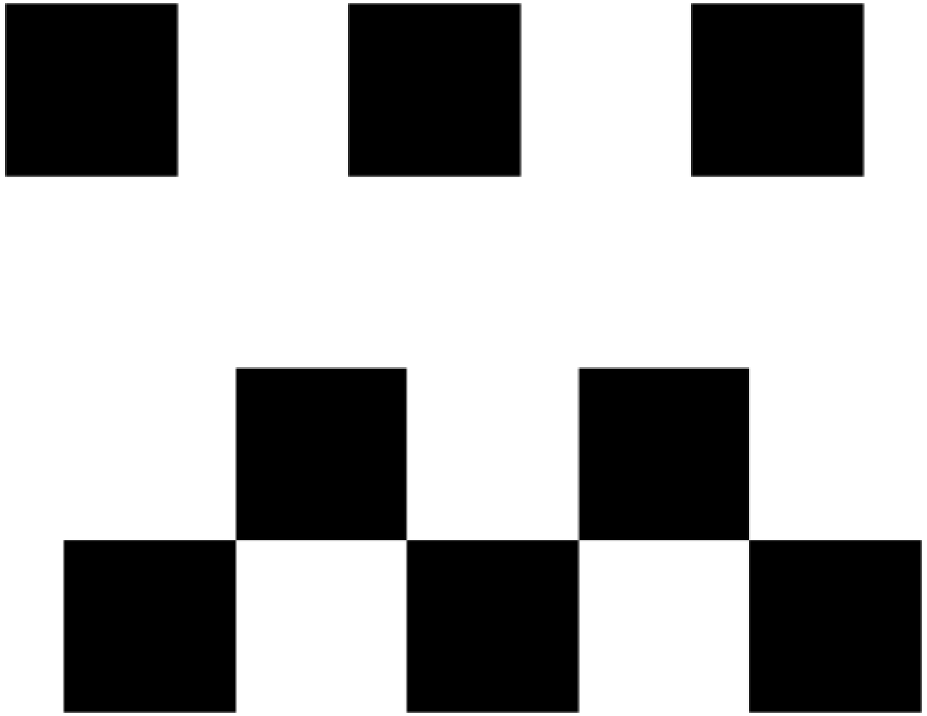
- Each pixel consist of only 0/1information
- Called 1-bit monochrome (since no color) image
- Suitable for simple graphics & text

- How much storage is required for a monochrome image of resolution 640 x 480?

BINARY IMAGES

- x =[0 1 0 1 0]
- x =

1 0 1 0 1
0 1 0 1 0



8 BIT IMAGE (GRAYSCALE)

- Each pixel is represented by a single byte.
- Gray levels between 0 to 255 (black to white).

- How much storage is required for a grayscale image of resolution 640 x 480?

256 gray levels (8bits/pixel) 32 gray levels (5 bits/pixel) 16 gray levels (4 bits/pixel)

8 gray levels (3bits/pixel) 4 gray levels (2bits/pixel) 2 gray levels (1bit/pixel)

COLOR IMAGES

- The two most common ways of storing color image contents are

    1) RGB representation (24 bit image)

    2) Indexed representation (8 bit image)

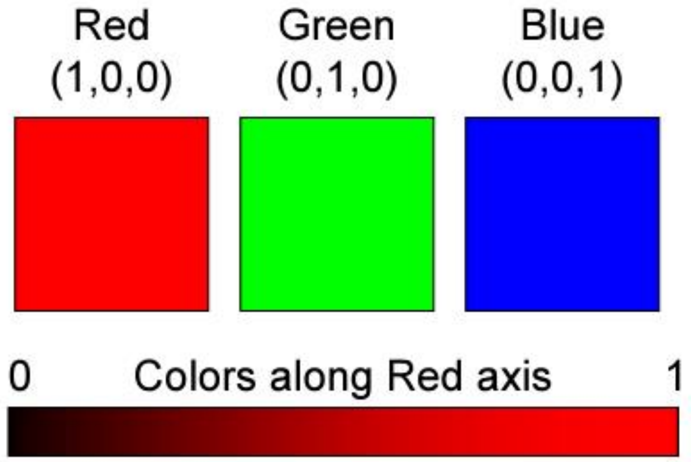
COLOR IMAGE

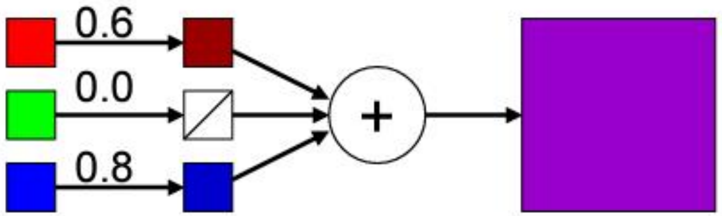
- 24- bit color image
- Each pixel is represented by 3 bytes, RGB
  - Each R, G, B are in the range 0-255
  - 256 x 256 x 256 possible colors

Example of 24-Bit Colors Image

- What is the size (in kB) of a 24-bit, 640 x 480 color image?

COLOR IMAGE


Red
(1,0,0)
Green
(0,1,0)
Blue
(0,0,1)
0
Colors along Red axis
1


0.6
0.0
0.8
+

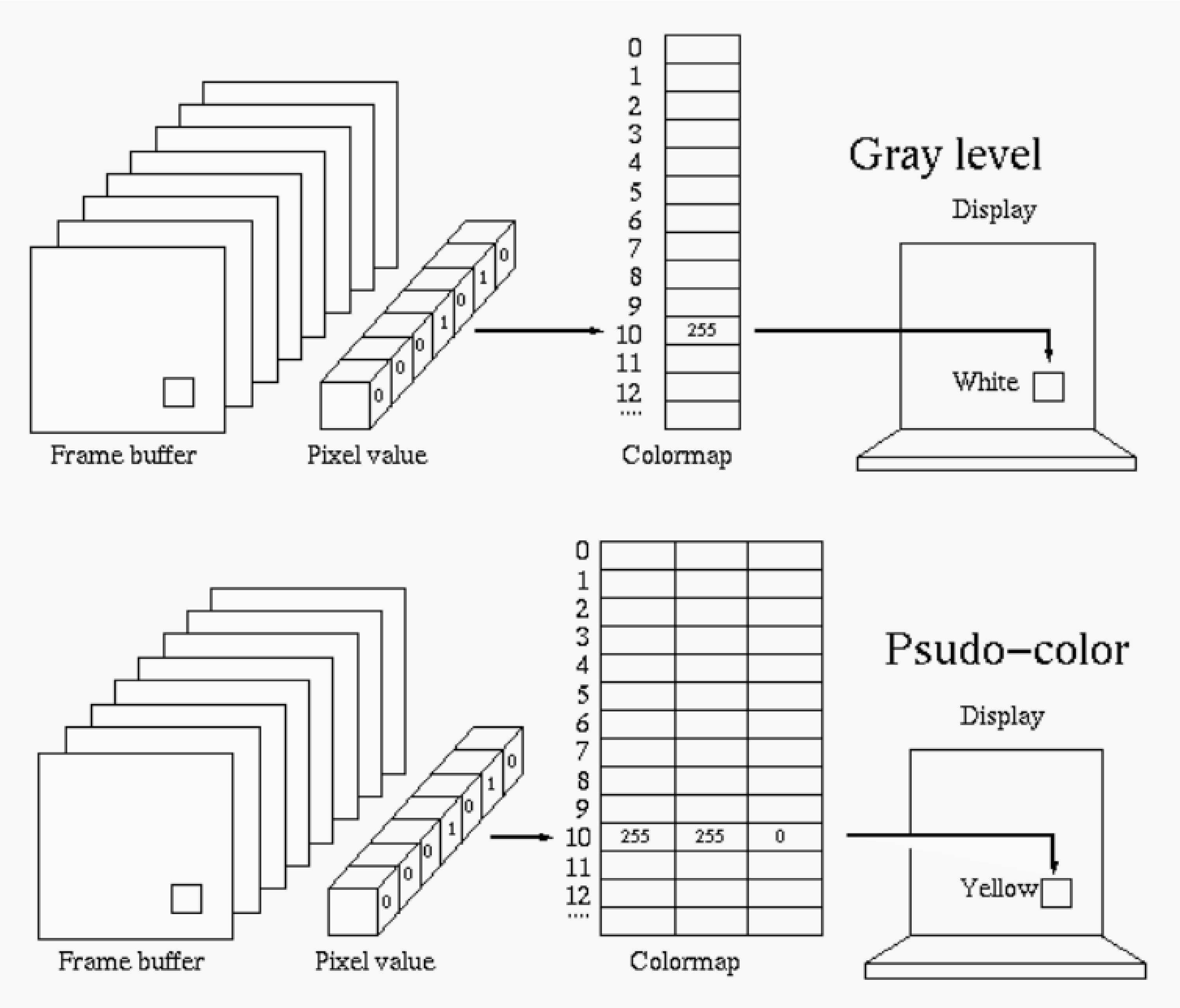

RGB
channels

8 BIT COLOR IMAGE

- 8- bit color image
  - Carefully chosen 256 colors represent the image
  - stores only the index of the color, the file header will contain the mapping information.
  - The mapping is performed using the color lookup table (LUT).

- What is the size (in kB) of a 8-bit, 640 x 480 color image?

COLOR LOOK UP TABLE



RGB TO GREY-SCALE IMAGE CONVERSION

- Can convert from an RGB colour space to a grey-scale image
- Grey-scale conversion is the initial step in many image analysis algorithms
  - simplifies (i.e. reduces) the amount of information in the image.

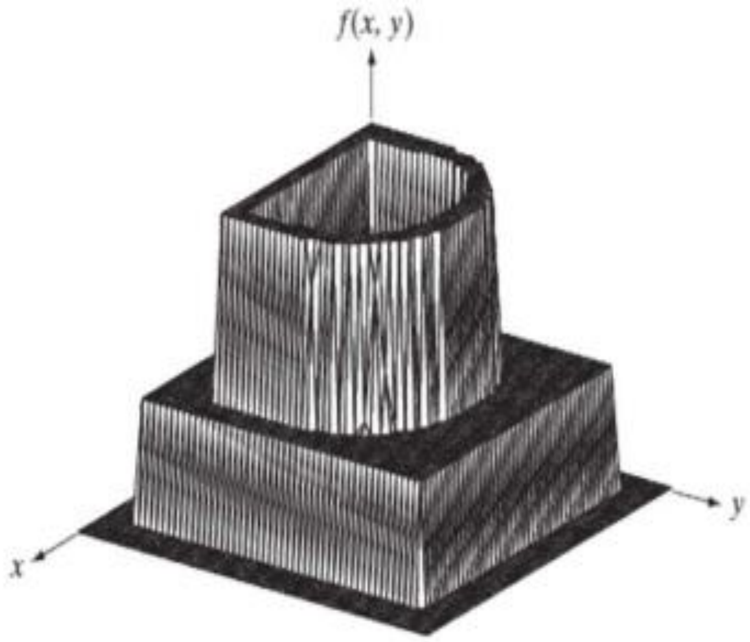
- Grey-scale image contains less information than a colour image, the majority of important, feature related information is maintained, such as edges, regions, blobs, junctions and so on.
- An RGB colour image can converted to grey scale

$$I_{\text{grey-scale}}(n, m) = \alpha I_{\text{colour}}(n, m, r) + \beta I_{\text{colour}}(n, m, g) + \gamma I_{\text{colour}}(n, m, b)$$

- Conversion is a noninvertible transformation

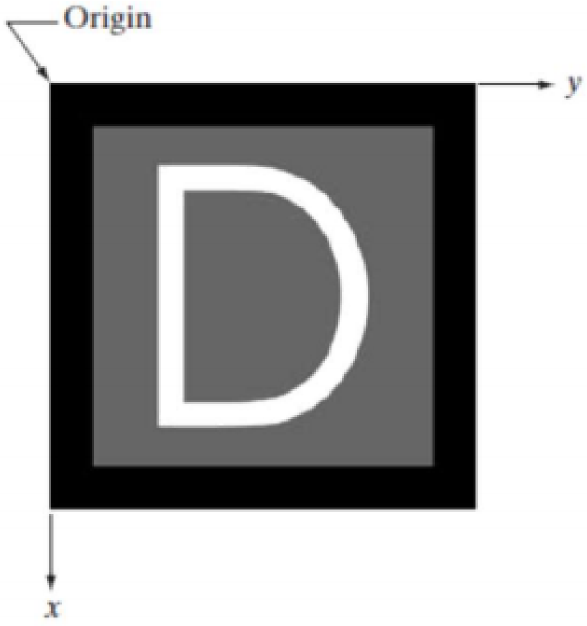
REPRESENTING DIGITAL IMAGES

- Basic ways to represent f(x, y):
- Image plotted as a surface
  - First method is a plot of the function f(x, y), with two axes determining spatial location and the third axis being the values of f (intensities) as a function of the



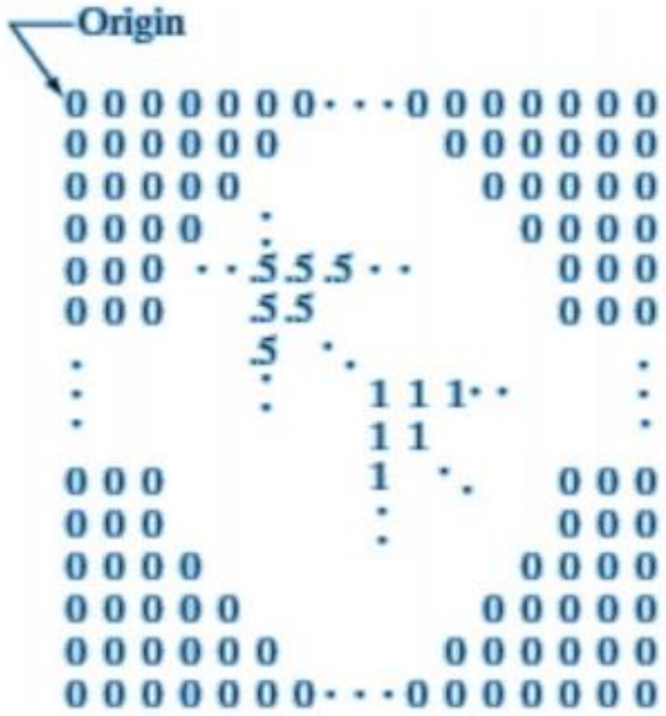
REPRESENTING DIGITAL IMAGES

- Image as a visual intensity
- In this figure, there are only three equally spaced intensity values.
- If the intensity is normalized to the interval [0, 1], then each point in the image has the value 0, 0.5, or 1.
- • A monitor or printer simply converts these three values to black, gray, or white, respectively



REPRESENTING DIGITAL IMAGES

- Image shown as a 2-D numerical array
- In this example, f is of size 600 X 600 elements, or 360,000 numbers
- Image displays allow us to view results at a glance and Numerical arrays are used for processing and algorithm development



REPRESENTING DIGITAL IMAGES

- Coordinate convention to represent digital image

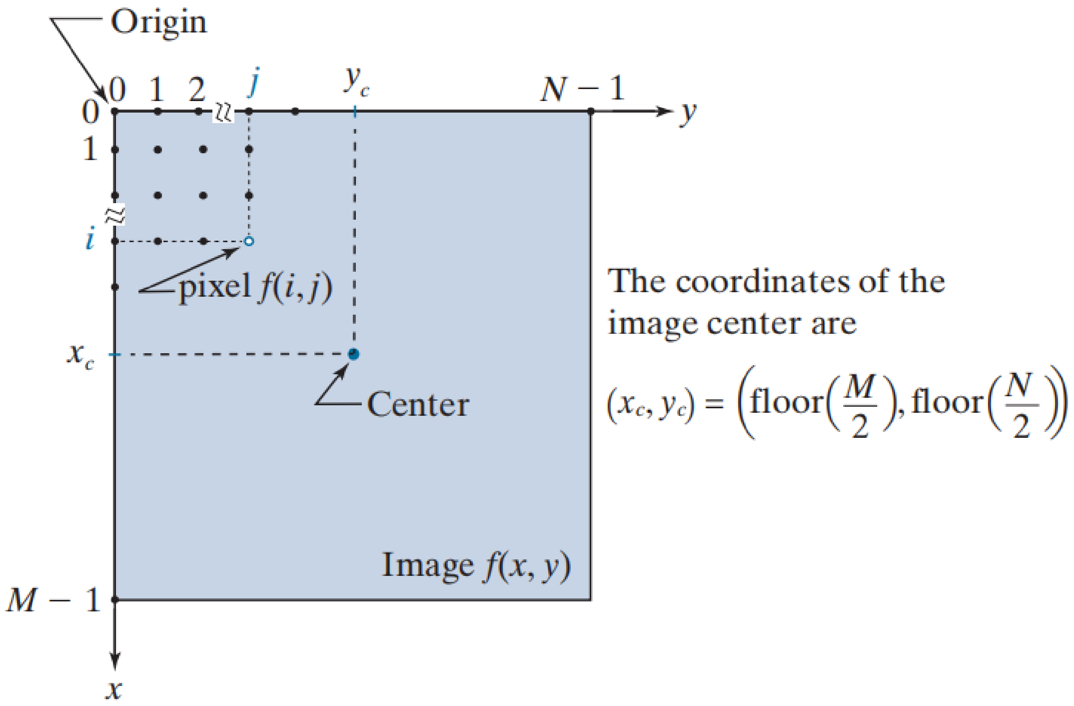
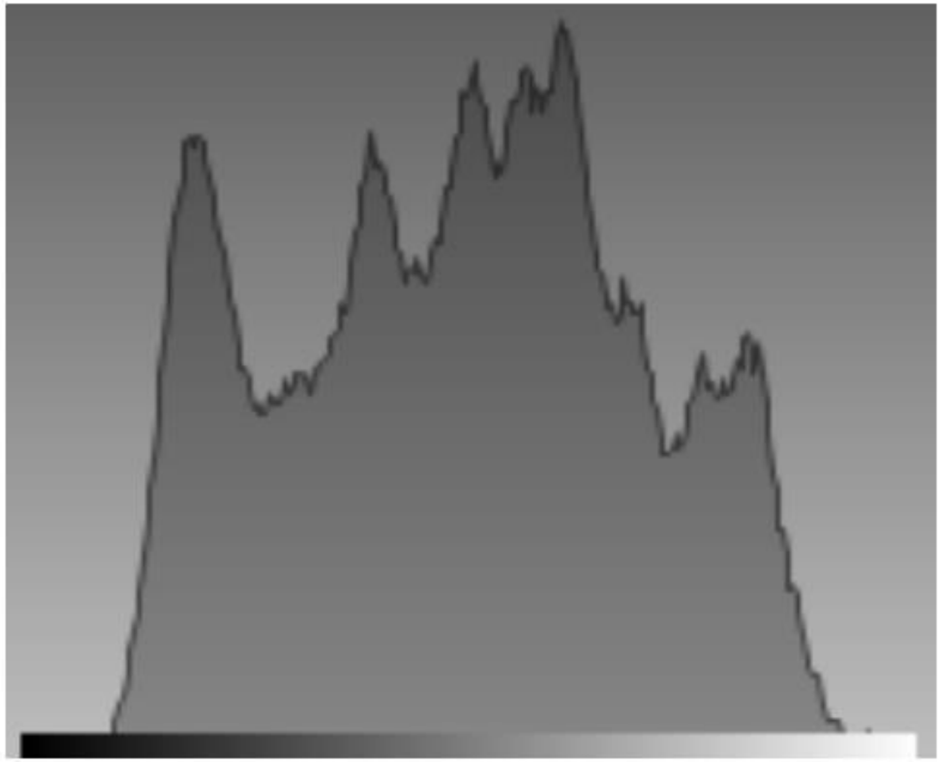


IMAGE HISTOGRAM

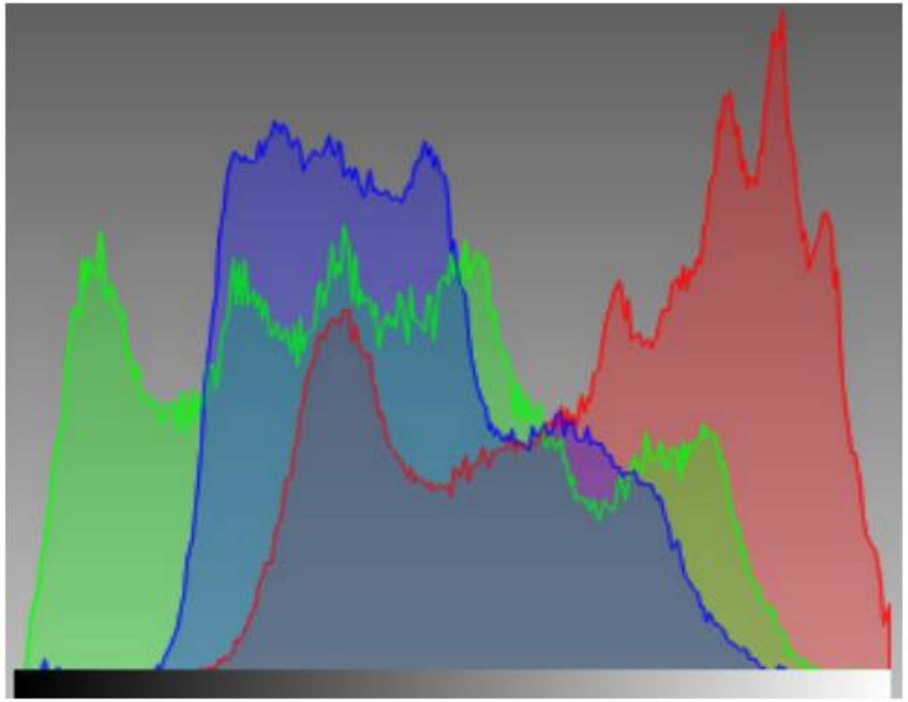
- Histogram which acts as a graphical representation of the tonal distribution in a digital image.
- It plots the number of pixels for each tonal value.
- It can be used to judge the entire tonal distribution of an image at a glance.

IMAGE HISTOGRAM



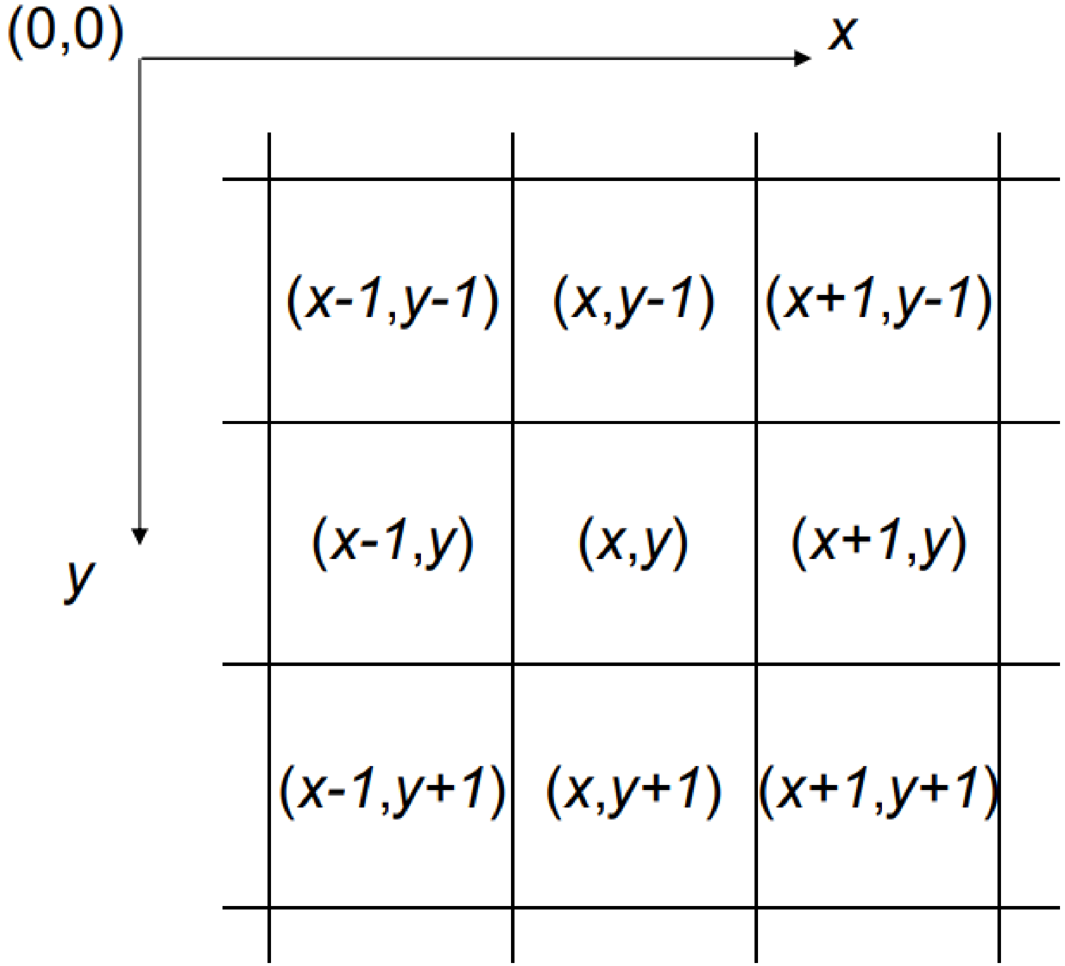
Histogram of Lena's grayscale image

IMAGE HISTOGRAM



Histogram of Lena’s colored image

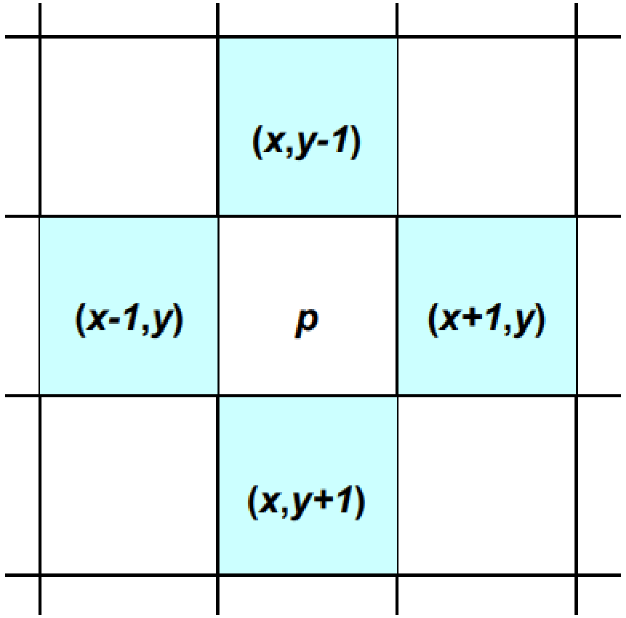
RELATIONSHIP BETWEEN PIXELS



Conventional indexing method

NEIGHBORS OF A PIXEL

- Neighborhood relation is used to tell adjacent pixels. It is useful for analyzing regions.

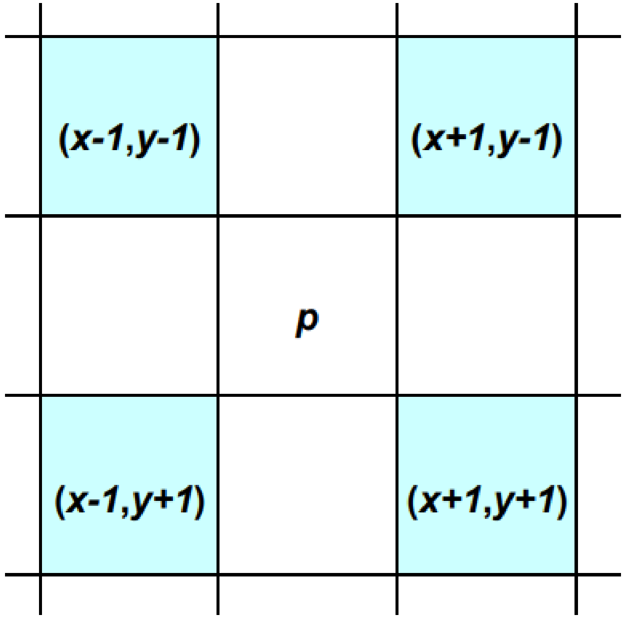


4-neighbors of *p*:

$$N_4(p) = \begin{Bmatrix} (x-1,y) \\ (x+1,y) \\ (x,y-1) \\ (x,y+1) \end{Bmatrix}$$

- 4-neighborhood relation considers only vertical and horizontal neighbors.

NEIGHBORS OF A PIXEL



Diagonal neighbors of *p*:

$$N_D(p) = \begin{Bmatrix} (x-1,y-1) \\ (x+1,y-1) \\ (x-1,y+1) \\ (x+1,y+1) \end{Bmatrix}$$

Diagonal-neighborhood relation considers only diagonal neighbor pixels.

NEIGHBORS OF A PIXEL

(x-1,y-1)	*(x,y-1)*	*(x+1,y-1)*
(x-1,y)	*p*	*(x+1,y)*
(x-1,y+1)	*(x,y+1)*	*(x+1,y+1)*

8-neighbors of *p*:

$$N_8(p) = \left\{ \begin{array}{c} (x-1,y-1) \\ (x,y-1) \\ (x+1,y-1) \\ (x-1,y) \\ (x+1,y) \\ (x-1,y+1) \\ (x,y+1) \\ (x+1,y+1) \end{array} \right\}$$

8-neighborhood relation considers all neighbor pixels.

SPATIAL OPERATIONS

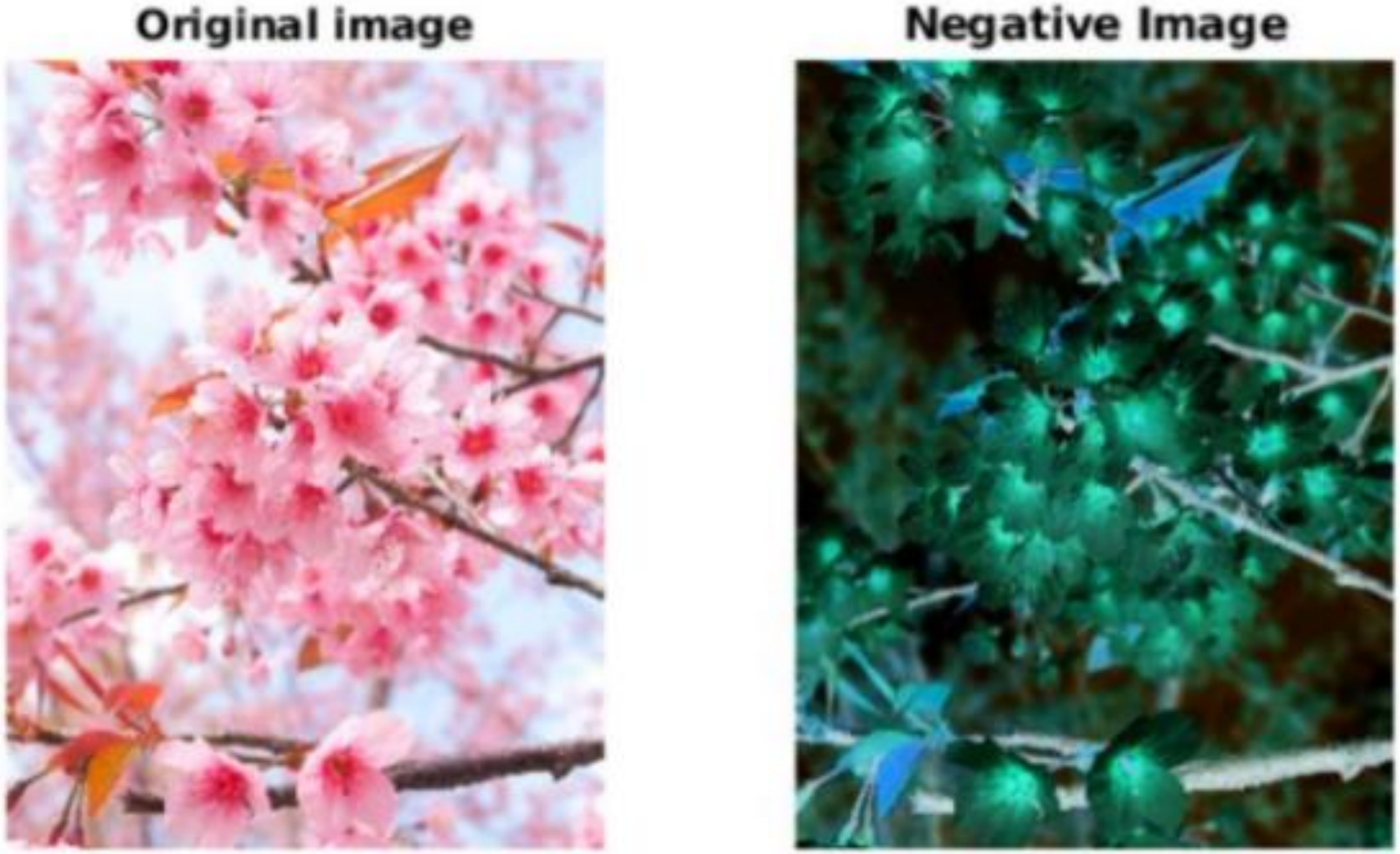
- Spatial operations are performed directly on the pixels of an image.
  - Single pixel operations
  - Neighborhood operations
  - Geometric spatial transformations

SINGLE-PIXEL OPERATIONS

- Alter the intensity of an image's pixels individually using a transformation function.

$$s = T(z)$$

EXAMPLE



NEIGHBORHOOD OPERATIONS

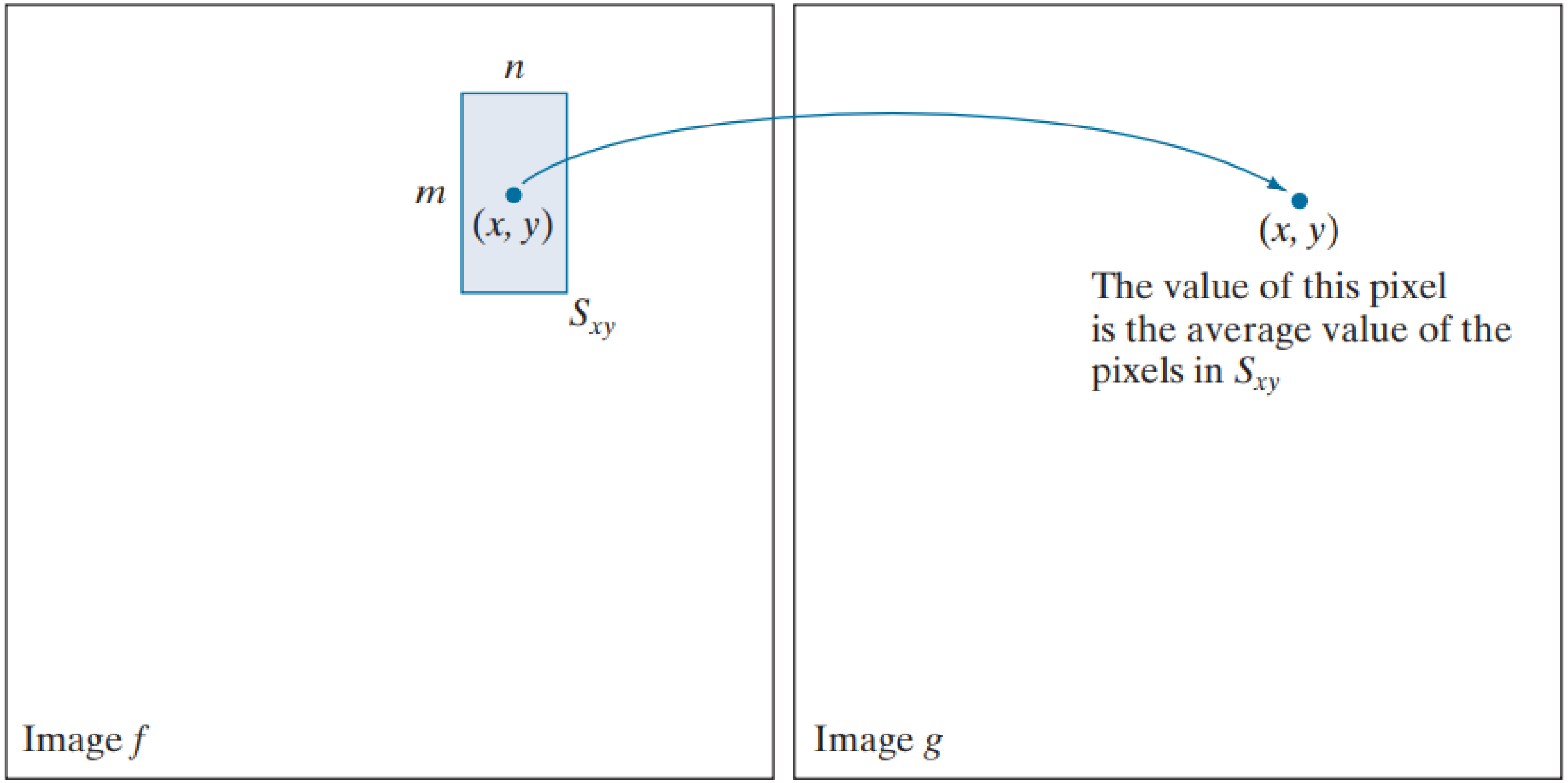
- Neighborhood processing generates a corresponding pixel at the same coordinates in an output image, such that the value of that pixel is determined by a specified operation on the neighborhood of pixels in the input image.

EXAMPLE

- Averaging Operation

$$g(x,y) = \frac{1}{mn} \sum_{(r,c)\in S_{xy}} f(r,c)$$

S_{xy} Represents the set of neighborhood, m and n represents rectangular size of neighborhood.



EXAMPLE

- Blurring of an image.