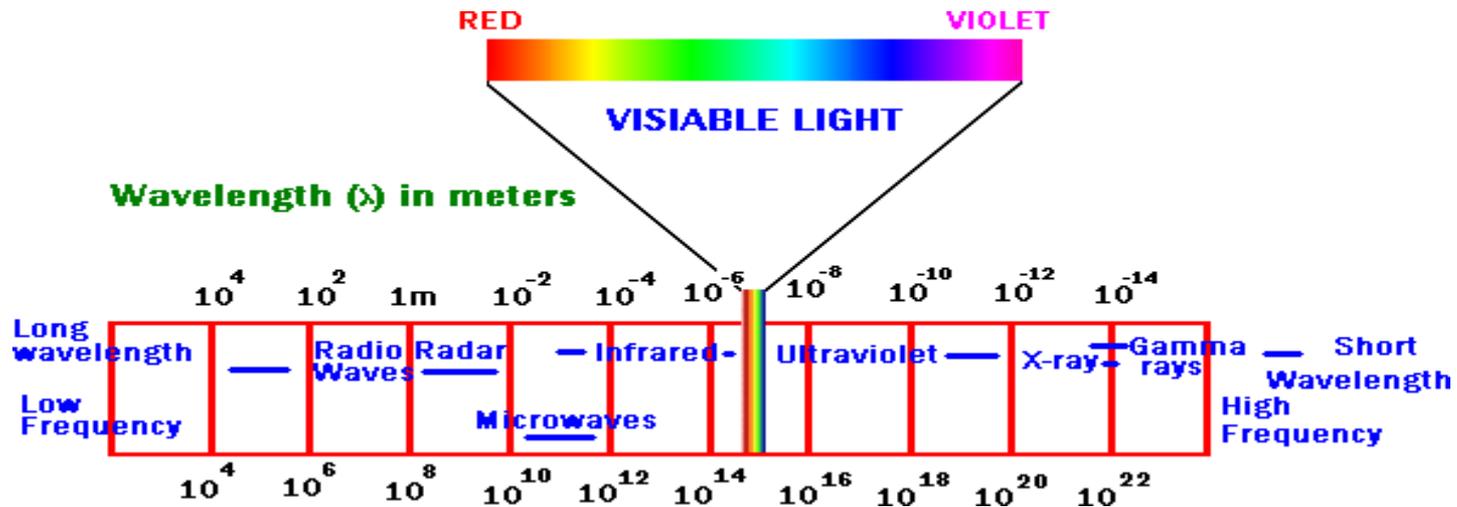


# Why Image Processing?

- For Human Perception
  - To make images more beautiful or understandable
- Automatic Perception of Image
  - We call it Machine Vision, Computer Vision, Machine Perception, Computer Recognition
- For Storage and Transmission
  - smaller, faster, more effective
- Image Processing for New Image Generation (New trends)
  - Computer Graphics introduced Image Processing and Computer Vision technologies

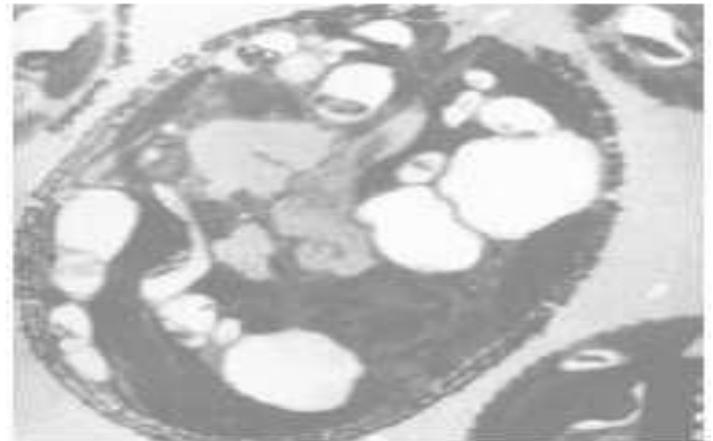
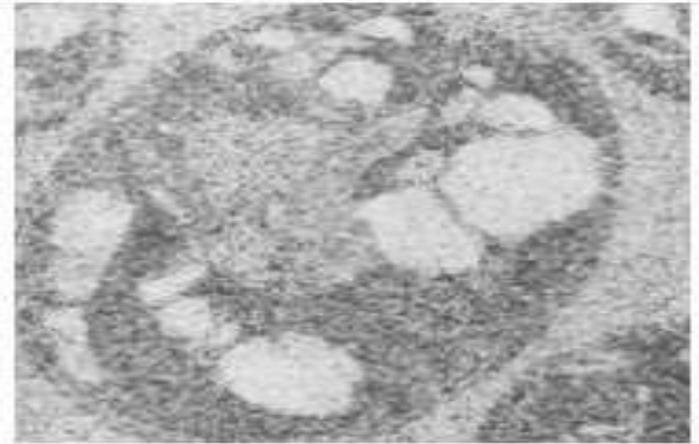
# The Electromagnetic Spectrum

- Images based on radiation from the EM spectrum
- EM : wave stream of mass less particles
- Each particle contains energy



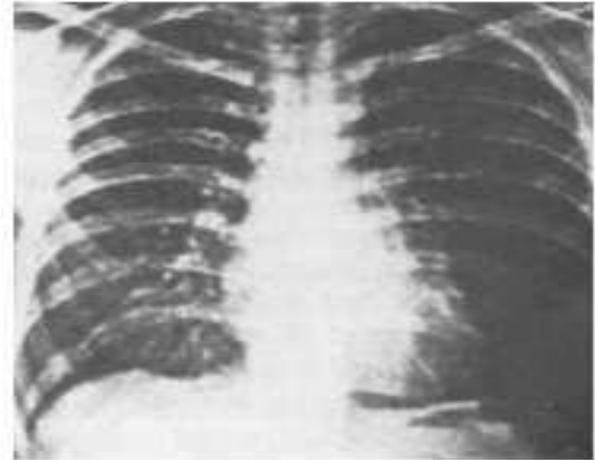
# Example: a cell

- Image of a cell corrupted by electronic noise.
- Result after averaging several noisy images (a common technique for noise reduction)



# Example: an x-ray

- An original x-ray image
- Result possible after contrast and edge enhancement



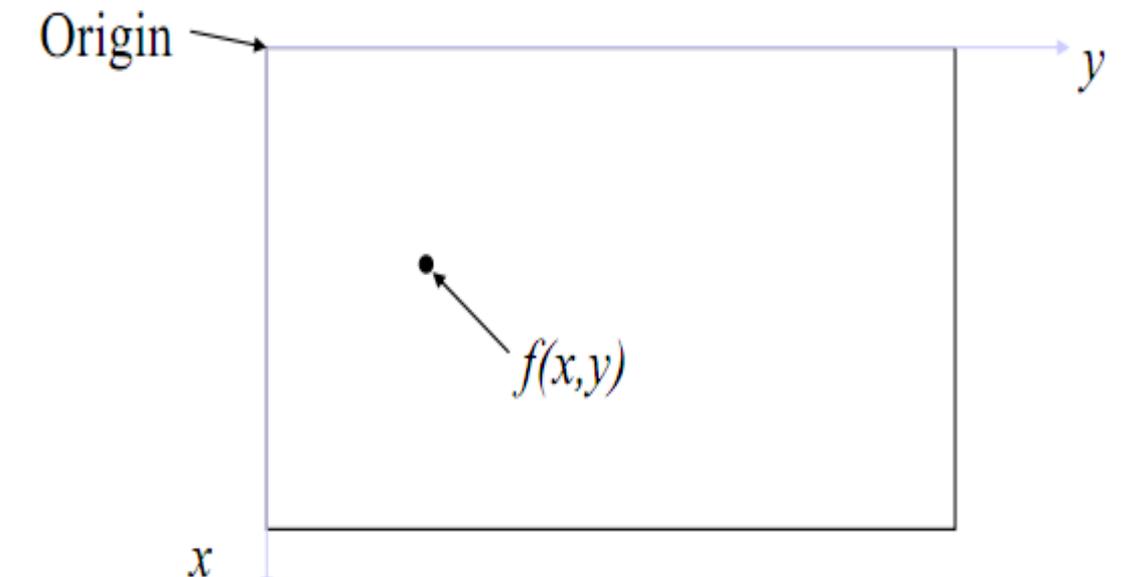
# Example: image deblurring

- Image of a human face blurred by uniform motion during exposure.
- Resulting image after application of a deblurring algorithm



# Simple Image Model

- Monochrome image (or simply image) refers to a 2-dimensional light intensity function  $f(x,y)$ .
  - $x$  and  $y$  denote spatial coordinates
  - the value of  $f(x,y)$  at  $(x,y)$  is proportional to the brightness (or gray level) of the image at that point.



## ➤ Simple image formation

- $f(x,y) = i(x,y)*r(x,y)$
- $0 < i(x,y) < \infty$  ; illumination or intensity of incident light
- $0 < r(x,y) < 1$  ; reflectance or reflectivity of object.

## ➤ In real situation

- $L_{\min} \leq f(x,y) \leq L_{\max}$

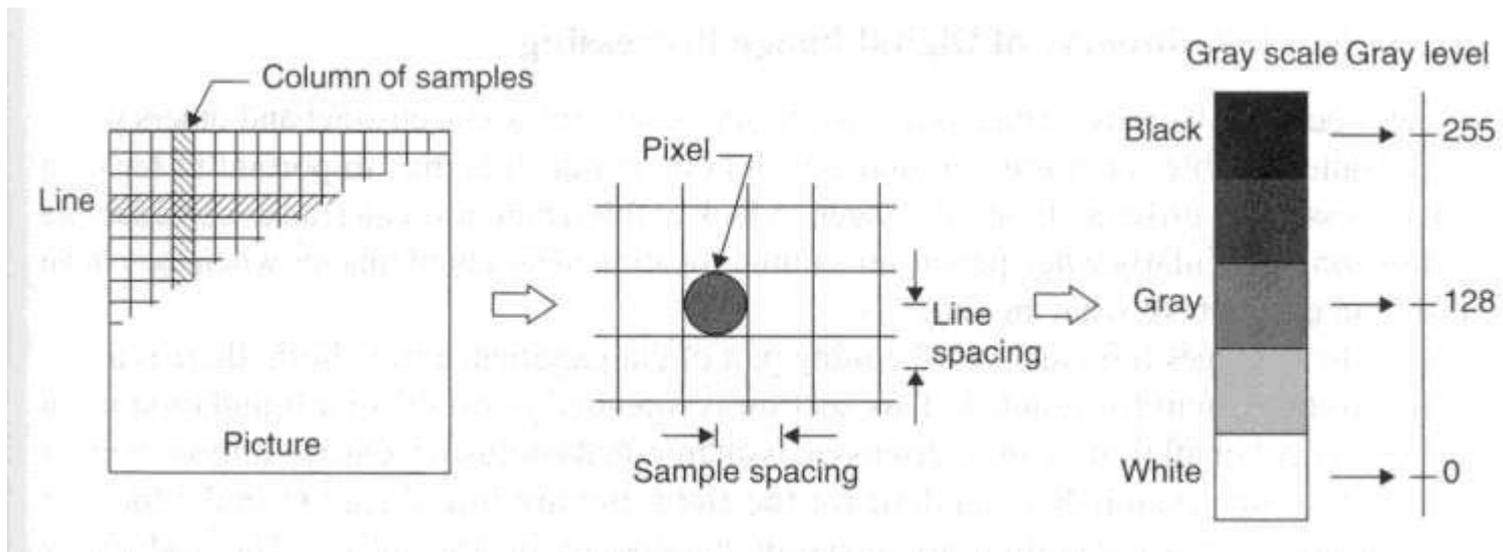
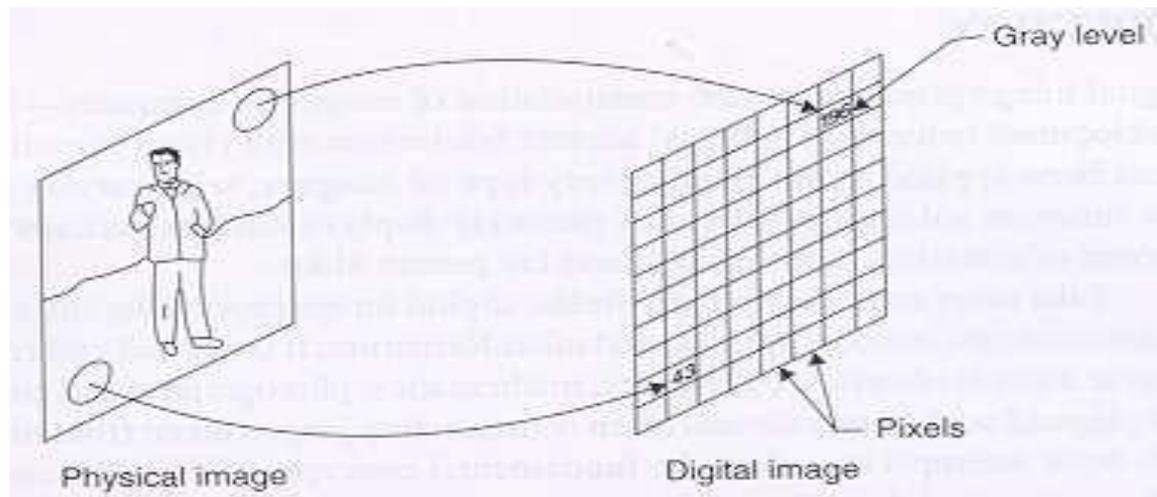


# Why Digital?

- Unification of processing
  - Computers is at the center of information processing
  - Digital information is just right form for computer processing
  - Text, Image, Sound, Movie, and other Multimedia are digitized into computer
- Noise reduction
  - Digital processing reduces noises
  - Guarantee the same quality regardless of time and place
- Easy storage
  - Since the same form is used for every information, it can be stored in H/D, CD, DVD, Flash memory, etc.
- Transmission
  - Less Bandwidth

# Digital image

- A digital image is an image  $f(x,y)$  that has been discretized both in spatial coordinates and in brightness.
- Considered as a matrix whose row and column indices represent a point in the image.
- The corresponding matrix element value represents the gray level at that point.
- The elements of such an array are referred to as:
  - image elements or picture elements (pixels or pels)



# Digital Image Processing

- The field of digital image processing refers to processing digital images by using computers.
- Image processing is a branch in which both the input and output of a process are images.
- The goal of computer vision is to use computers to emulate human vision, including learning, making inferences and taking actions.
- The area of image analysis is in between image processing and computer vision.

# Types of Processes in Image Processing

- There are 3 types of computerized processes.
  - Low level processes
  - mid level processes and
  - high level processes.
- Low-level processes involve primitive operations such as image preprocessing to reduce noise, contrast enhancement and image sharpening.
  - Here both the input and output are images.
- Mid-level processing involves segmentation (partitioning image into regions), description of objects to reduce them to a form so that a computer can process and classification (recognition) of objects.
  - Here inputs are images but outputs are attributes extracted from images.

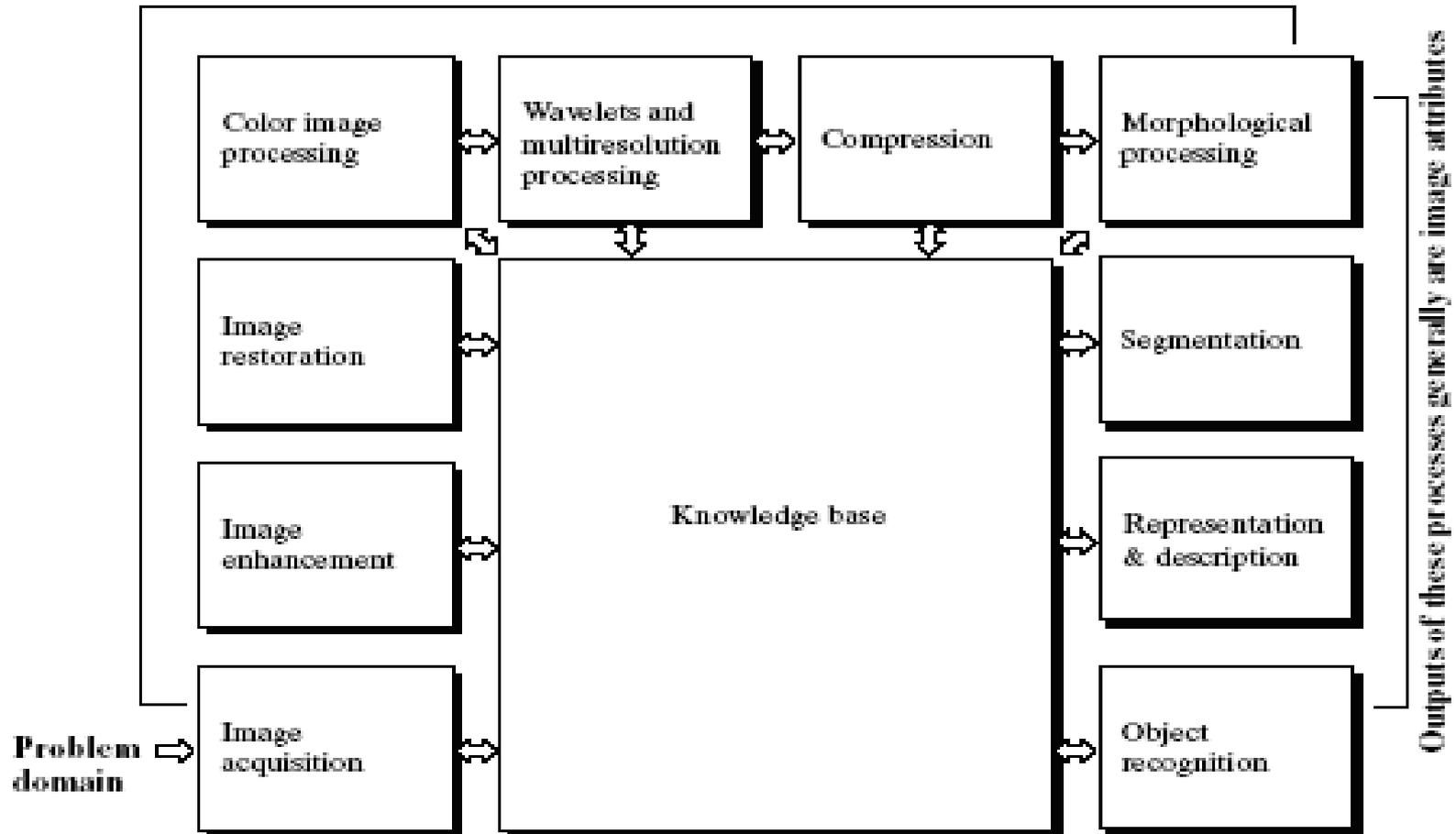
- In high-level processing, we ‘make sense’ of a collection of recognized objects.
- The process of acquiring an image of a text, processing it, extracting (segmenting) individual characters, describing characters suitable for computer processing and recognizing those individual characters are in the scope of digital image processing.
- Making sense of the content of the page (text) is viewed as the domain of image analysis and computer vision.

# Fundamental steps in Digital Image Processing

- Image acquisition
- Image enhancement
- Image Restoration
- Color Image Processing
- Image Compression
- Morphological Processing
- Image Segmentation
- Representation and description
- Recognition

# Fundamental steps in Digital Image Processing

Outputs of these processes generally are images



# Steps in an image processing system

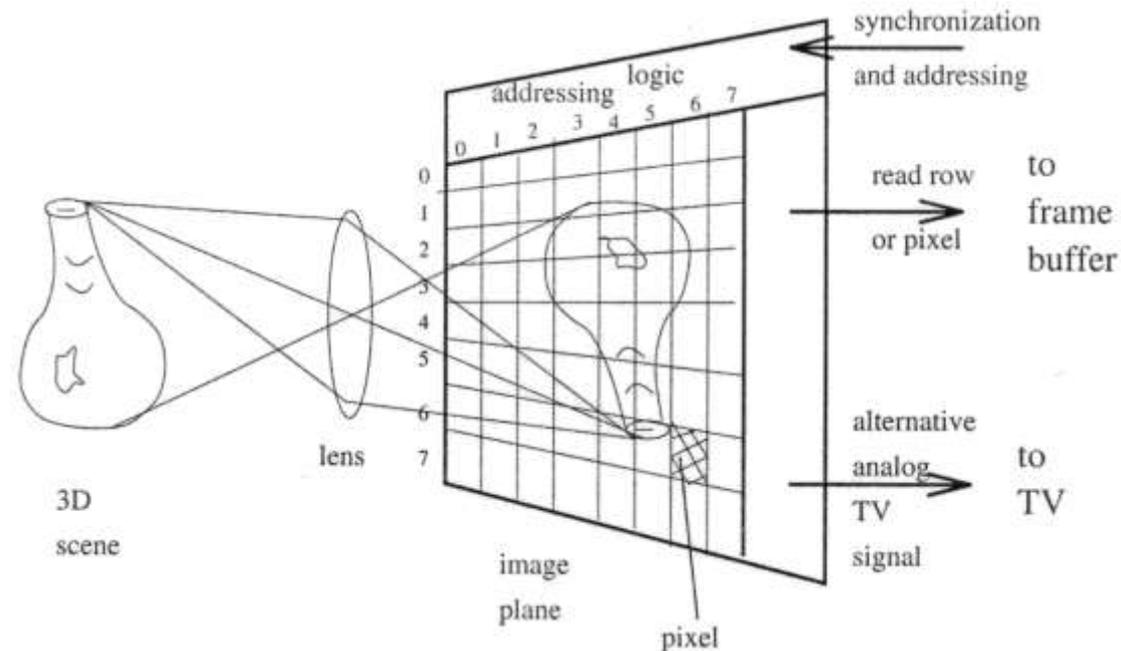


## **Image acquisition**

- This stage involves preprocessing, such as scaling.
- Acquire a digital image using an image sensor
- In detail, devices that are sensitive to energy(electromagnetic, sound, ... )
- If not digital, an analog-to-digital conversion process is required
- The nature of the image sensor (and the produced image) are determined by the application
- In general, CCD(charge-coupled device) or CMOS sensors are widely used
- Examples : Digital camera, Video camera, Scanner, ..

# CCD (Charged-Coupled Device) cameras

- Tiny solid state cells convert light energy into electrical charge.
- The image plane acts as a digital memory that can be read row by row by a computer.



# Steps in an image processing system

- Image enhancement – Here we bring out details that were obscured or highlight some features of interest in an image. (eg) increasing the contrast of an image.
- Image Restoration – Here we talk about how to improve the appearance of an image. Unlike enhancement, which is subjective, this is objective.
- Color Image Processing – Due to Internet, this area is becoming popular. Various color models are worthy to know.
- Wavelets – Representing the images in various degrees of resolution in the basis of wavelets.

# Steps in an image processing system

- Compression – It is a technique for reducing the storage required to save an image or bandwidth needed to transmit.
- Morphological Processing – It deals with tools for extracting image components that are useful in the representation and description of shape.

# Steps in an image processing system



## Segmentation

- Broadly defined: breaking an image into its constituent parts
- In general, one of the most difficult tasks in image processing
- Good segmentation simplifies the rest of the problem
- Poor segmentation make the task impossible
- Output is usually raw pixel data: may represent region boundaries, points in the region itself, etc.
- Boundary representation can be useful when the focus is on external shape characteristics (e.g. corners, rounded edges, etc.)
- Region representation is appropriate when the focus is on internal properties

# Steps in an image processing system

- Representation & description
  - Representation: transforming raw data into a form suitable for computer processing
  - Description (also called feature extraction) deals with extracting features that result in some quantitative information of interest or features which are basic for differentiating one class of objects from another
  - In terms of character recognition, descriptors such as lakes (holes) and bays help differentiate one part of the alphabet from another

# Steps in an image processing system

- Recognition & Interpretation
- Recognition: The process which assigns a label to an object based on the information provided by its descriptors
  - may be the alphanumeric character A
- Interpretation: Assigning meaning to an ensemble of recognized objects.
  - 35487-0286 may be a ZIP code

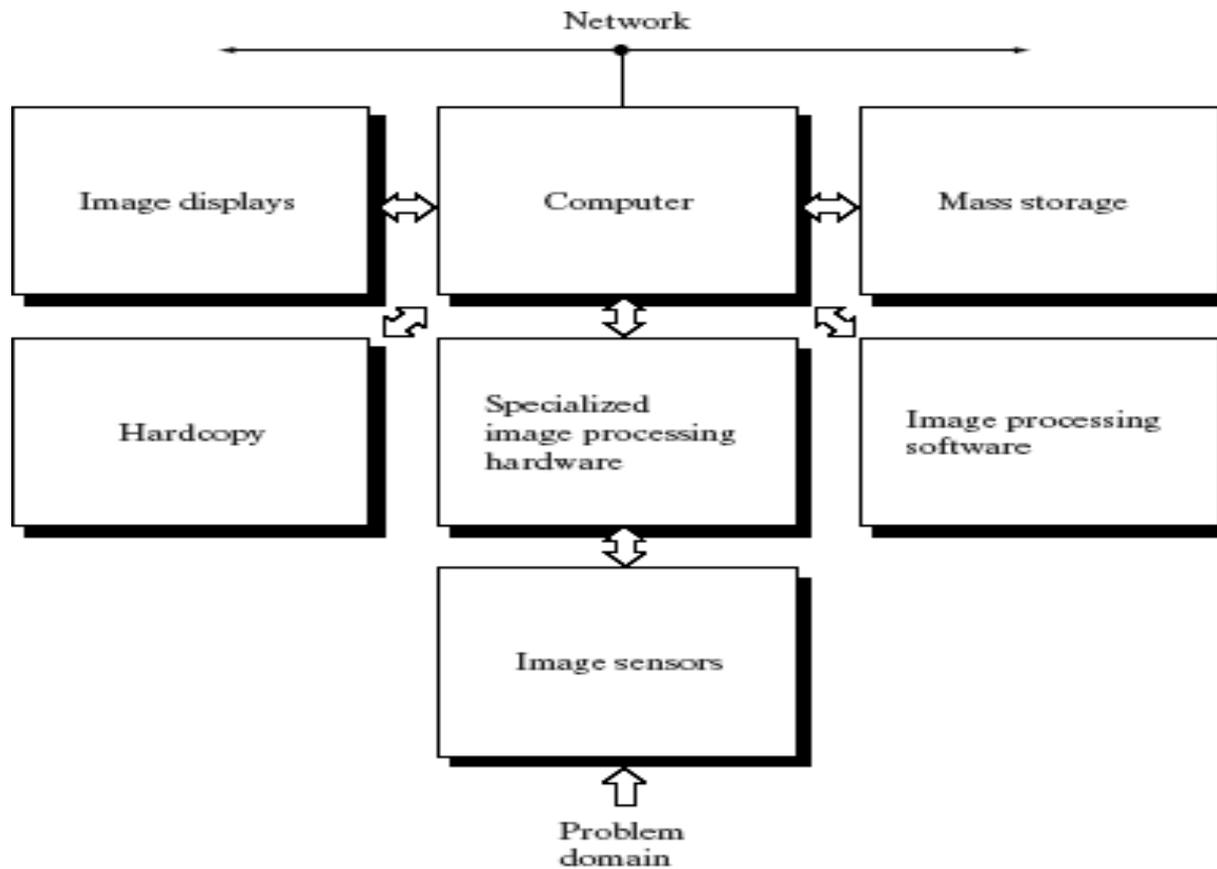
# The knowledge base

- Knowledge about a problem domain is coded into an image processing system in the form of a knowledge database
  - May be simple:
    - detailing areas of an image expected to be of interest
  - May be complex
    - A list of all possible defects of a material in a vision inspection system
  - Guides operation of each processing module
  - Controls interaction between modules
  - Provides feedback through the system

# Steps in an image processing system

- Not all image processing systems would require all steps/processing modules
  - Image enhancement for human visual perception may not go beyond the preprocessing stage
- A knowledge database may not be required
- Processing systems which include recognition and interpretation are associated with image analysis systems in which the objective is autonomous (or at least partially automatic)

# Components of an Image Processing System



# Basic components of a general-purpose system used for digital image processing

- Image sensors – Two elements are needed to acquire digital images.
  - First one is the physical device that is sensitive to energy radiated by the object that we want to image.
  - The second one, called the digitizer, is a device for converting the output of the physical sensing device into digital form.
  - Ex. - in a digital video camera, the sensors produce an electrical output proportional to light intensity.

# Basic components of a general-purpose system used for digital image processing

- Specialized Image Processing Hardware -
  - It consists of digitizer plus hardware that performs other primitive operations such as an arithmetic logic unit (ALU), which performs arithmetic and logical operations on entire image.
  - This type of hardware is also called as front-end subsystem and its characteristic is speed.
  - This unit does things that require fast data throughputs which main computer cannot handle.
- Computer – In an image processing system it is a general-purpose computer.
- Software – It consists of specialized modules that does specific tasks (eg. matlab)

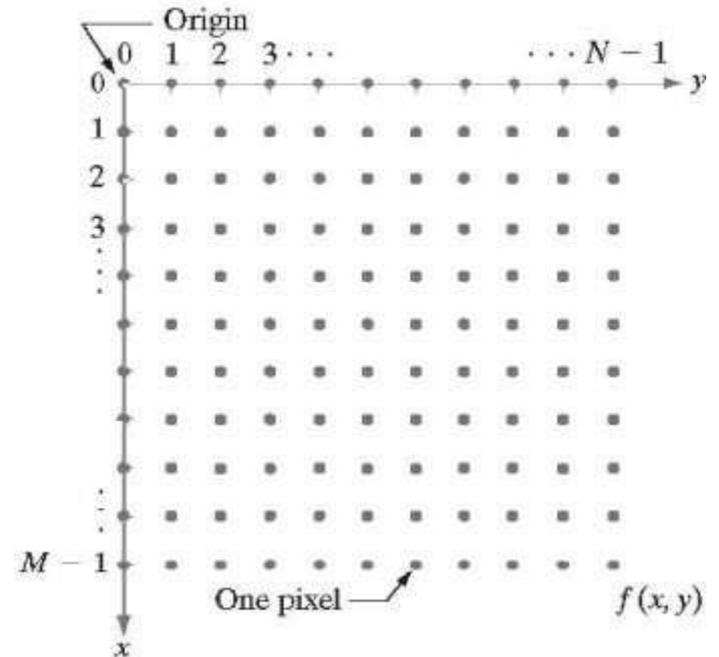
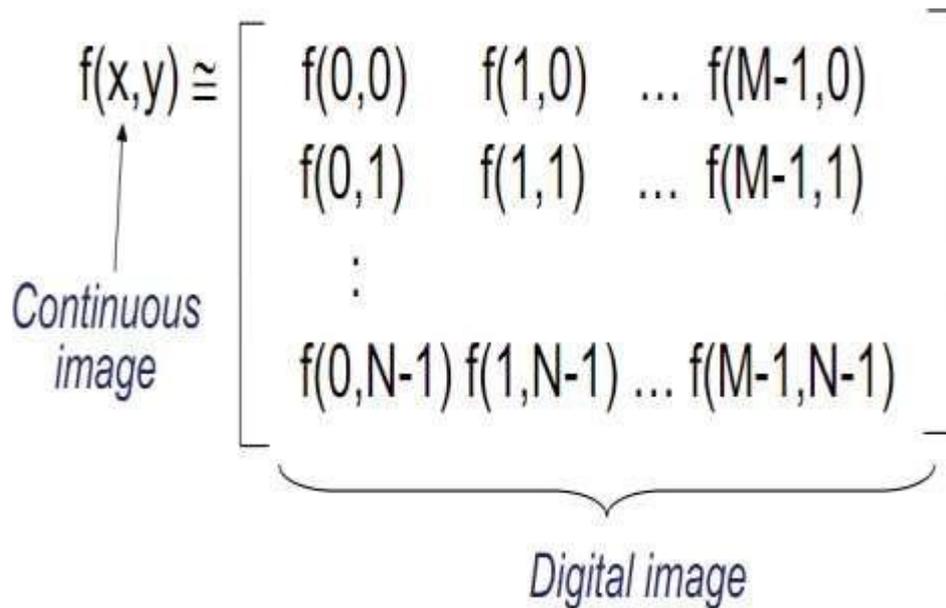
# Basic components of a general-purpose system used for digital image processing

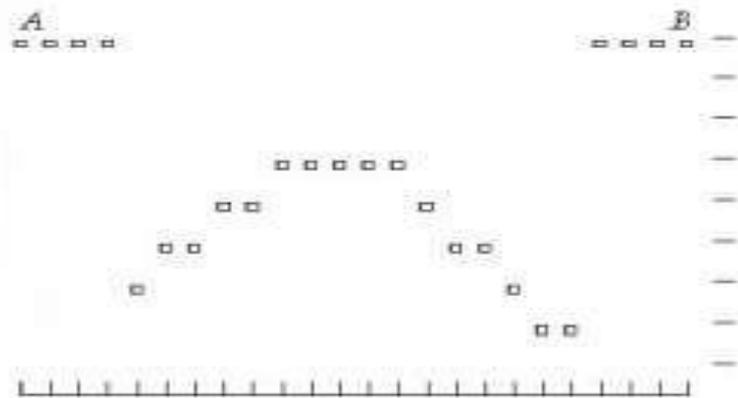
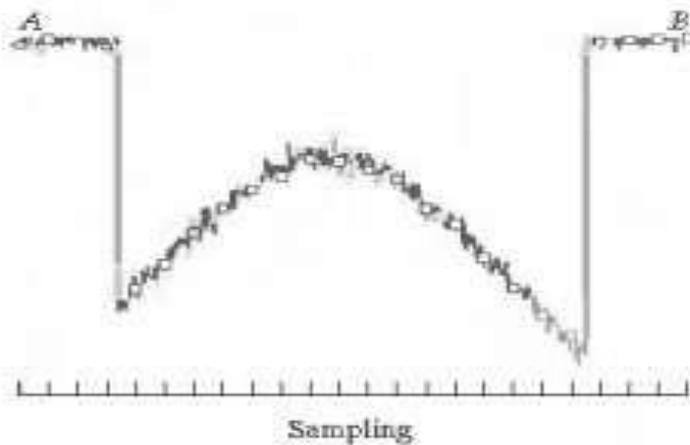
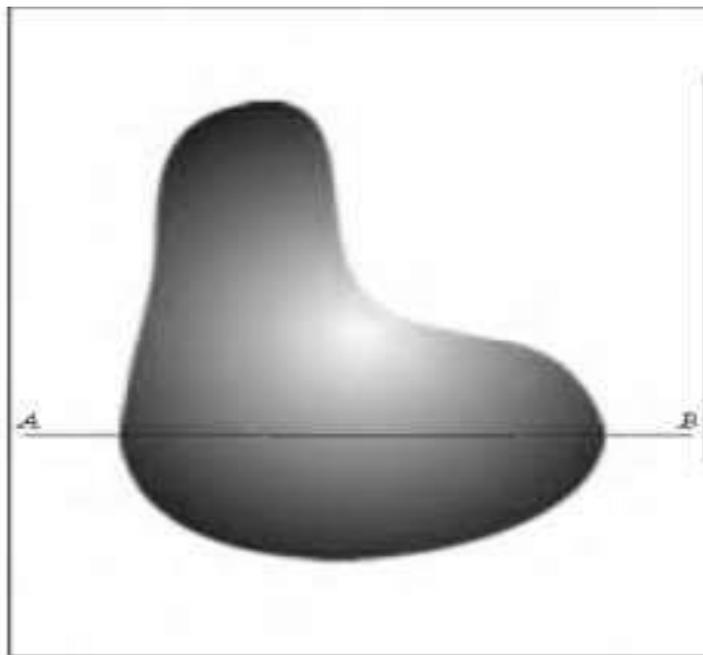
- Mass storage – An image of 1024 X 1024 size, storing the intensity of each pixel in 8 bits, requires one megabyte of storage.
- For short-time storage, we can use computer memory.
- Another method is to use a specialized board called frame buffer, that store one or more images and can be accessed rapidly.
- They enable us to instantaneously zoom, scroll (vertical shift) and pan (horizontal shift).
- For on-line storage magnetic disks or optical-media are used.
- The archival storage needs massive capacity but are accessed infrequently.
- Image Displays – These are mainly color TV monitors.
- Hardcopy – These devices include laser printers, film cameras, inkjet units,

# Sampling & Quantization

- Image sampling
  - Digitization of spatial coordinates (x,y)
- Quantization
  - Amplitude digitization
- The quality of a digital image is determined to a large degree by the number of samples and discrete gray levels used in sampling and quantization

# Sampling & Quantization

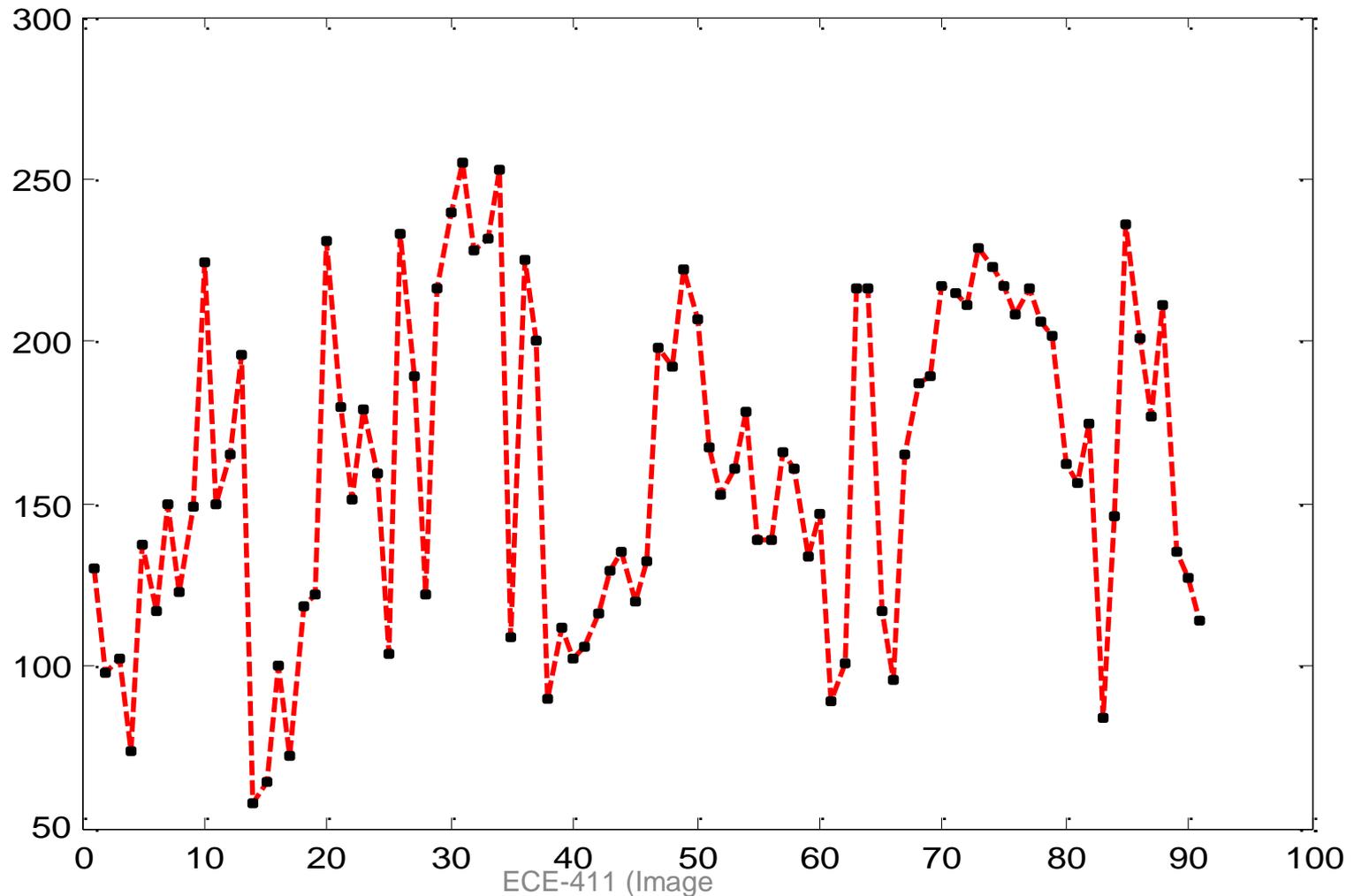




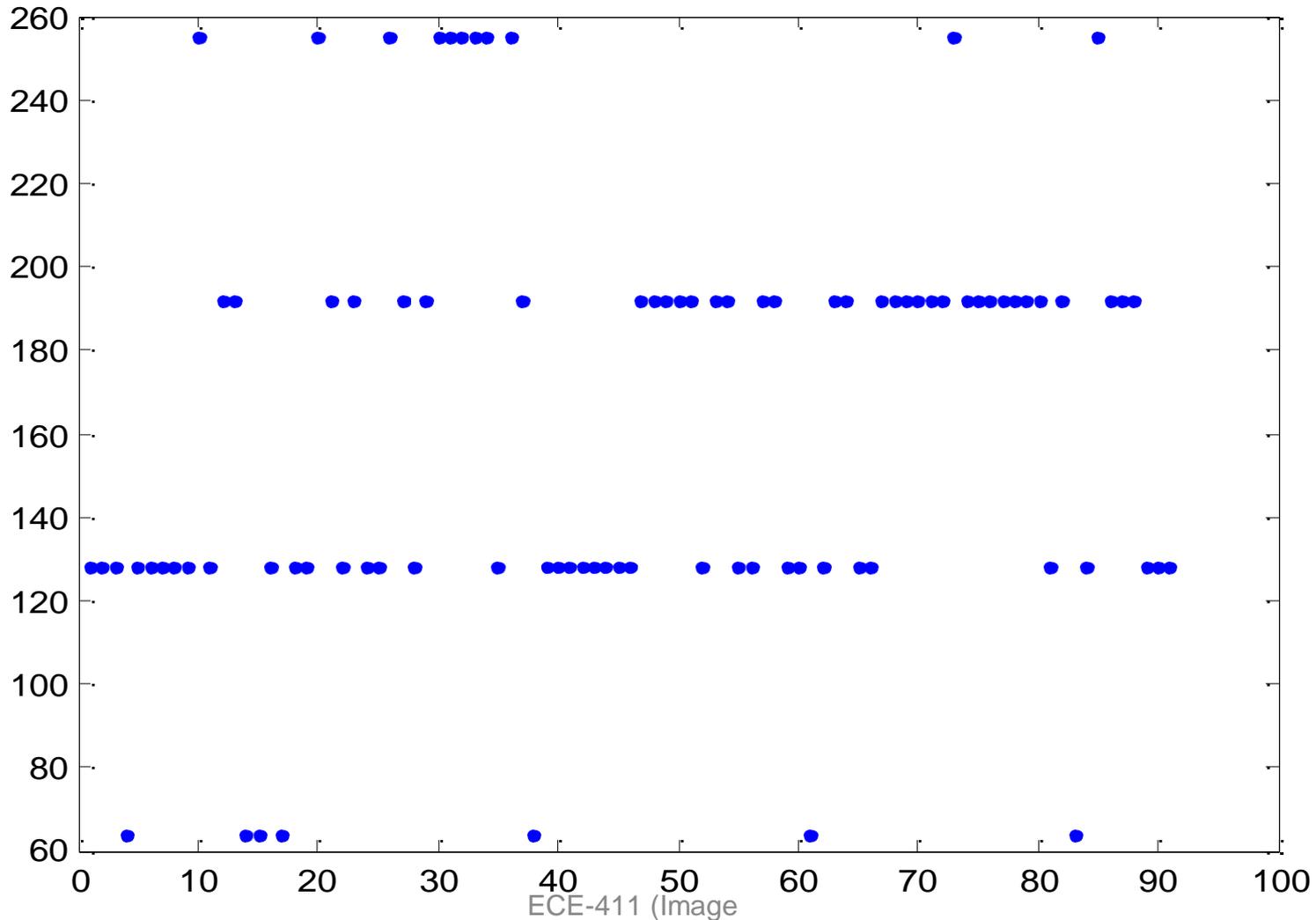
a b  
c d

**FIGURE 2.16** Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

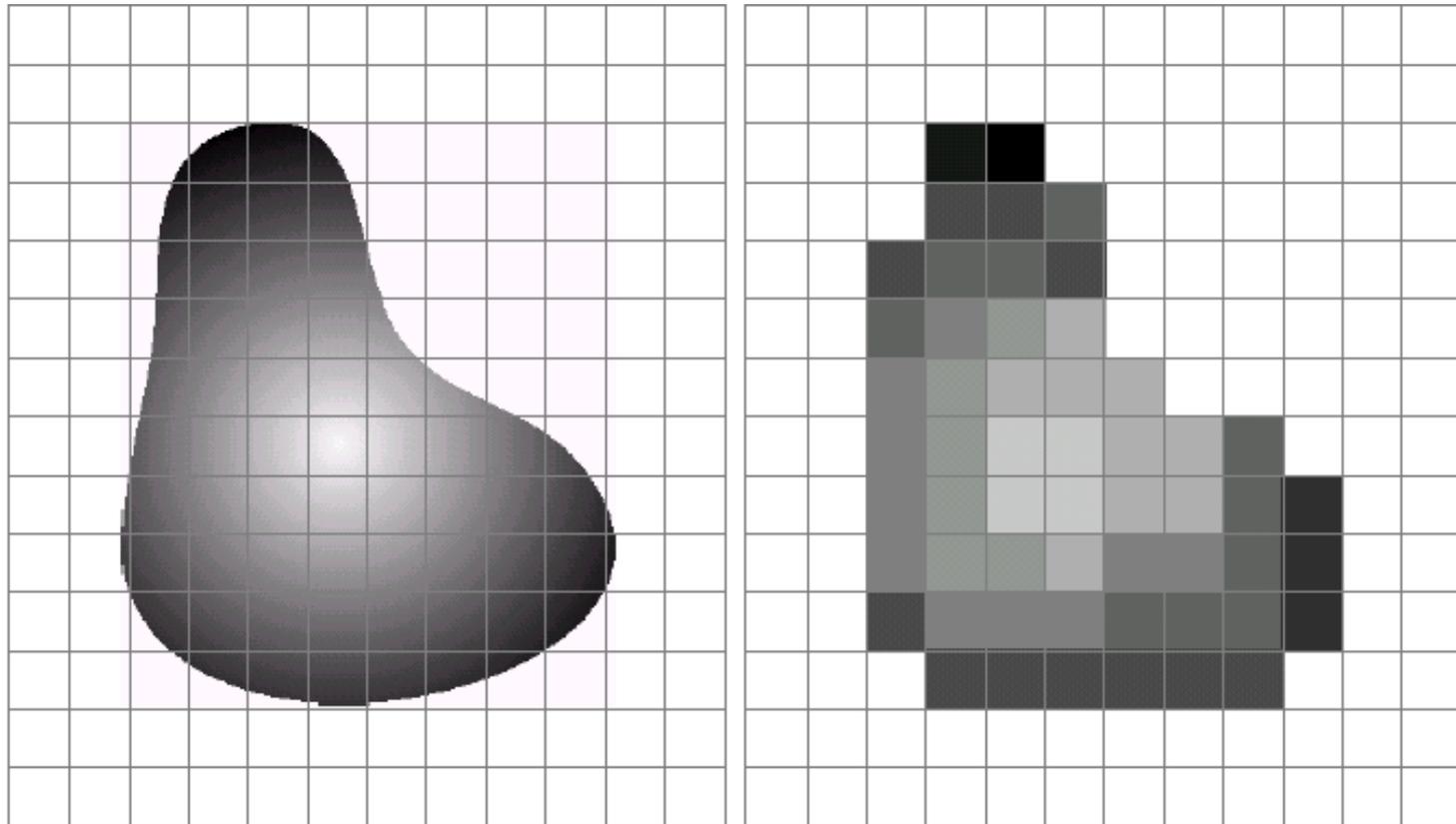
# The intensity variation sampled at regular intervals along the scan line



# Four level intensity quantization of sampled scan line

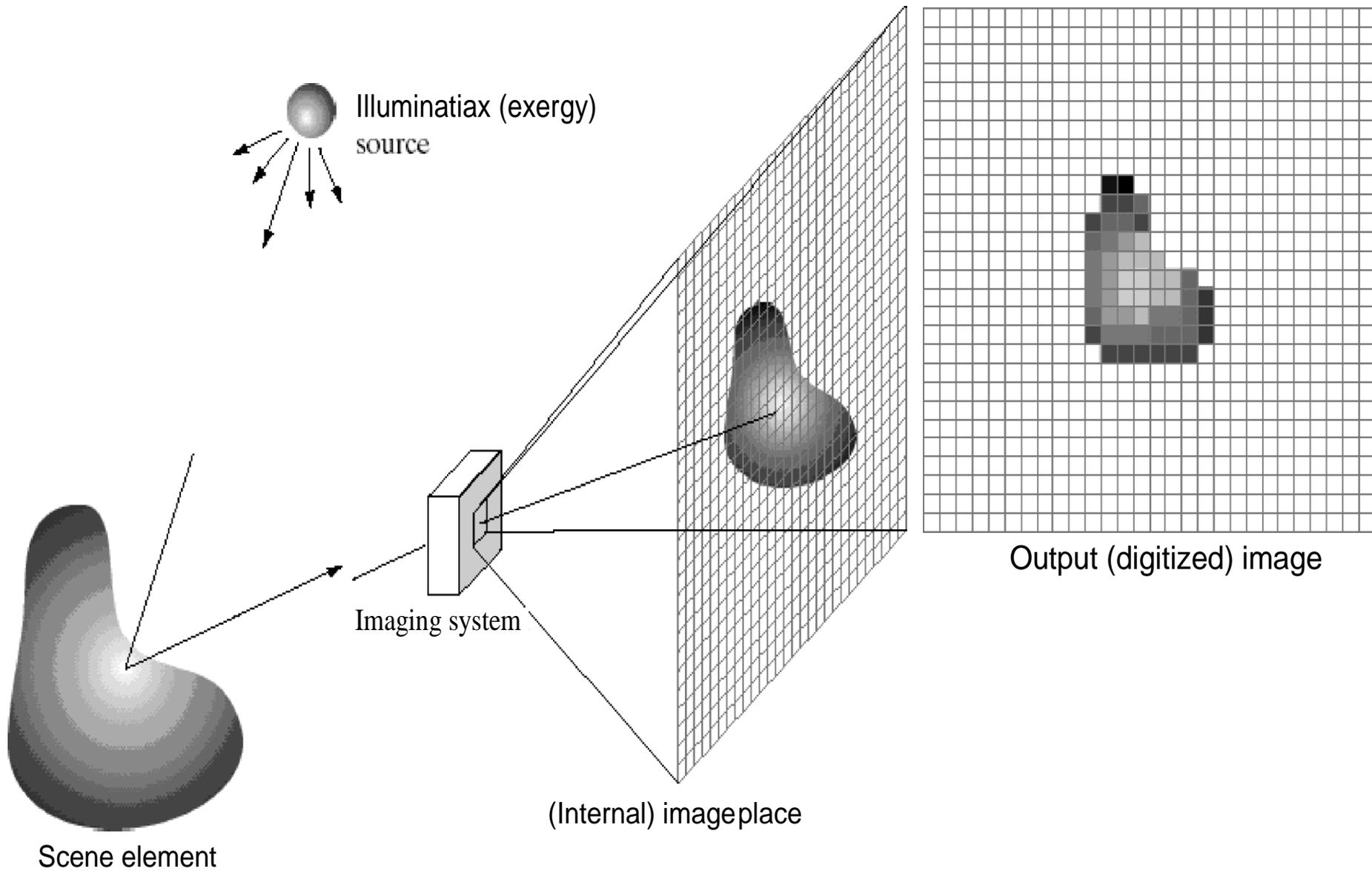


# Formulation of Digital Image



a b

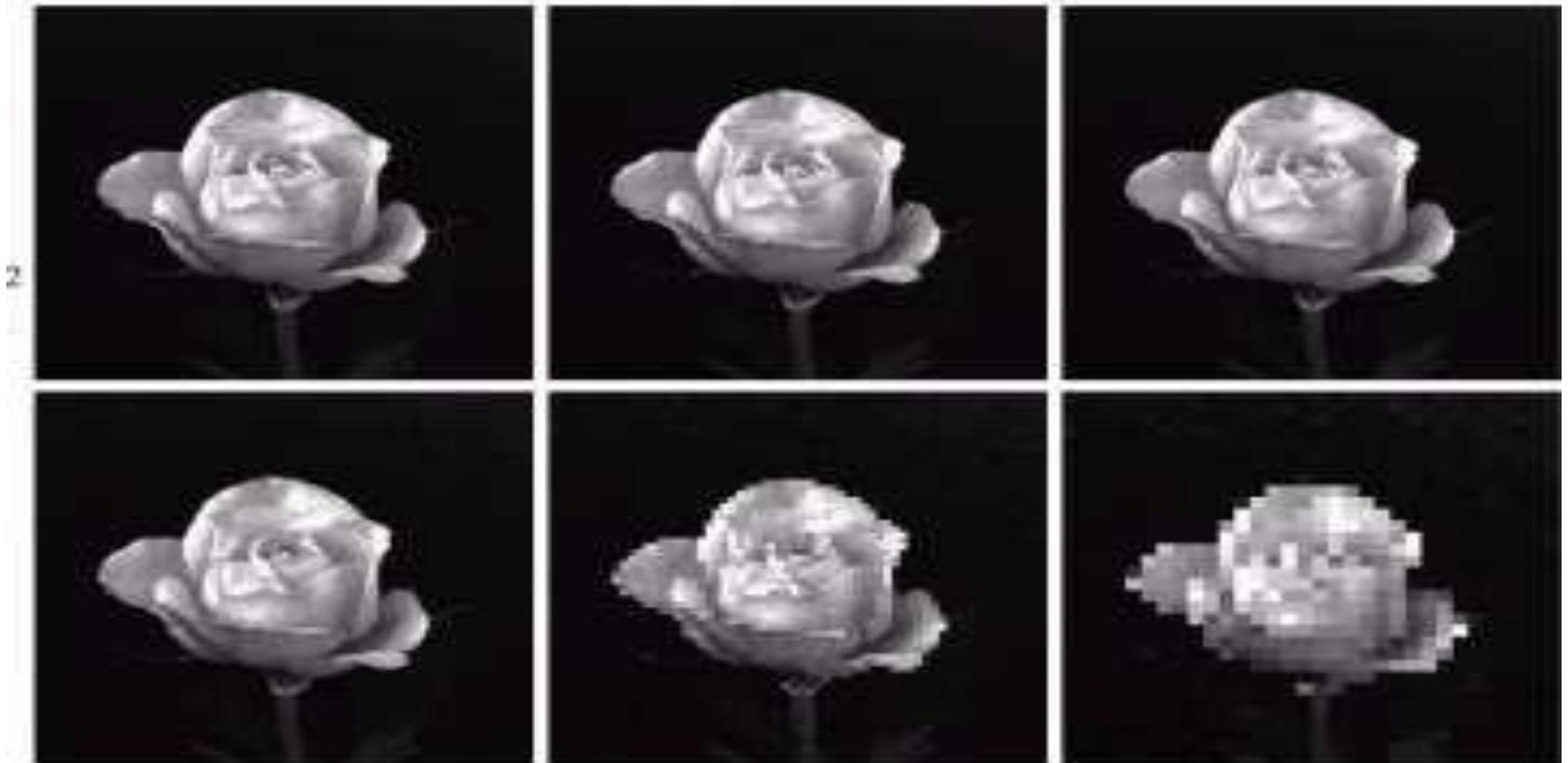
**FIGURE 2.17** (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.



# Image Resolution

- Spatial Resolution (x,y)
  - Spatial resolution is the smallest discernible detail in an image
  - A line pair : a line and its adjacent space
  - A widely used definition of resolution is the smallest number of discernible line pairs per unit distance .
  - Ex: 100 line pairs/mm
  - But, unit distance or unit area is omitted in most cases

# Spatial Resolution



a b c  
d e f

**FIGURE 2.20** (a)  $1024 \times 1024$ , 8-bit image. (b)  $512 \times 512$  image resampled into  $1024 \times 1024$  pixels by row and column duplication. (c) through (f)  $256 \times 256$ ,  $128 \times 128$ ,  $64 \times 64$ , and  $32 \times 32$  images resampled into  $1024 \times 1024$  pixels.

# Image Resolution(Cont..)

- Gray-level Resolution
  - Gray-level resolution is the smallest discernible change in gray level (but, highly subjective!)
  - Due to hardware considerations, we only consider quantization level
  - Usually an integer power of 2. The most common level is  $2^8=256$
  - However, we can find some systems that can digitize the gray levels of an image with 10 to 12 bits of accuracy.

# Gray-level Resolution

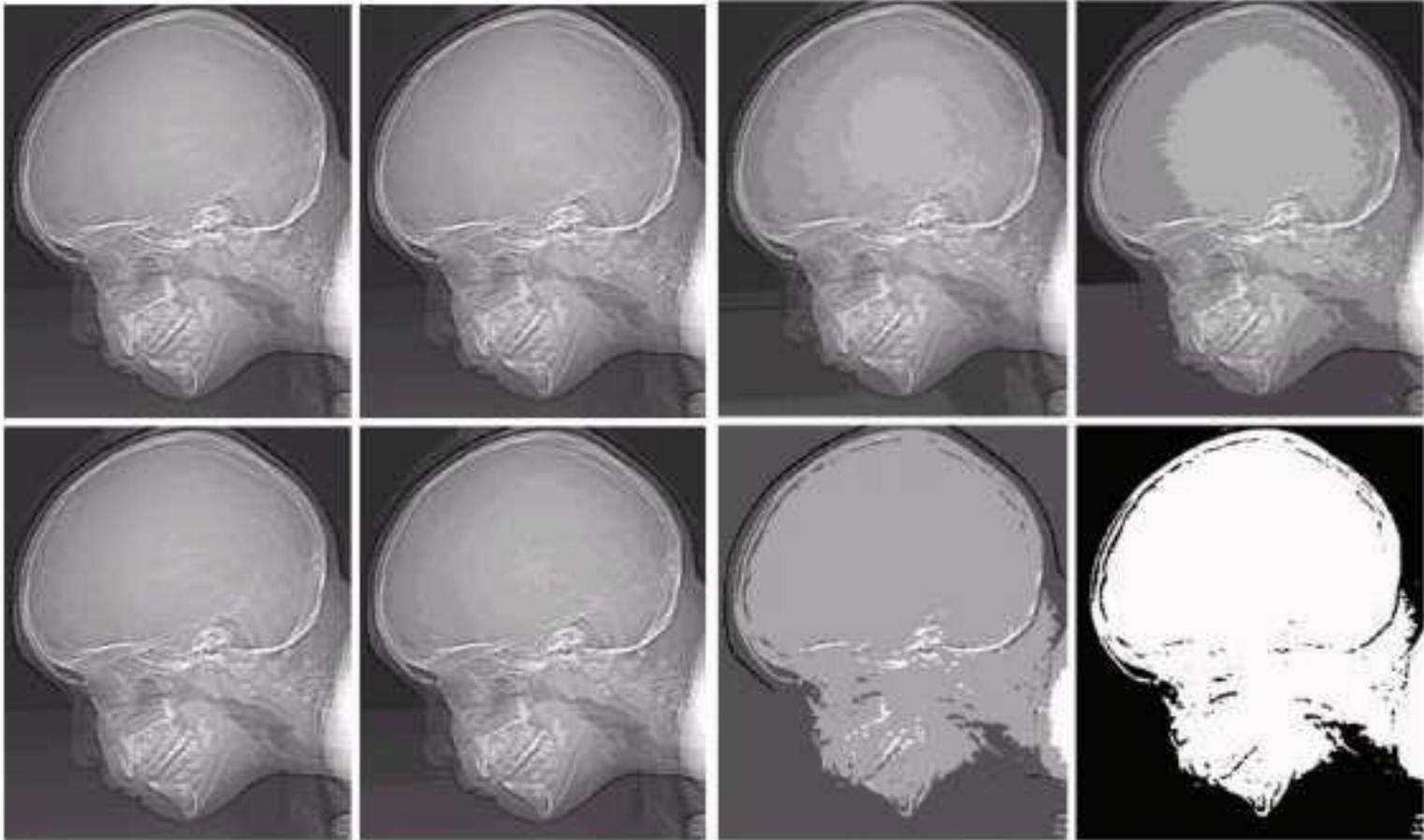


Image displayed in 256, 128, 64, 32, 16, 8, 4, 2 gray-levels

# Storage

- For  $M \times N$  image with  $L (=2^k)$  discrete gray level
  - The number,  $b$ , of bits required to store the image is

$$b = M * N * k \text{ bits}$$

- Ex1:  $1024 \times 1024 \times 8 \text{bit} = 1 \text{Mbytes}$

## ➤ Common image file formats

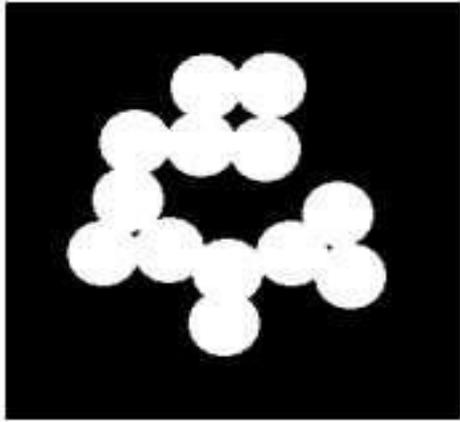
- GIF (Graphic Interchange Format) -
- PNG (Portable Network Graphics)
- JPEG (Joint Photographic Experts Group)
- TIFF (Tagged Image File Format)
- PGM (Portable Gray Map)
- FITS (Flexible Image Transport System)

# Image types

- $x(m,n) = 0$  or  $1$ : binary image
- $x(m,n) = 0, 1, 2, \dots, P-1$ : grayscale image
  - $P$  typically something like 256, 512 or some power of 2.
  - 256 is really the most common
  - $0 = \text{black}$ ,  $P = \text{white}$
- $x(m,n) = [0 \text{ to } P-1, 0 \text{ to } P-1, 0 \text{ to } P-1]$ 
  - Red, green, blue color image
  - Like three grayscale images
- $x(m,n) = \text{index into color map}$ .
  - Color map = three column table with all possible colors
  - Image index says which row in that table gives RGB values for that pixel
  - So long as table is known, very easy to store indices

# Image Type

## Examples



Binary



Grayscale (256 levels)



RGB

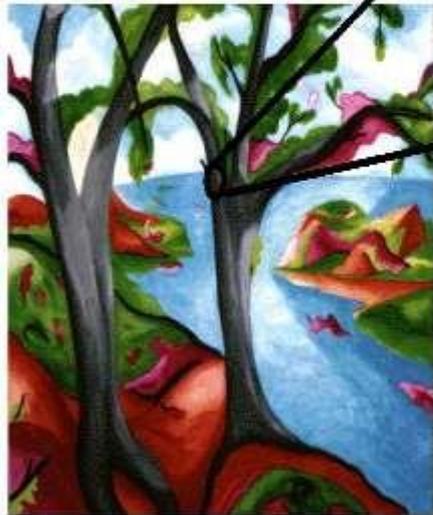
← How to tell difference? →

Indexed



# Difference between Indexed Image and RGB Image

## Indexed Image



2	21	40
14	17	21
5	8	5
8	10	30
15	18	31
18	31	31
0	0	0
0.0627	0.0627	0.0314
0.2902	0.0314	0
0	0	1.0000
0.2902	0.0627	0.0627
0.3882	0.0314	0.0941
0.4510	0.0627	0
0.2588	0.1608	0.0627
⋮		

## RGB Image



0.2235	0.1294	<b>Blue</b>	0.4196	0.2588
0.5804	0.2902	<b>0.0627</b>	0.2902	0.2902
0.5804	0.0627	0.0627	0.0627	0.2235
0.5176	0.1922	0.0627	<b>Green</b>	0.1922
0.5176	0.1294	<b>0.1608</b>	0.1294	0.2588
0.5176	0.1608	0.0627	0.1608	0.1922
0.5490	0.2235	0.5490	<b>Red</b>	0.7412
0.490	0.3882	<b>0.5176</b>	0.5804	0.5804
0	0.2588	0.2902	0.2588	0.2235
0	0.2235	0.1608	0.2588	0.2588
0	0.1608	0.2588	0.2588	0.2588
0.5490	0.2235	0.5490	0.7412	0.7765
0.490	0.3882	0.5176	0.5804	0.5804
0	0.2588	0.2902	0.2588	0.2235
0	0.2235	0.1608	0.2588	0.2588
0	0.1608	0.2588	0.2588	0.2588

Thank You.