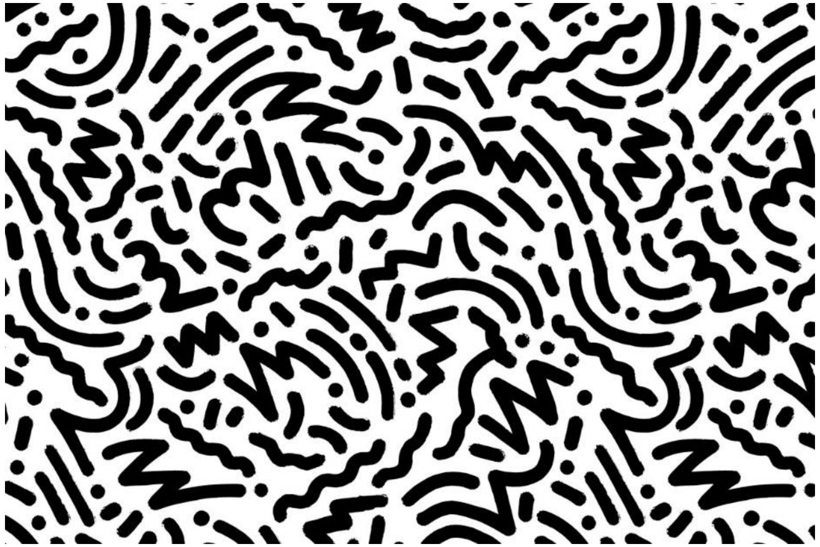
CSE395

Image processing

Module-1: Introduction: Fundamentals



CONTENTS

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- Steps in digital image processing

IMAGES

ANALOG

Continuous

For Human Viewing

DIGITAL

Matrix of Pixels

Each Image Point

Brightness
Film Density
Color

Number

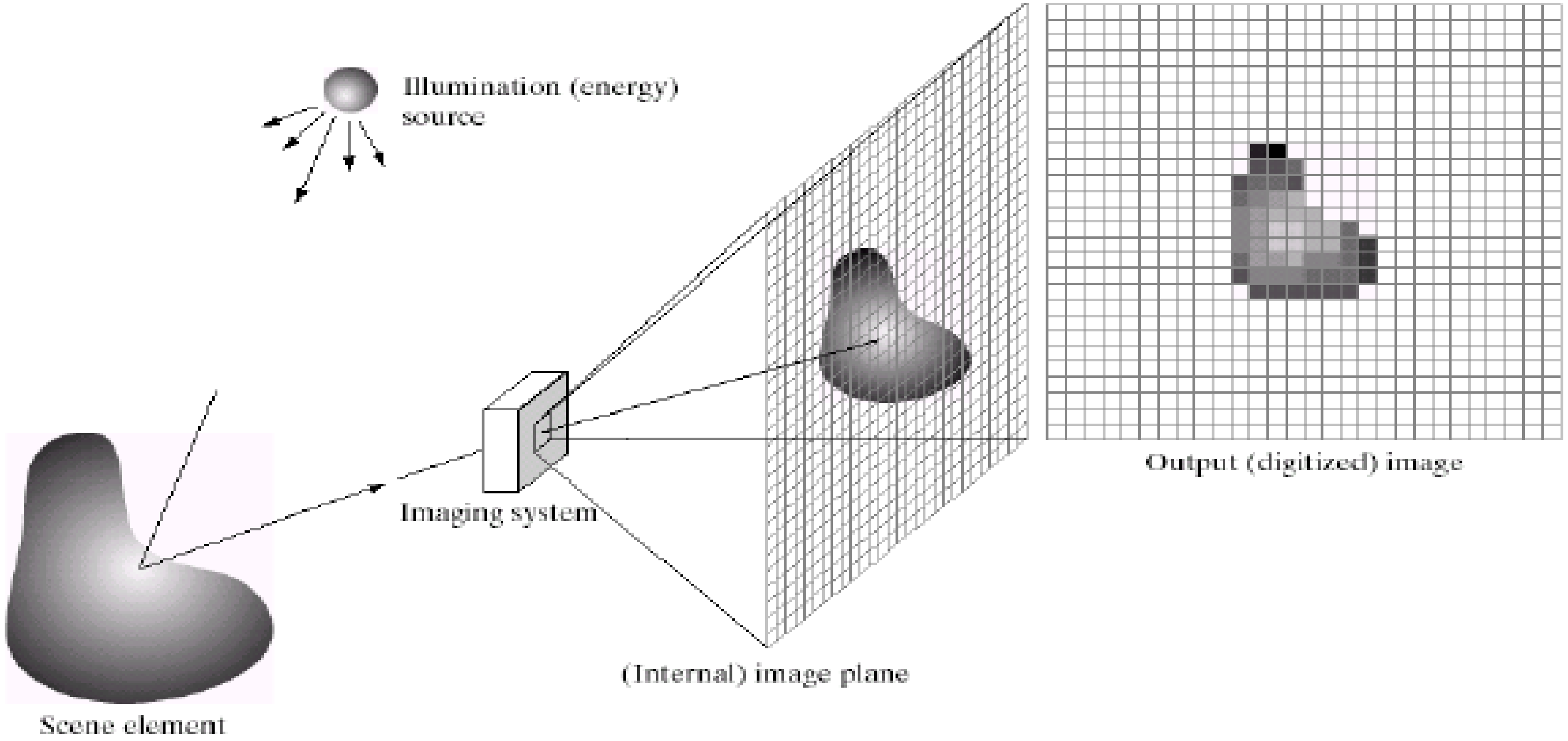
56	56	57	56
56	56	57	56
57	57	57	59
58	58	58	60

For Computer Systems

Sprawls

WHAT IS A DIGITAL IMAGE?

A digital image is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels



A Simple Image Formation Model

$$f(x, y) = i(x, y) \cdot r(x, y)$$

$f(x, y)$: intensity at the point (x, y)

$i(x, y)$: illumination at the point (x, y)

(the amount of source illumination incident on the scene)

$r(x, y)$: reflectance/transmissivity at the point (x, y)

(the amount of illumination reflected/transmitted by the object)

where $0 < i(x, y) < \infty$ and $0 < r(x, y) < 1$

- What is Digital Image Processing?

Digital Image

— a two-dimensional function $f(x, y)$

x **and** ***y*** **are spatial coordinates**

The amplitude of ***f*** **is called intensity or gray level at the point (x, y)**

Digital Image Processing

— process digital images by means of computer, it covers low-, mid-, and high-level processes

low-level: inputs and outputs are images

mid-level: outputs are attributes extracted from input images

high-level: an ensemble of recognition of individual objects

Pixel

— the elements of a digital image

Common image formats include:

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)

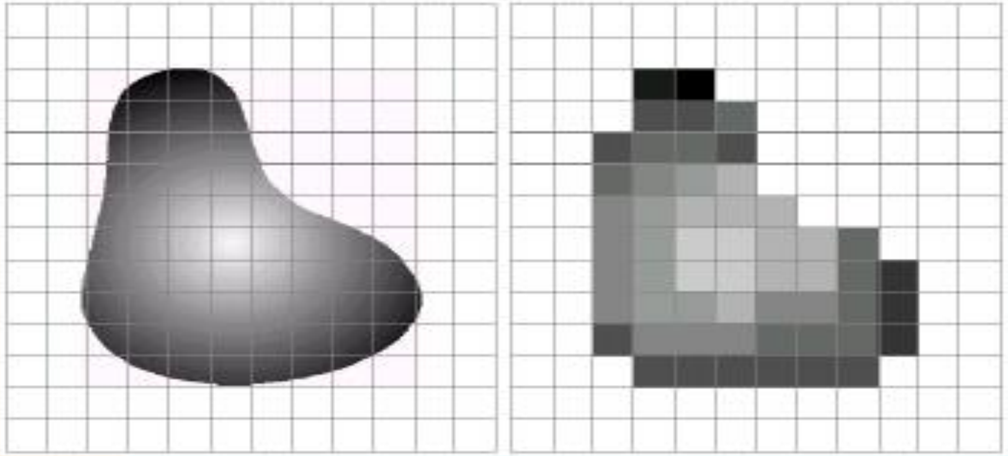
For most of this presentation we will focus on greyscale images.

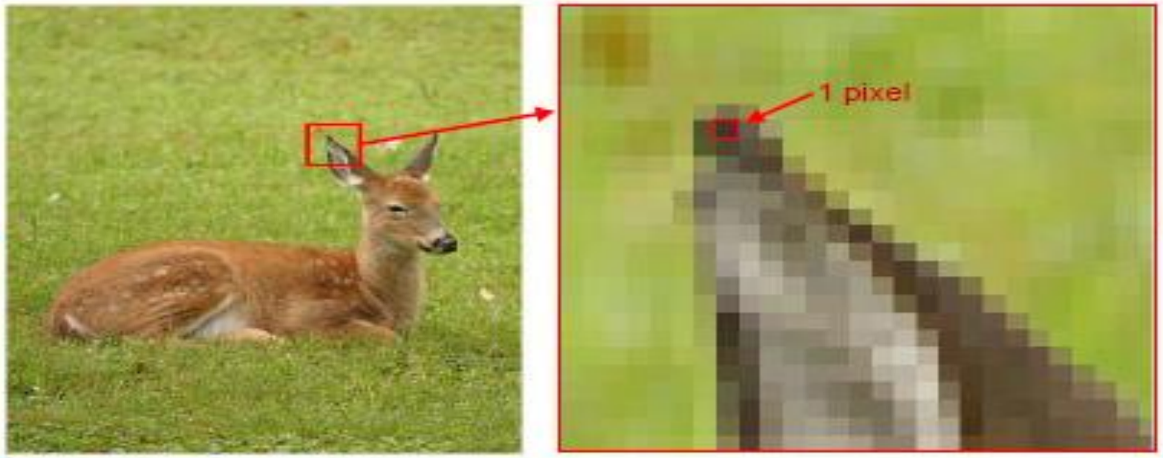
The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes

Low Level Process	Mid Level Process	High Level Process
Input: Image **Output:** Image **Examples:** Noise removal, image sharpening	**Input:** Image **Output:** Attributes **Examples:** Object recognition, segmentation	**Input:** Attributes **Output:** Understanding **Examples:** Scene understanding, autonomous navigation

Pixel values typically represent gray levels, colours, heights, opacities etc

Remember *digitization* implies that a digital image is an *approximation* of a real scene





HISTORY OF DIGITAL IMAGE PROCESSING

Early 1920s: One of the first applications of digital imaging was in the news-paper industry

- The Bartlane cable picture transmission service
- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

Early digital image

Mid to late 1920s: Improvements to the Bartlane system resulted in higher quality images

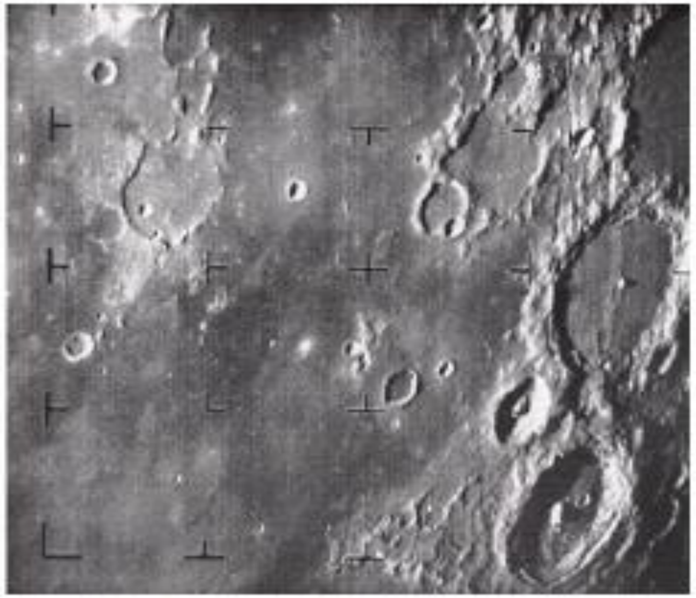
- New reproduction processes based on photographic techniques
- Increased number of tones in reproduced images

Improved digital image

Early 15 tone digital image

1960s: Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing

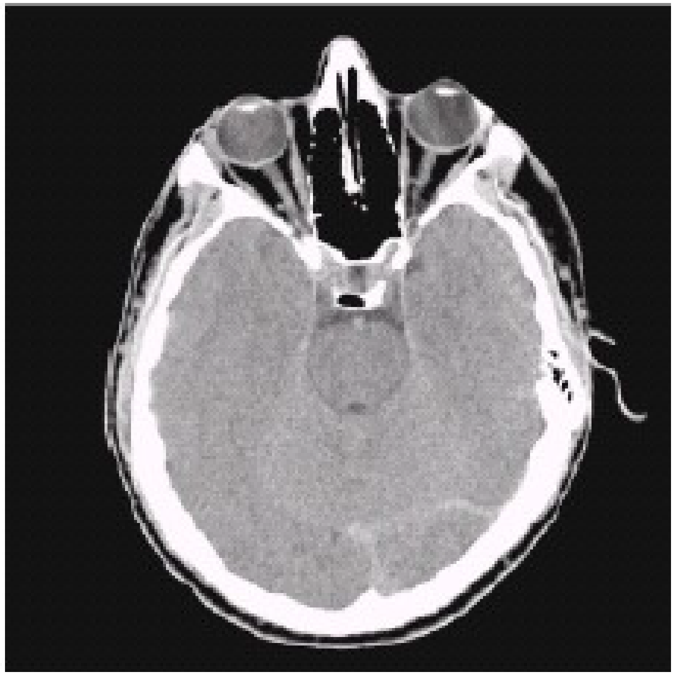
- **1964:** Computers used to improve the quality of images of the moon taken by the *Ranger 7* probe
- Such techniques were used in other space missions including the Apollo landings



A picture of the moon taken by the Ranger 7 probe minutes before landing

1970s: Digital image processing begins to be used in medical applications

- **1979**: Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerised Axial Tomography (CAT) scans

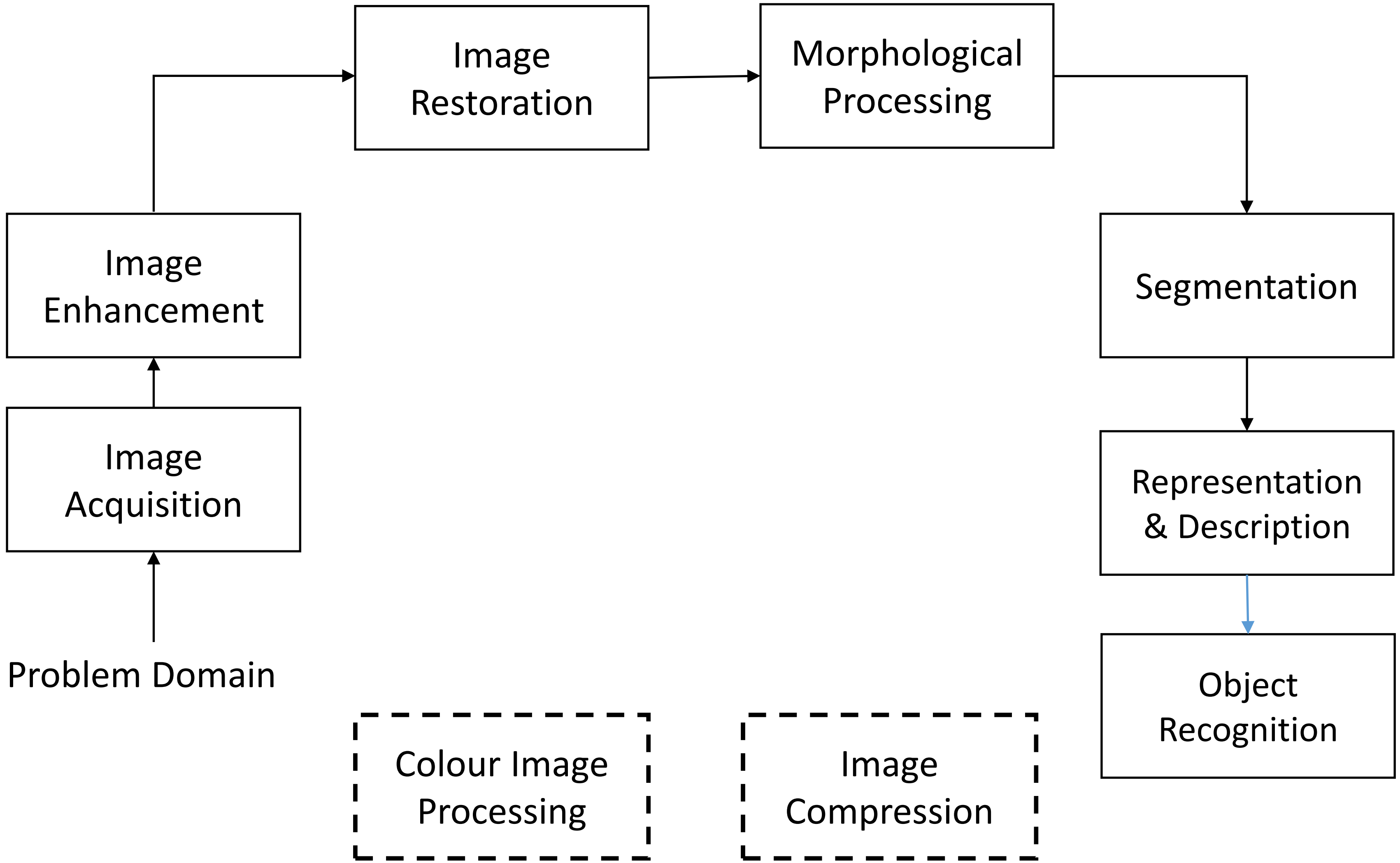


Typical head slice CAT image

1980s - Today: The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all kinds of areas

- Image enhancement/restoration
- Artistic effects
- Medical visualisation
- Industrial inspection
- Law enforcement
- Human computer interfaces

Key Stages in Digital Image Processing



Key Stages in Digital Image Processing: Image Acquisition

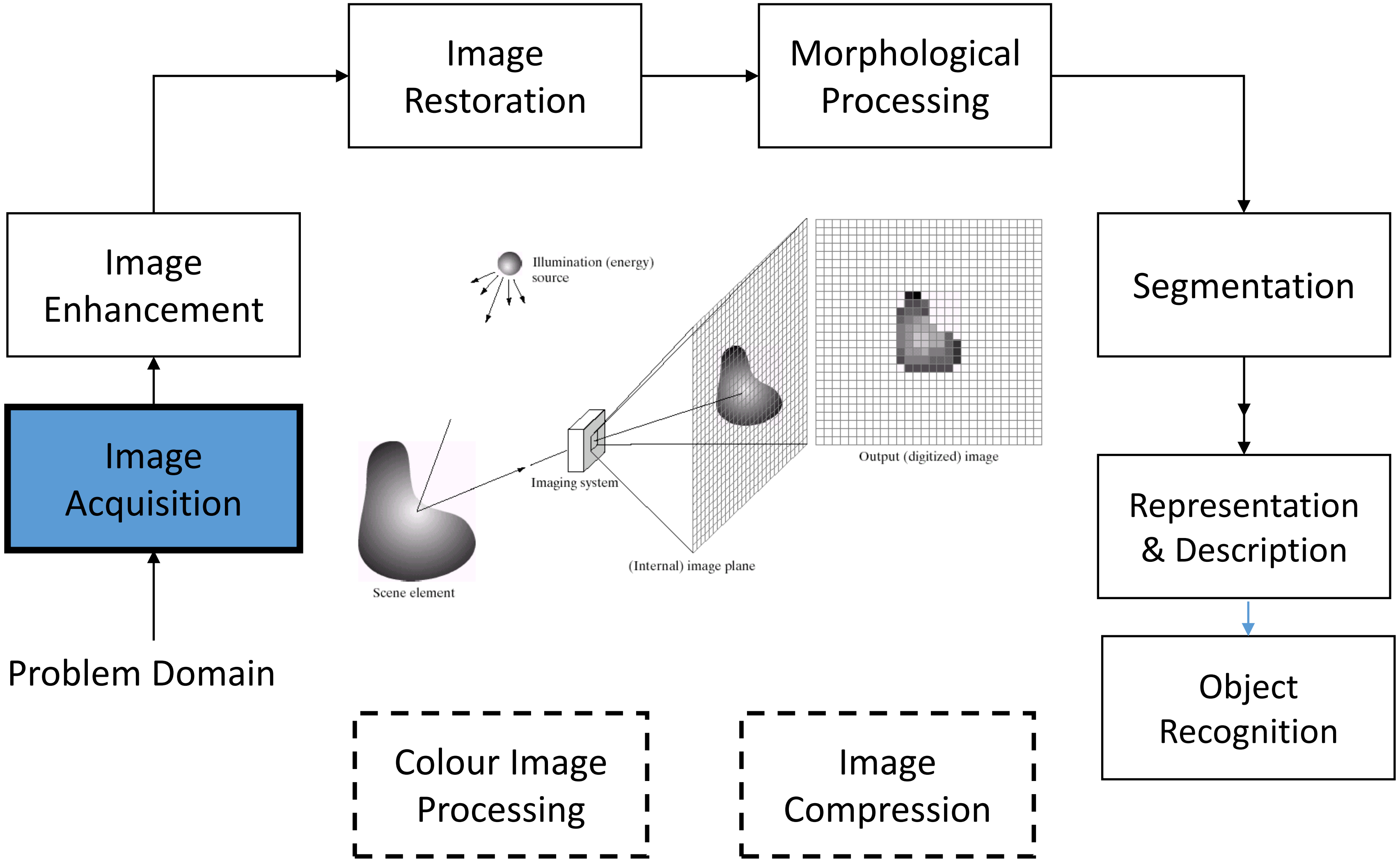
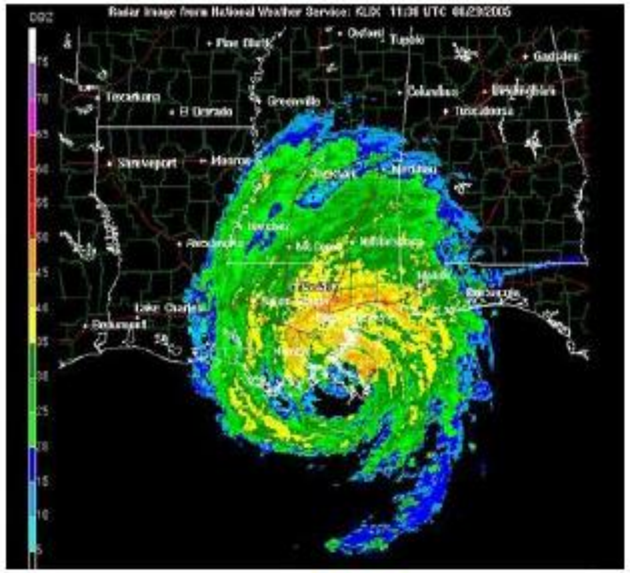


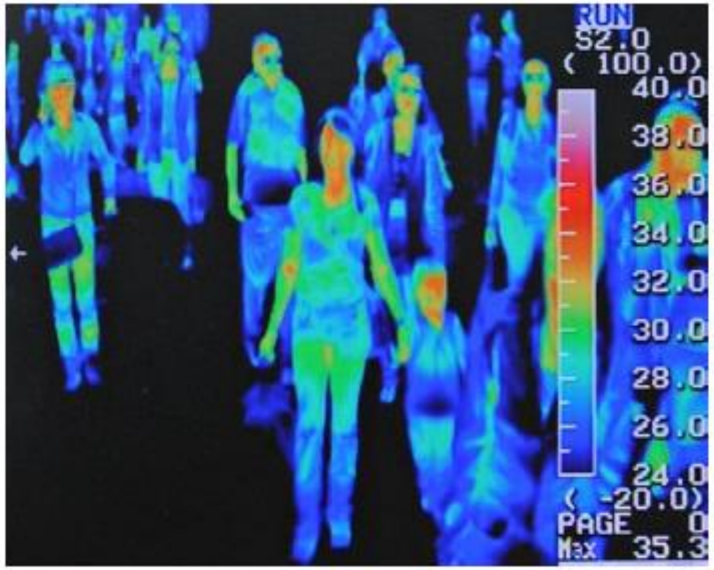
Image Acquisition

- A digital image is produced by one or several image sensors, which, besides various types of light-sensitive cameras, include range sensors, tomography devices, radar, ultra-sonic cameras, etc.
- Depending on the type of sensor, the resulting image data is an ordinary 2D image, a 3D volume, or an image sequence.
- The pixel values typically correspond to light intensity in one or several spectral bands (gray images or colour images), but can also be related to various physical measures, such as depth, absorption or reflectance of sonic or electromagnetic waves, or nuclear magnetic resonance.

Image Acquisition – Other Sensors



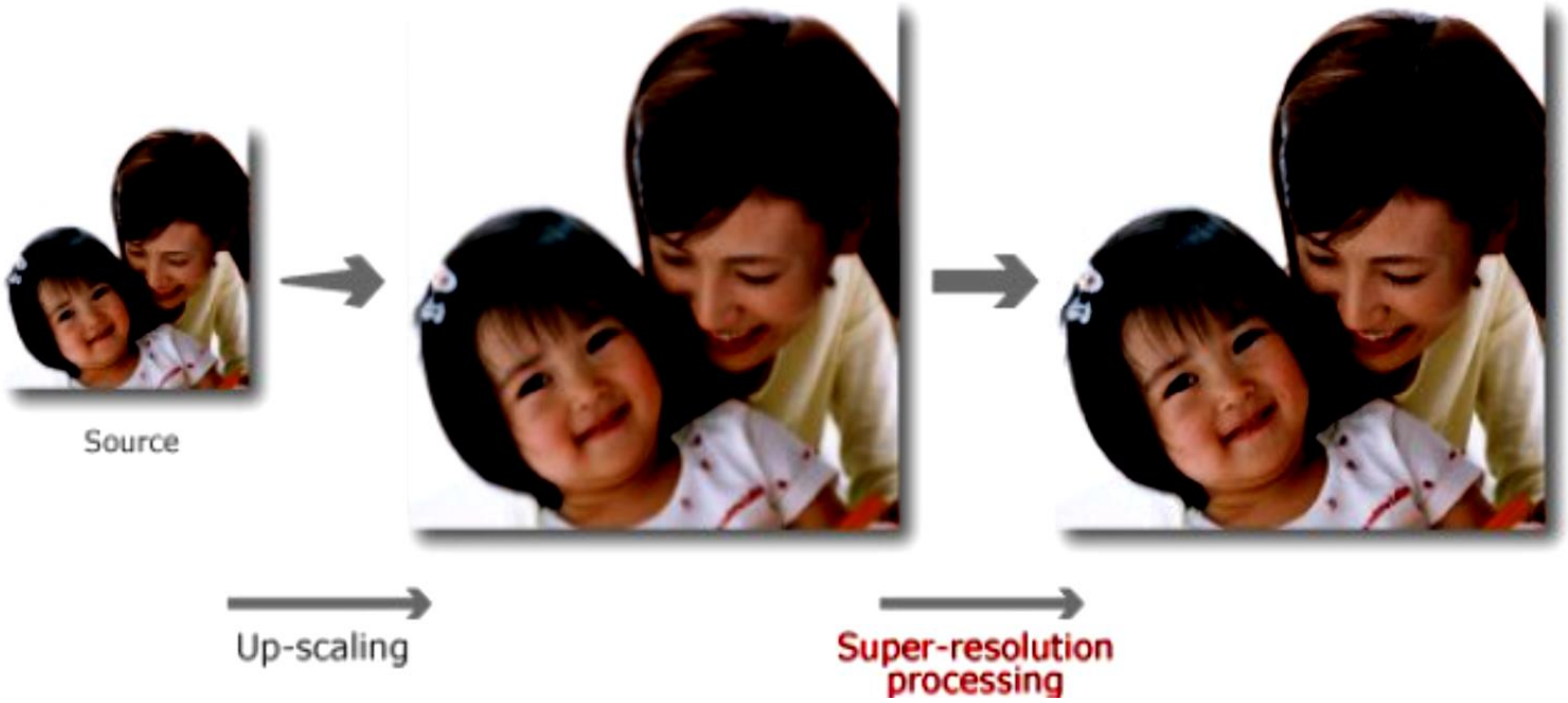
Weather radar image



Thermal image

Super-Resolution Technology

"Super resolution" is a technology that is used to sharpen out-of-focus images or smooth rough edges in images that have been enlarged using a general up-scaling process (such as a bilinear or bicubic process), thereby delivering an image with high-quality resolution.



Key Stages in Digital Image Processing: Image Enhancement

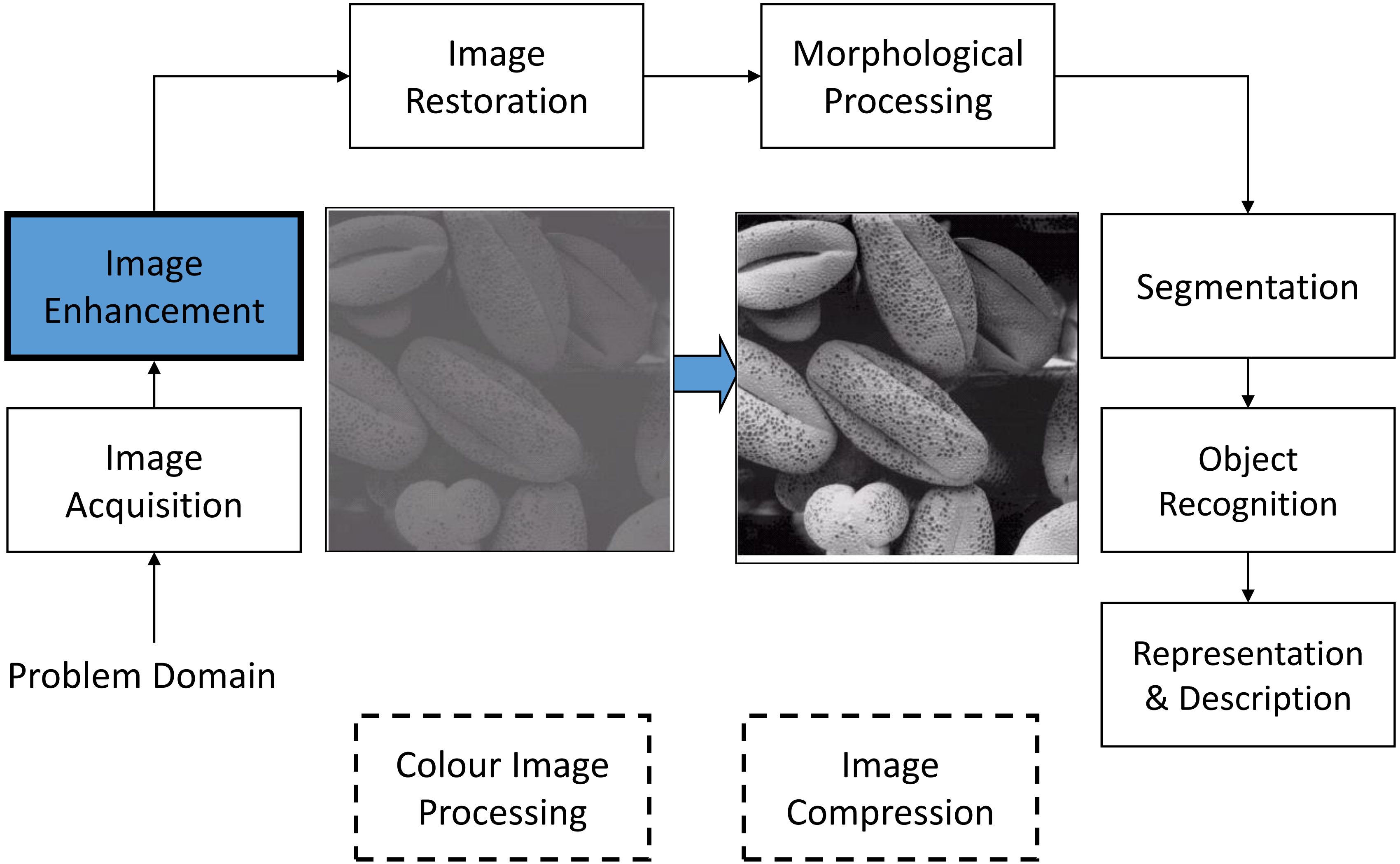
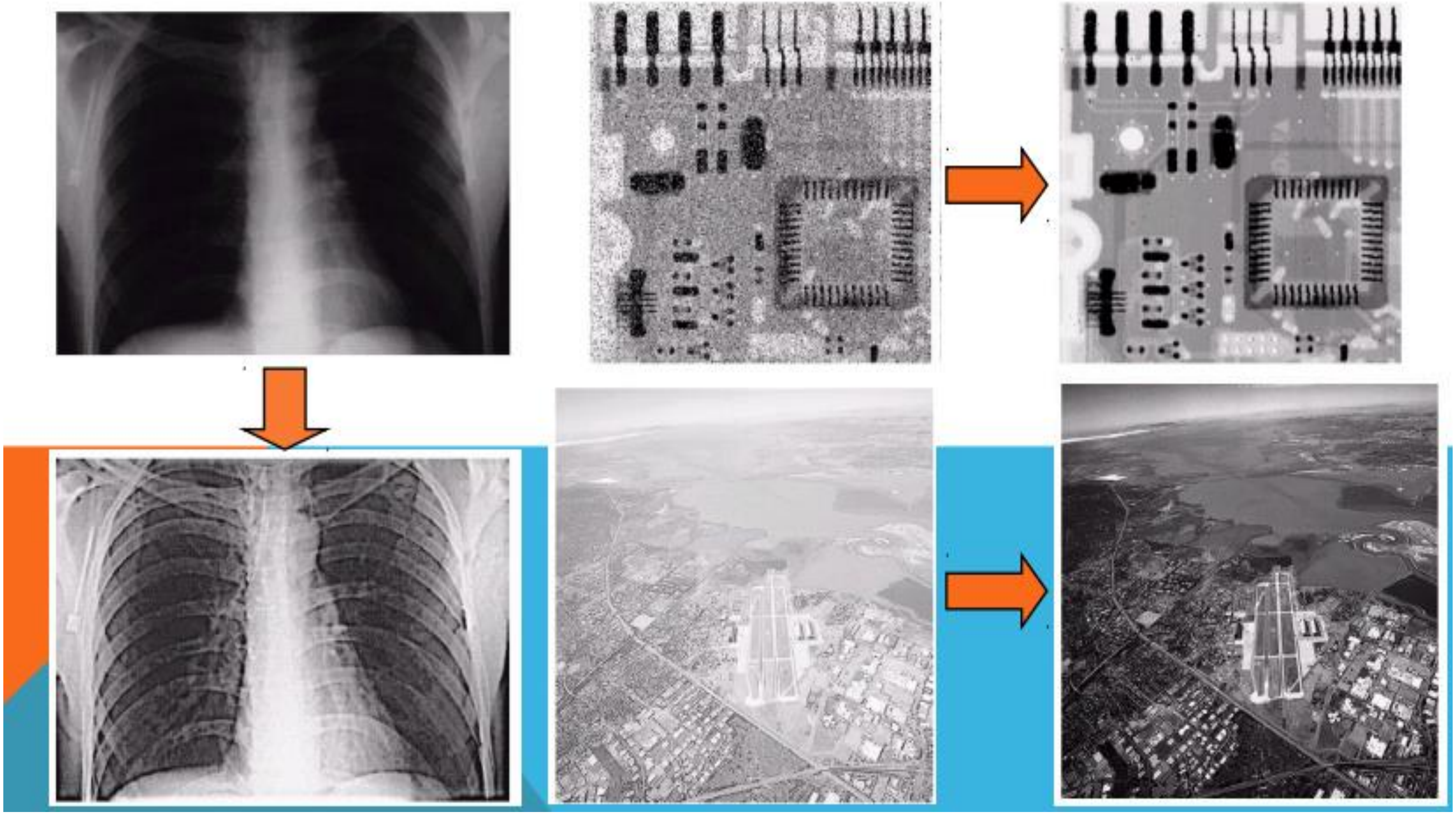


Image Enhancement

- Process of manipulating an images
- Suitable for specific applications eg medical Imaging such as X-ray
- Satellite Images



Key Stages in Digital Image Processing: Image Restoration

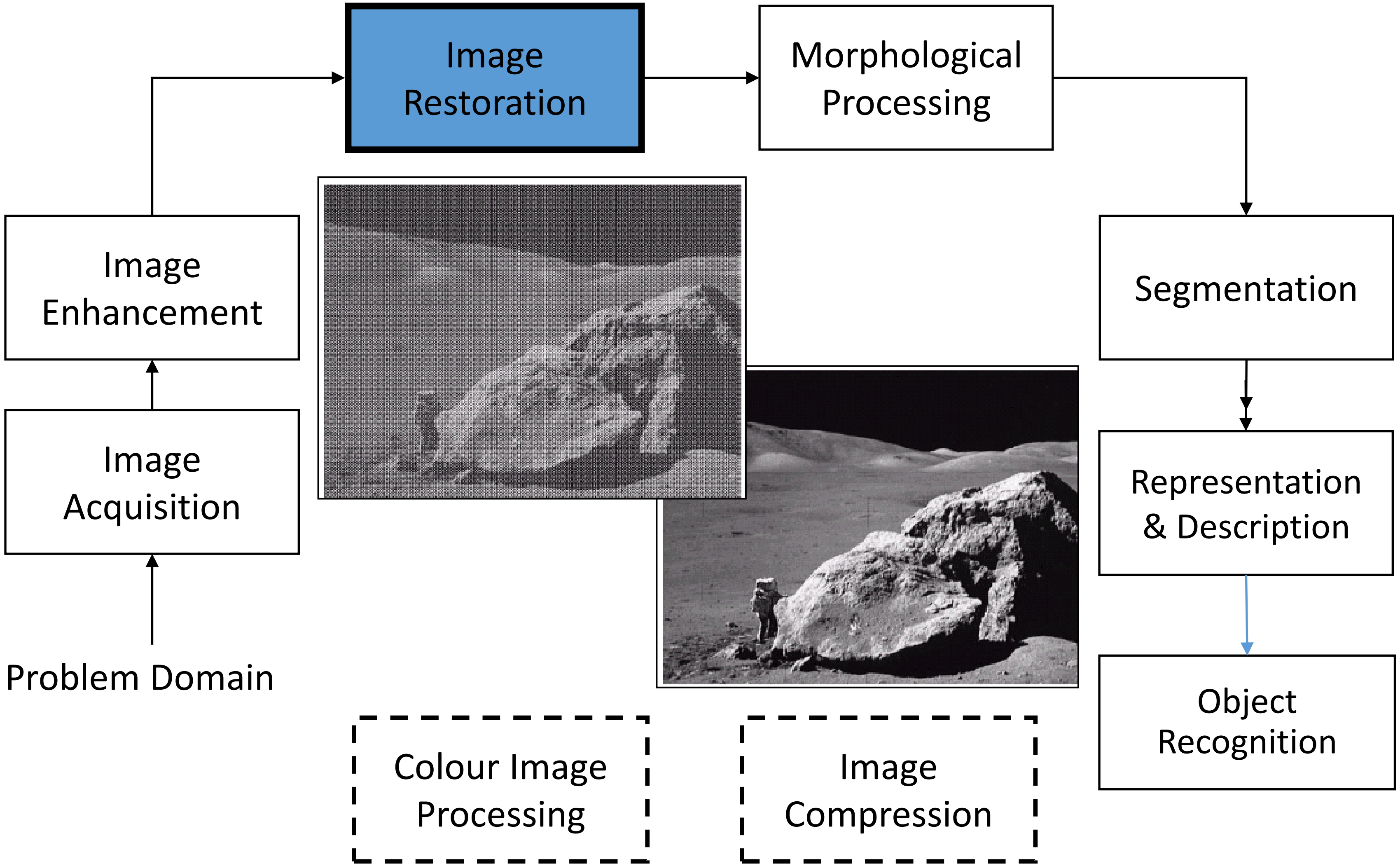
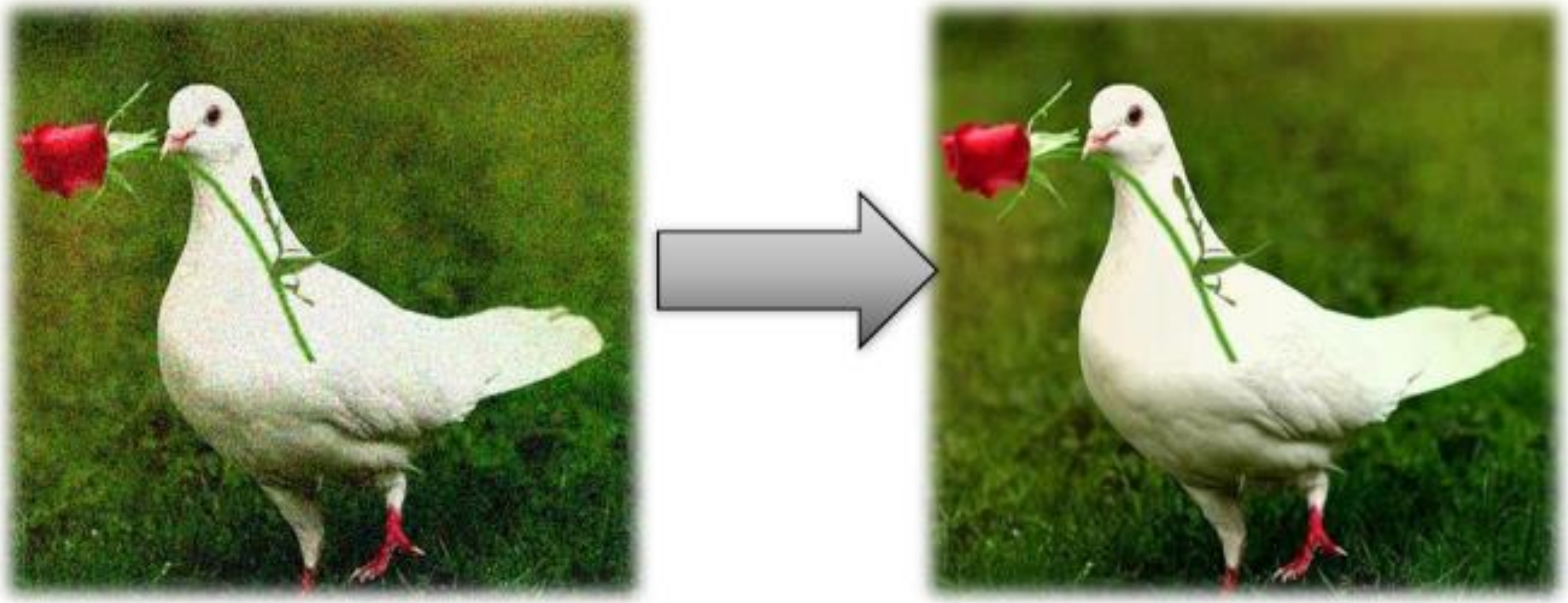


Image Restoration

- Improving the appearance of an image
- Based on mathematical or probabilistic based model



- Image restoration attempts to restore images that have been degraded
- Identify the degradation process and attempt to reverse it.
- Almost Similar to image enhancement, but more objective.

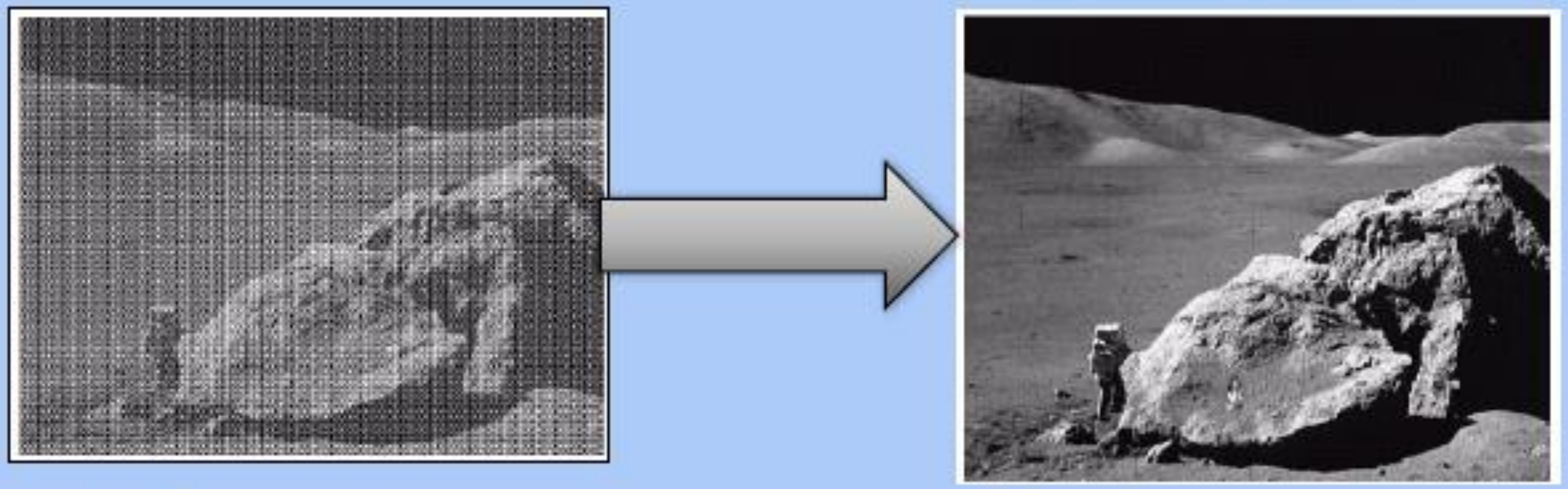
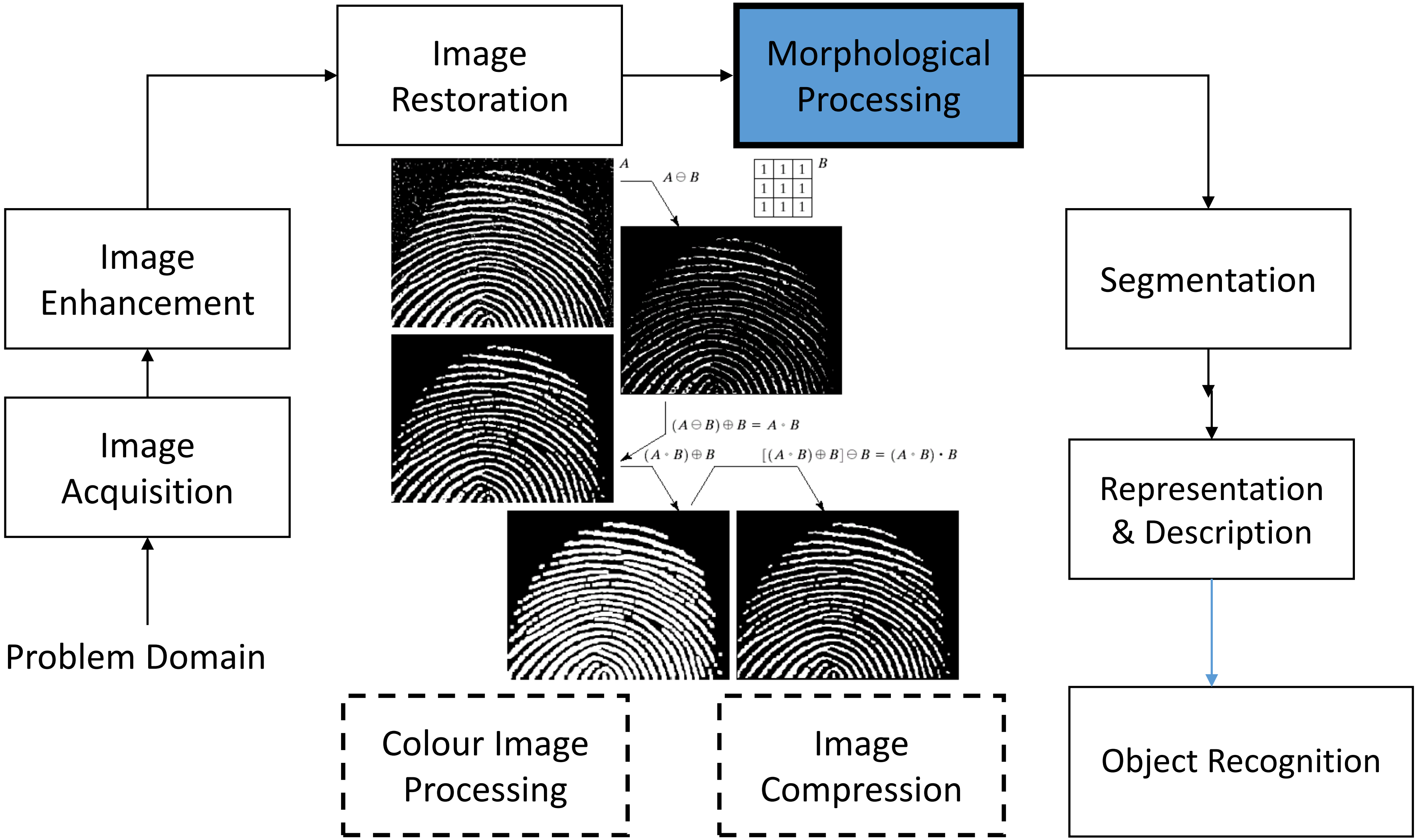


Fig: Degraded image

Fig: Restored image

S.no	Image Enhancement	Image Restoration
1	Image Enhancement is subjective	Image restoration is objective process.
2	Better visual representation	Its removes effects of sensing environment
3	No Quantitative measure is required	Mathematical model is required
4	It concerns about the extraction of features	It concerns about the restoration of degradation

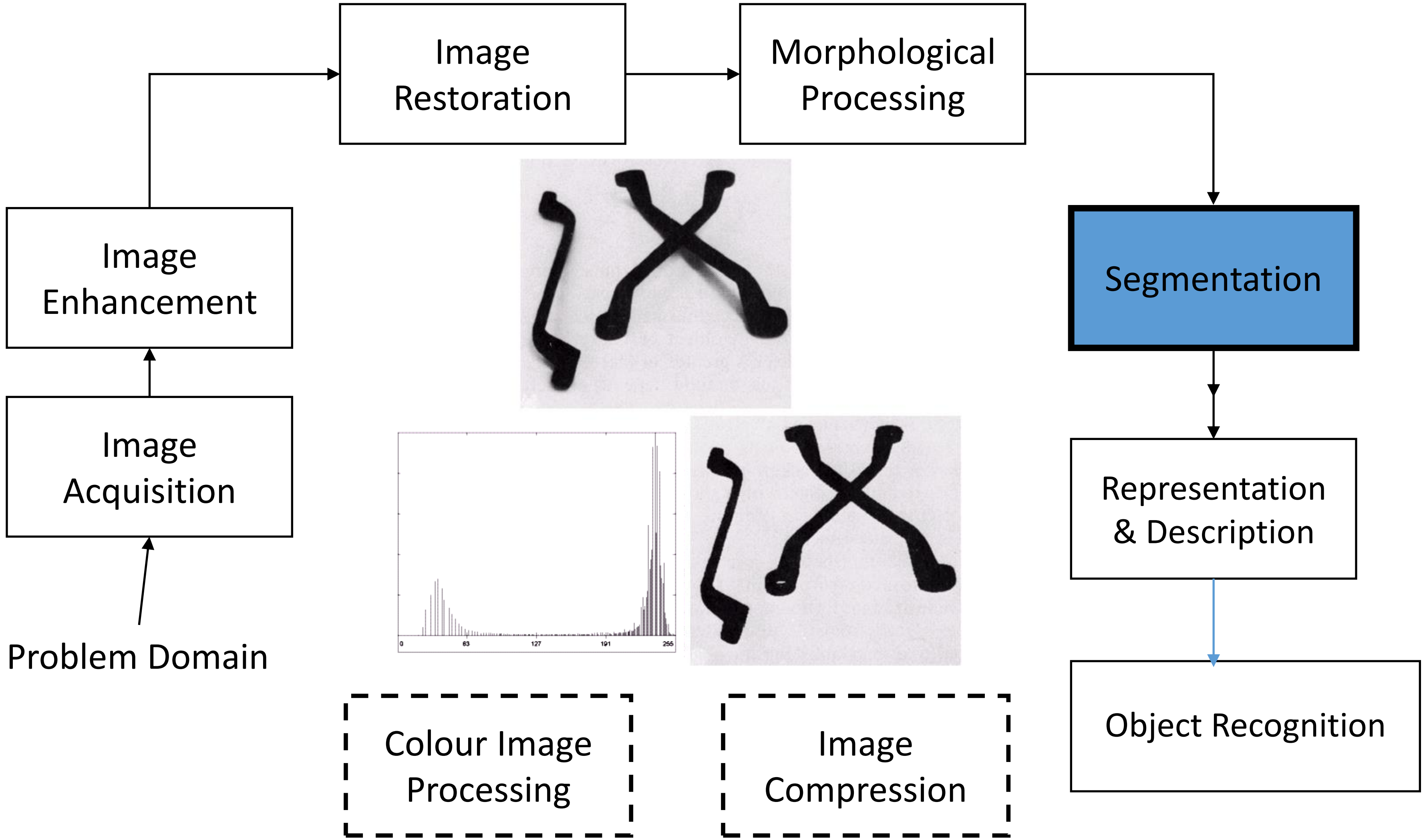
Key Stages in Digital Image Processing: Morphological Processing



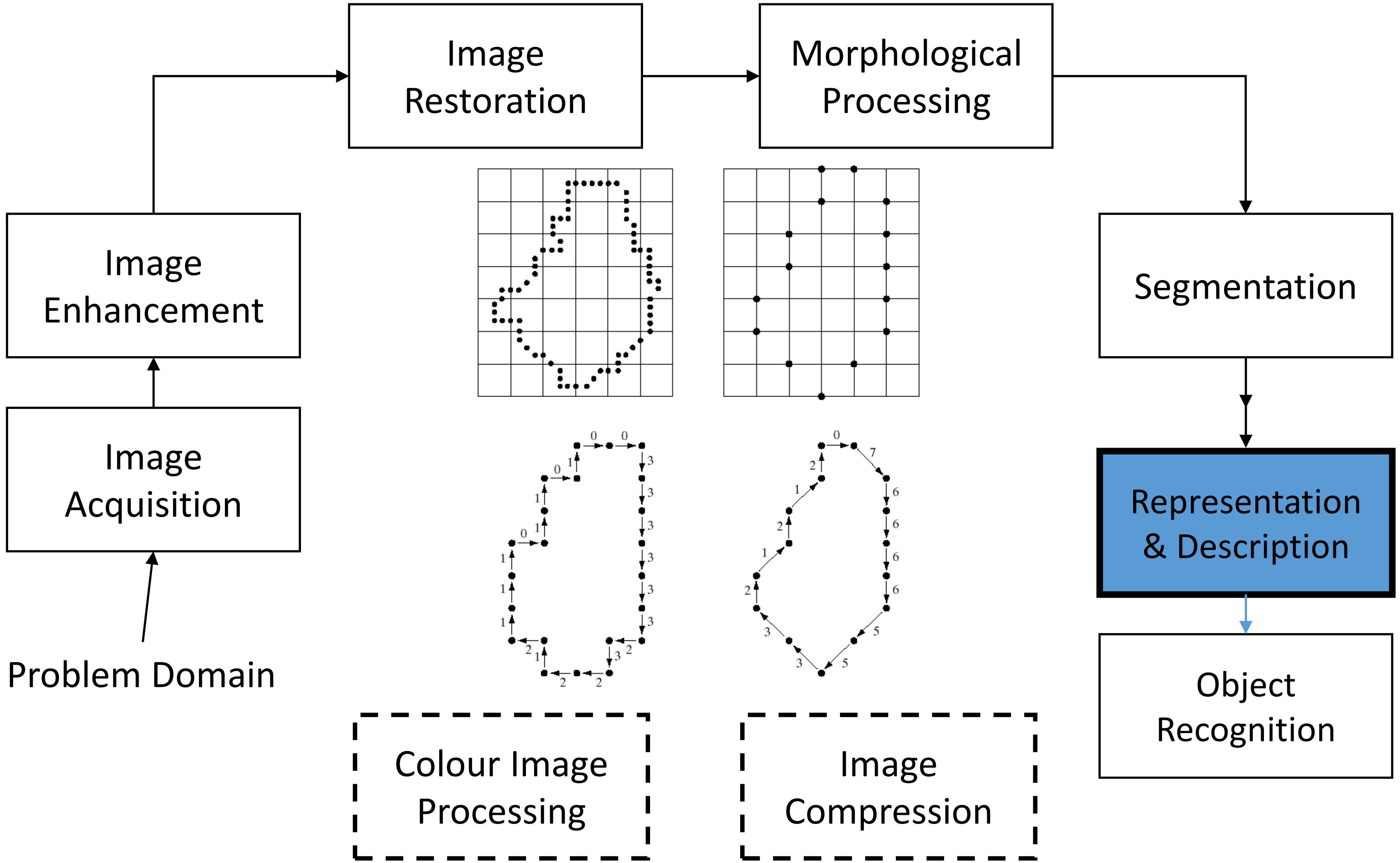
Morphological Processing

- *Morphology* is a broad set of image processing operations that process images based on shapes.
- Morphological operations apply a structuring element to an input image, creating an output image of the same size.
- In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors.
- Step deals with tools for extracting image components those are useful in the representation and description of shape

Key Stages in Digital Image Processing: Segmentation



Key Stages in Digital Image Processing: Representation & Description



Representation & Description

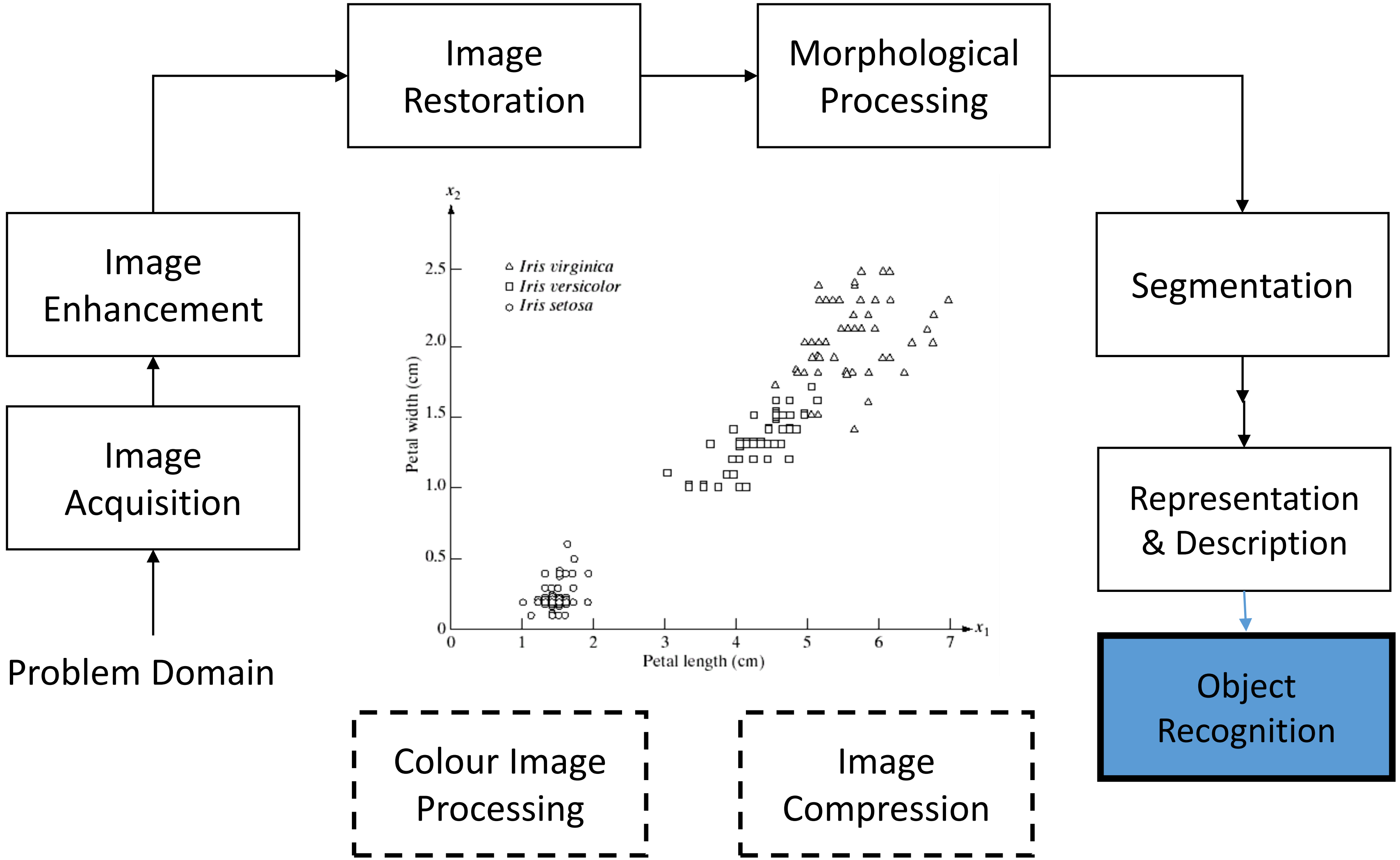
Representation

- Follow the output of Segmentation usually either the boundary of regions or all the point of region
- Converting to the suitable form for computer processing
- Decision should be made either a boundary or complete region
- Boundary representation -for external shape characteristics such corner and inflections
- Regional representation –for internal part such as texture or Skeletal shape

Description

- Features selection
- Some quantitative information of Interest
- Differentiate from class to another class

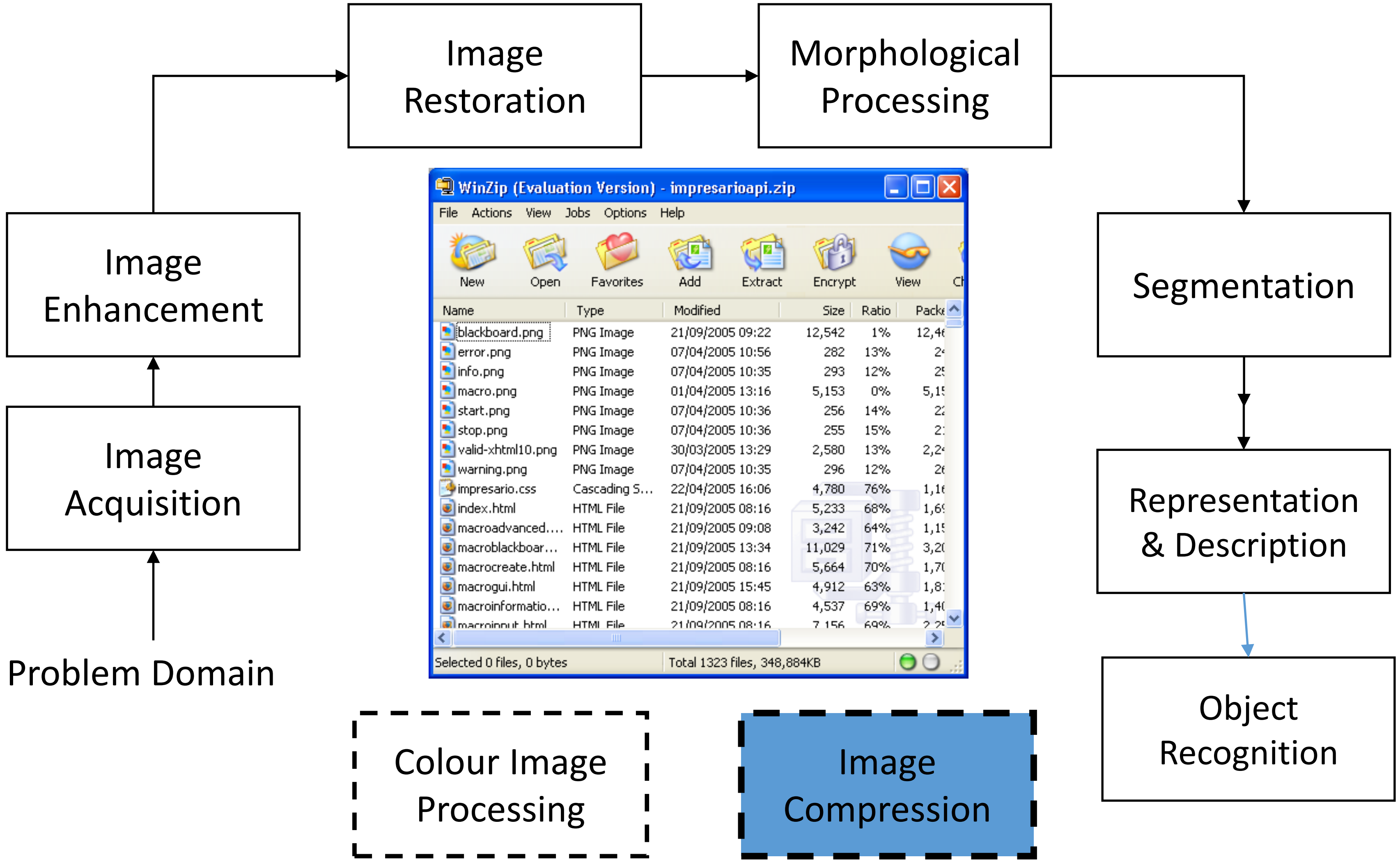
Key Stages in Digital Image Processing: Object Recognition



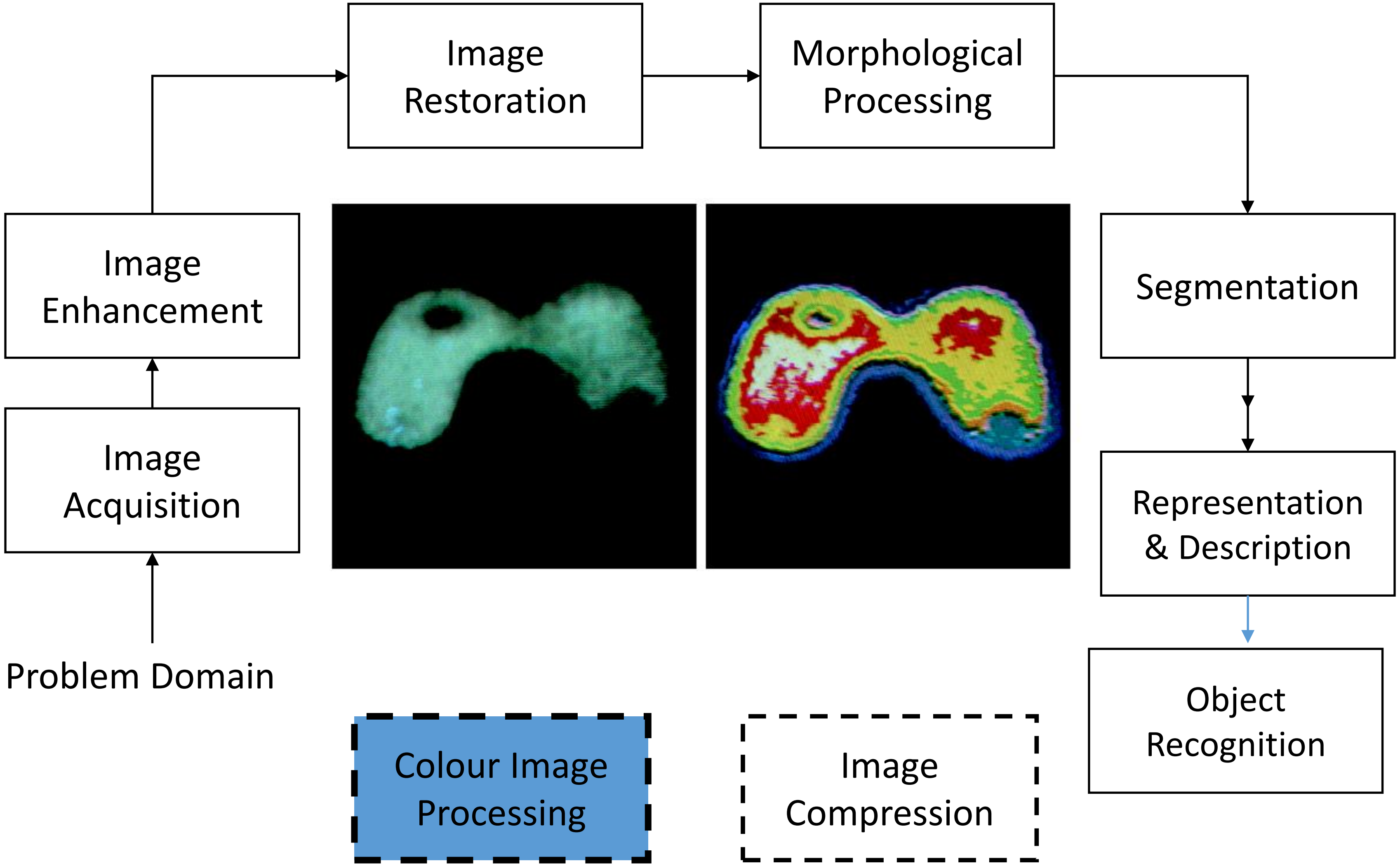
Object Recognition

- Process that assign a label such as vehicle ,animals etc. based on object descriptors
- Recognitions of individual objects in the image
- E.g Face detection , Biometrics, Tumors classifications

Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Colour Image Processing



Sample Questions

1)Identify the majors steps in Digital Image processing.

2)Mathematical formula for Image representation.

3)Differentiate Image Enhancement and Image restoration.

Multiple Choice Questions

What is the first and foremost step in Image Processing?
a) Image restoration
b) Image enhancement
c) Image acquisition
d) Segmentation

Answer is
c) Image acquisition

In which step of the processing, assigning a label (e.g., “vehicle”) to an object based on its descriptors is done?

a) Object recognition
b) Morphological processing
c) Segmentation
d) Representation & description

Answer is
a) Object recognition

What role does the segmentation play in image processing?

a) Deals with extracting attributes that result in some quantitative information of interest
b) Deals with techniques for reducing the storage required saving an image, or the bandwidth required transmitting it
c) Deals with partitioning an image into its constituent parts or objects
d) Deals with property in which images are subdivided successively into smaller regions

Answer is
c) Deals with partitioning an image into its constituent parts or objects

Which of the following step deals with tools for extracting image components those are useful in the representation and description of shape?

a) Segmentation

b) Representation & description

c) Compression

d) Morphological processing

Answer is

d) Morphological processing

Fields that use Image Processing

Examples of Fields that Use Digital Image Processing

- Electromagnetic energy spectrum

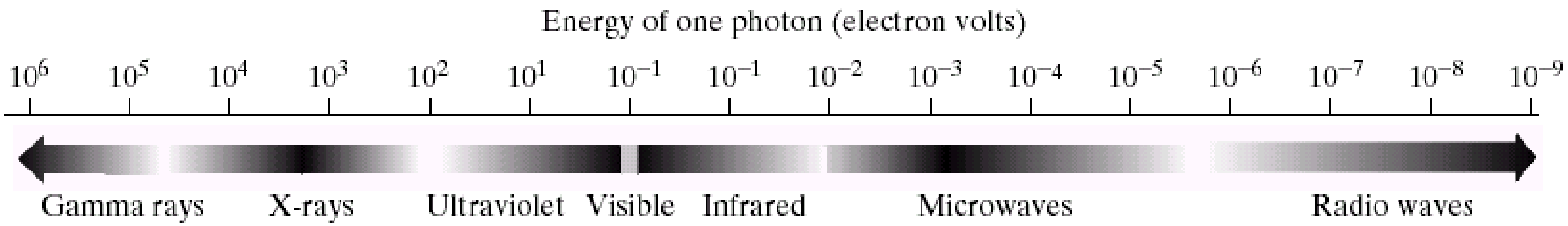


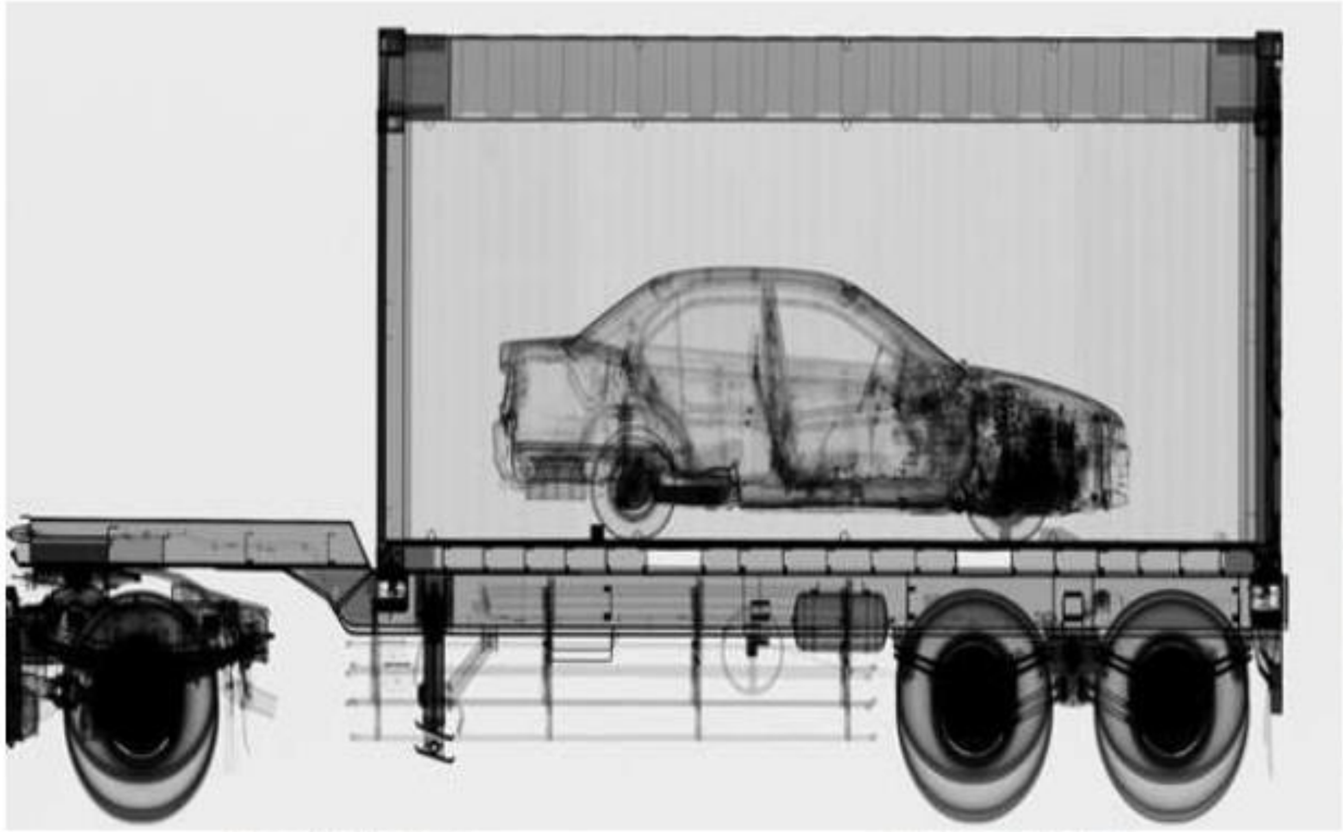
FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

- **GAMMA-RAY IMAGING**
- **X-RAY IMAGING**
- **IMAGING IN THE ULTRAVIOLET BAND**
- **IMAGING IN THE VISIBLE AND INFRARED BANDS**
- **IMAGING IN THE MICROWAVE BAND**
- **IMAGING IN THE RADIO BAND**

Gamma Rays Imaging

- Gamma rays are an energetic form of electromagnetic radiation
- Produced by radioactivity or nuclear or subatomic processes such as electron-positron annihilation.
- Gamma rays are the rays that have the most powerful of emerge power in comparison with alpha and beta rays
- Gamma rays are so light that has a wavelength higher than the other beam.
- Gamma Camera Equipment is a tool used in nuclear medical depiction.
- To see and analyze or diagnose overview of the human body by detecting the radiation beam from a radio isotope that is inserted into the patient's body

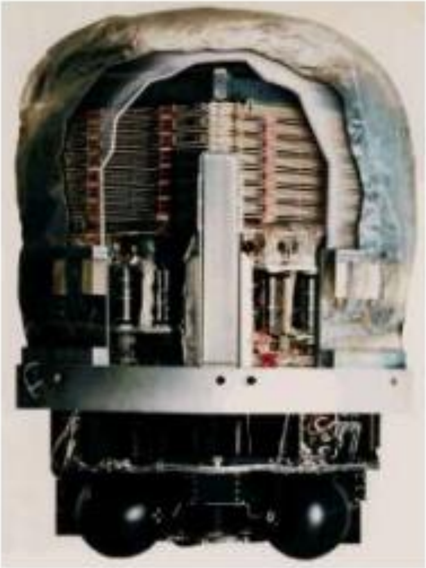
Gamma Ray Container Scanner



Application

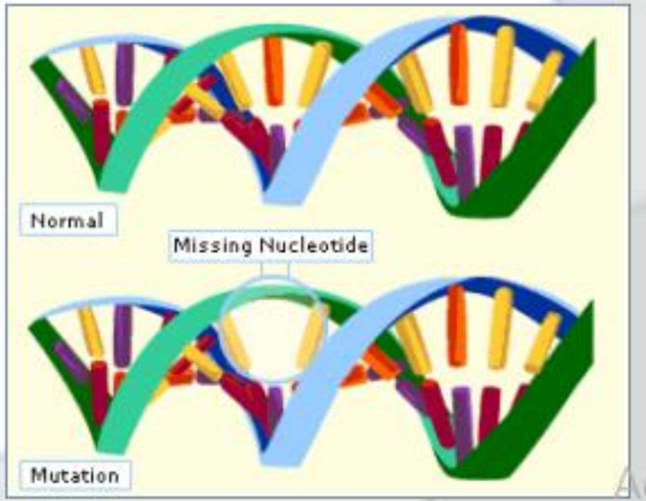
Fermi Gamma-ray Space Telescope

Compton Gamma Ray Observatory



Energetic Gamma Ray Experiment Telescope

Preserving of sorghum



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X RAYS

- X-rays are among the oldest sources of EM radiation used for imaging.
- Use of X-rays is medical diagnostics, and extensively in industry and other areas, like astronomy.
- X-rays for medical and industrial imaging are generated using an X-ray tube, which is a vacuum tube with a cathode and anode.
- The cathode is heated, causing free electrons to be released. These electrons flow at high speed to the positively charged anode.
- When the electrons strike a nucleus, energy is released in the form of X-ray radiation. The energy (penetrating power) of X-rays is controlled by a voltage applied across the anode, and by a current applied to the filament in the cathode.

- In digital radiography, digital images are obtained by one of two methods:

  (1) by digitizing X-ray films; or

  (2) by having the X-rays that pass through the patient fall directly onto devices (such as a phosphor screen) that convert X-rays to light.

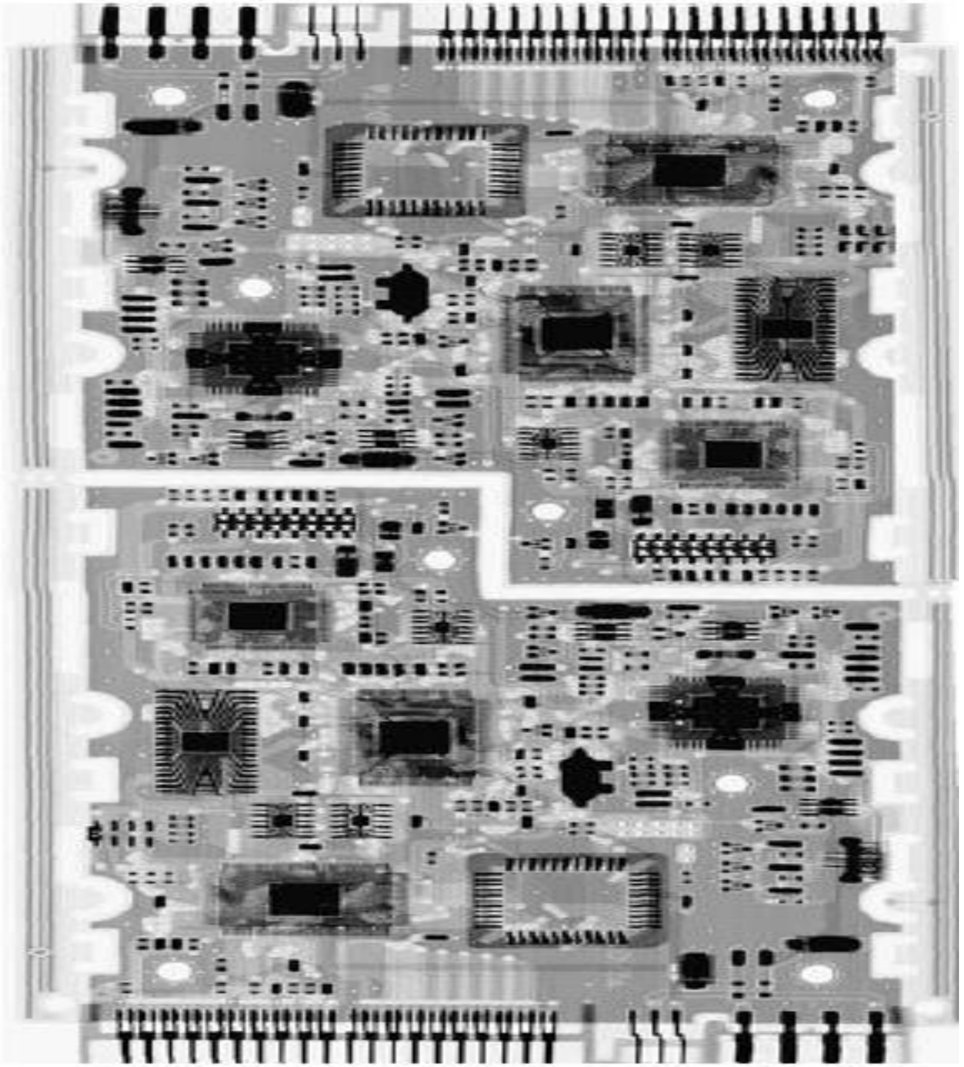
- The light signal in turn is captured by a light-sensitive digitizing system.

- Angiography is another major application in an area called contrast enhancement radiography.
- This procedure is used to obtain images (called angiograms) of blood vessels.
- A catheter (a small, flexible, hollow tube) is inserted, for example, into an artery or vein in the groin.
- The catheter is threaded into the blood vessel and guided to the area to be studied.
- When the catheter reaches the site under investigation, an X-ray contrast medium is injected through the tube.
- This enhances contrast of the blood vessels and enables the radiologist to see any irregularities or blockages

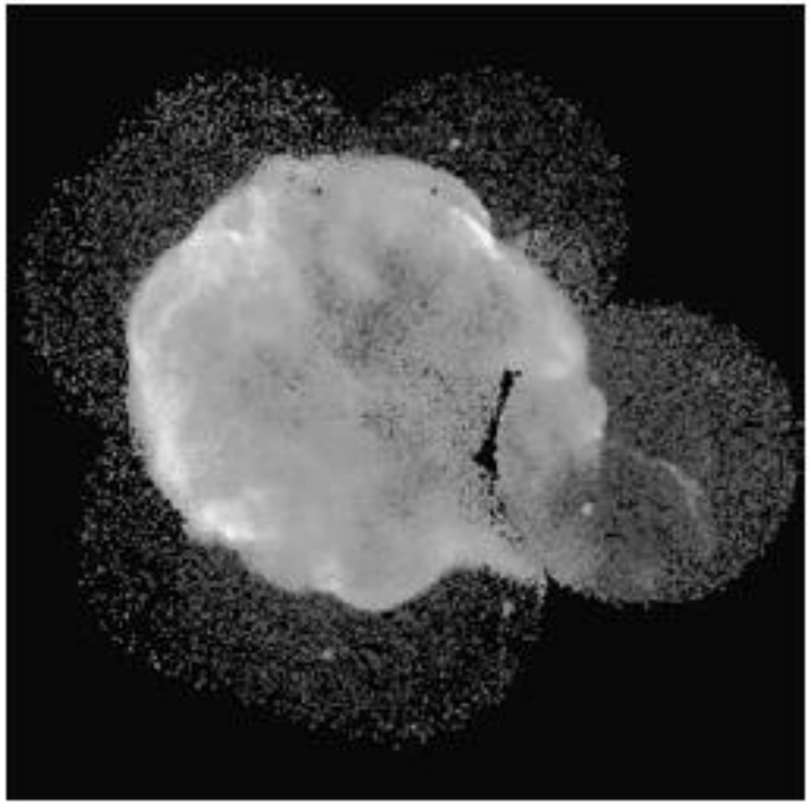
CAT

- Another important use of X-rays in medical imaging is computerized axial tomography (CAT).
- Each CAT image is a “slice” taken perpendicularly through the patient. Numerous slices are generated as the patient is moved in a longitudinal direction.
- The ensemble of such images constitutes a 3-D rendition of the inside of the body, with the longitudinal resolution being proportional to the number of slice images taken.

Higher energy X-rays, are applicable in industrial processes. Figure shows an X-ray image of an electronic circuit board are used to examine circuit boards for flaws in manufacturing, such as missing components or broken traces.



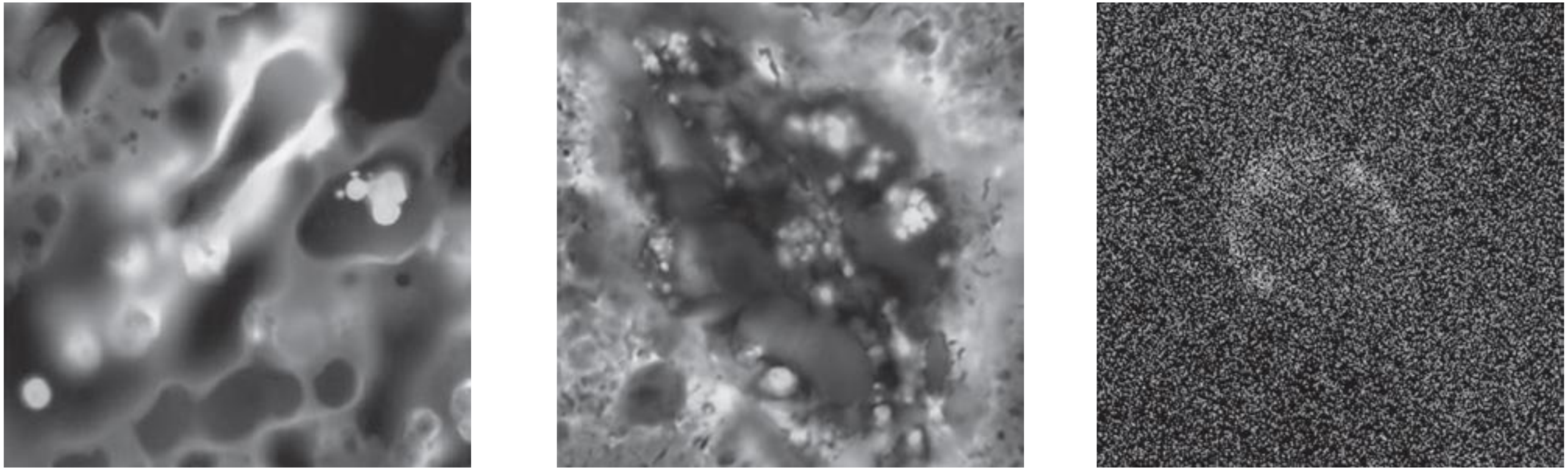
X-ray imaging in astronomy



IMAGING IN THE ULTRAVIOLET BAND

- Applications of ultraviolet “light” are varied.
- They include lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations.
- We illustrate imaging in this band with examples from microscopy and astronomy

Examples of ultraviolet imaging



Examples of ultraviolet imaging. (a) Normal corn. (b) Corn infected by smut. (c) Cygnus Loop

- Ultraviolet light is used in fluorescence microscopy, one of the fastest growing areas of microscopy.
- Fluorescence microscopy is an excellent method for studying materials that can be made to fluoresce, either in their natural form (primary fluorescence) or when treated with chemicals capable of fluorescing (secondary fluorescence).

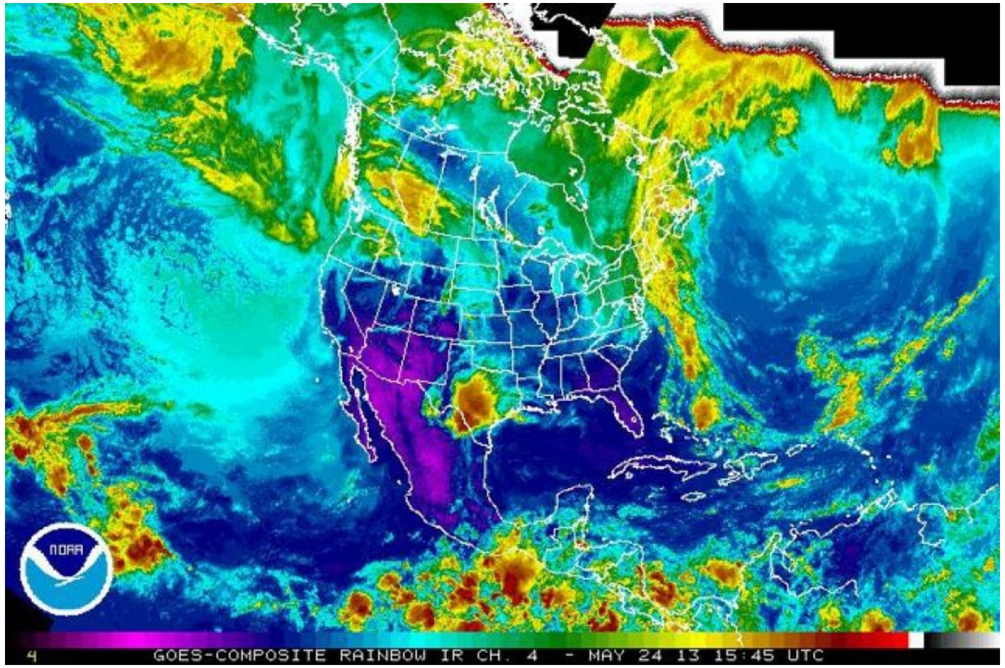
IMAGING IN THE VISIBLE AND INFRARED BANDS

- The infrared band often is used in conjunction with visual imaging, so we have grouped the visible and infrared bands

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.53–0.61	Measures plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.78–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content: soil/vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Short-wave infrared	2.09–2.35	Mineral mapping

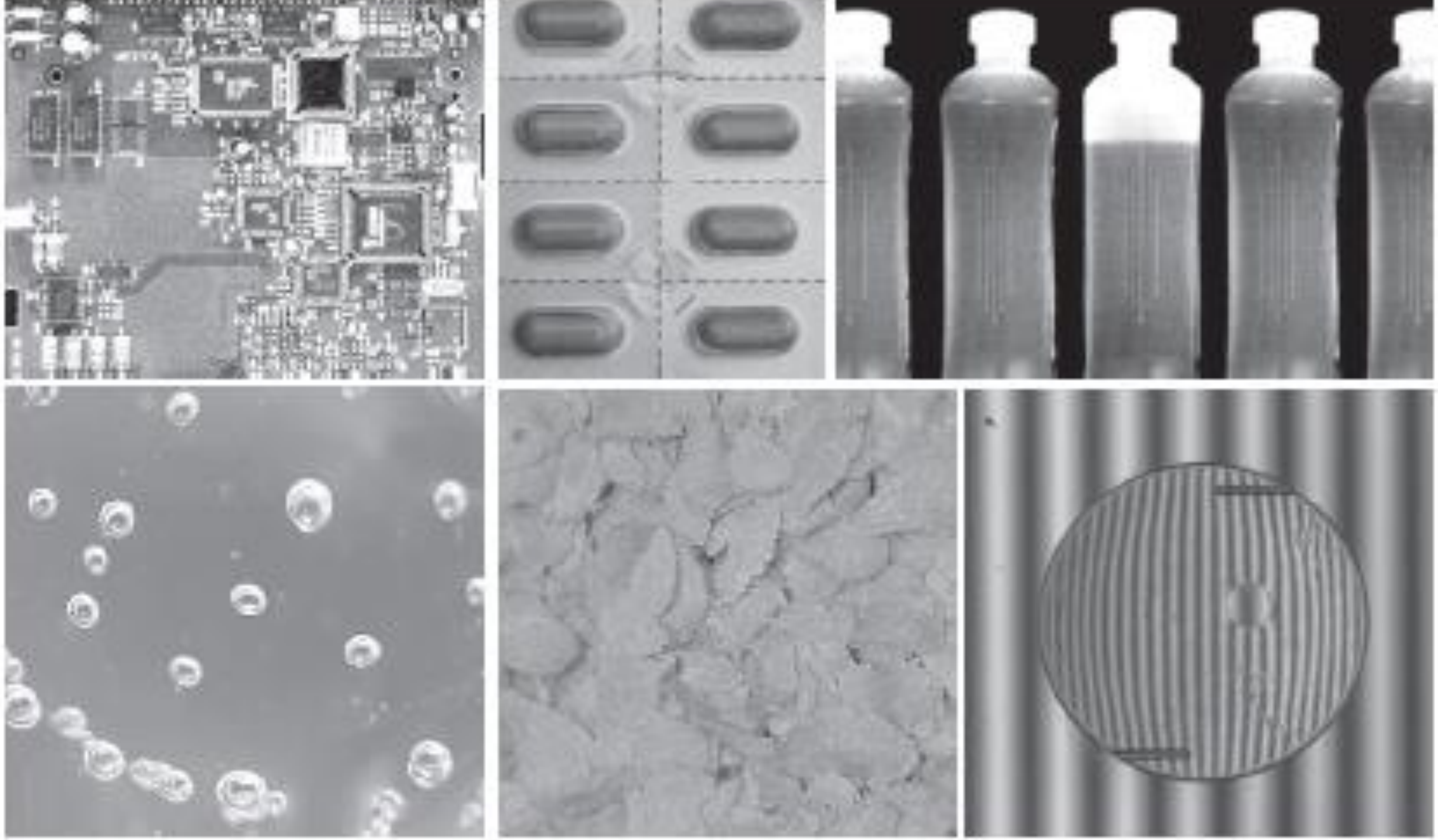
- Images of population centers are used over time to assess population growth and shift patterns, pollution, and other factors affecting the environment.
- The differences between visual and infrared image features are quite noticeable in these images.

- Weather observation and prediction also are major applications of multispectral imaging from satellites.



- The infrared system operates in the band 10.0 to 13.4 mm
- Has the unique capability to observe faint sources of visible, near infrared emissions present on the Earth’s surface, including cities, towns, villages, gas flares, and fires.
- Even without formal training in image processing, it is not difficult to imagine writing a computer program that would use these images to estimate the relative percent of total electrical energy used by various regions of the world.

- A major area of imaging in the visible spectrum is in automated visual inspection of manufactured goods. Figure shows some examples.(a) is a controller board for a CD-ROM drive.
- A typical image processing task with products such as this is to inspect them for missing parts (the black square on the top, right quadrant of the image is an example of a missing component).



a b c
d e f

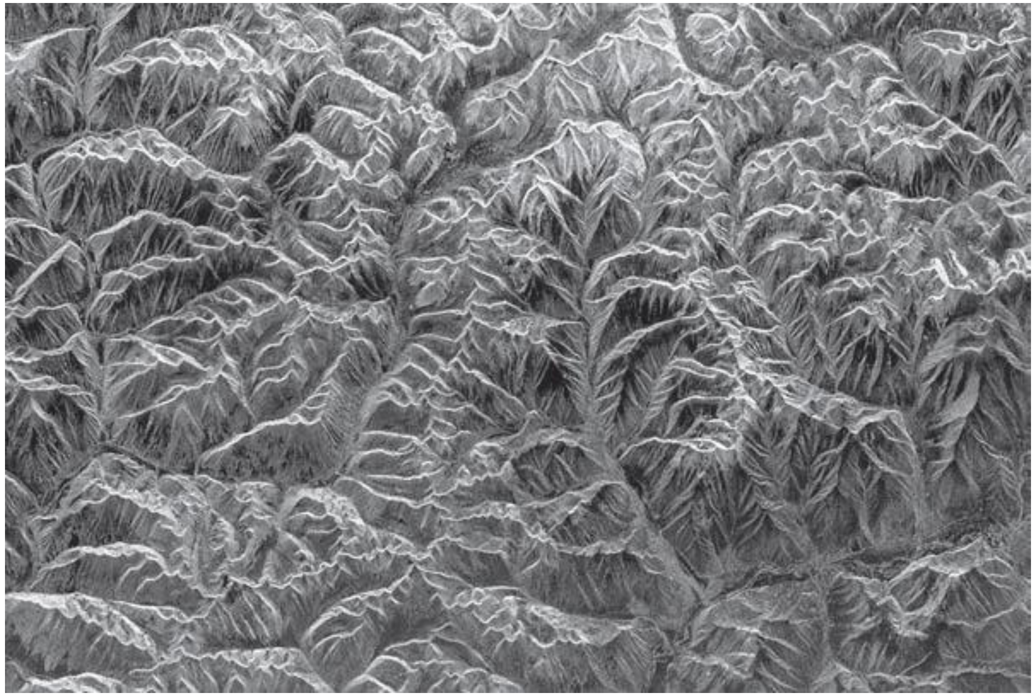
FIGURE 1.14 Some examples of manufactured goods checked using digital image processing. (a) Circuit board controller. (b) Packaged pills. (c) Bottles. (d) Air bubbles in a clear plastic product. (e) Cereal. (f) Image of intraocular implant. (Figure (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

IMAGING IN THE MICROWAVE BAND

- The principal application of imaging in the microwave band is radar.
- The unique feature of imaging radar is its ability to collect data over virtually any region at any time
- Regardless of weather or ambient lighting conditions.
- Some radar waves can penetrate clouds, and under certain conditions, can also see through vegetation, ice, and dry sand.
- In many cases, radar is the only way to explore inaccessible regions of the Earth’s surface.
- An imaging radar works like a flash camera in that it provides its own illumination (microwave pulses) to illuminate an area on the ground and take a snapshot image.

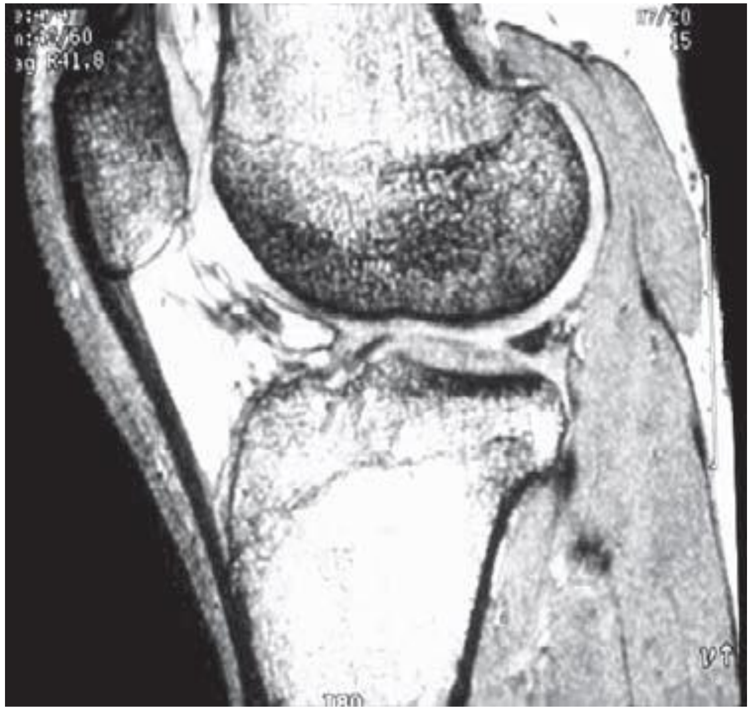
- Instead of a camera lens, a radar uses an antenna and digital computer processing to record its images.
- In a radar image, one can see only the microwave energy that was reflected back toward the radar antenna.

Space borne radar image of mountainous region in southeast Tibet.

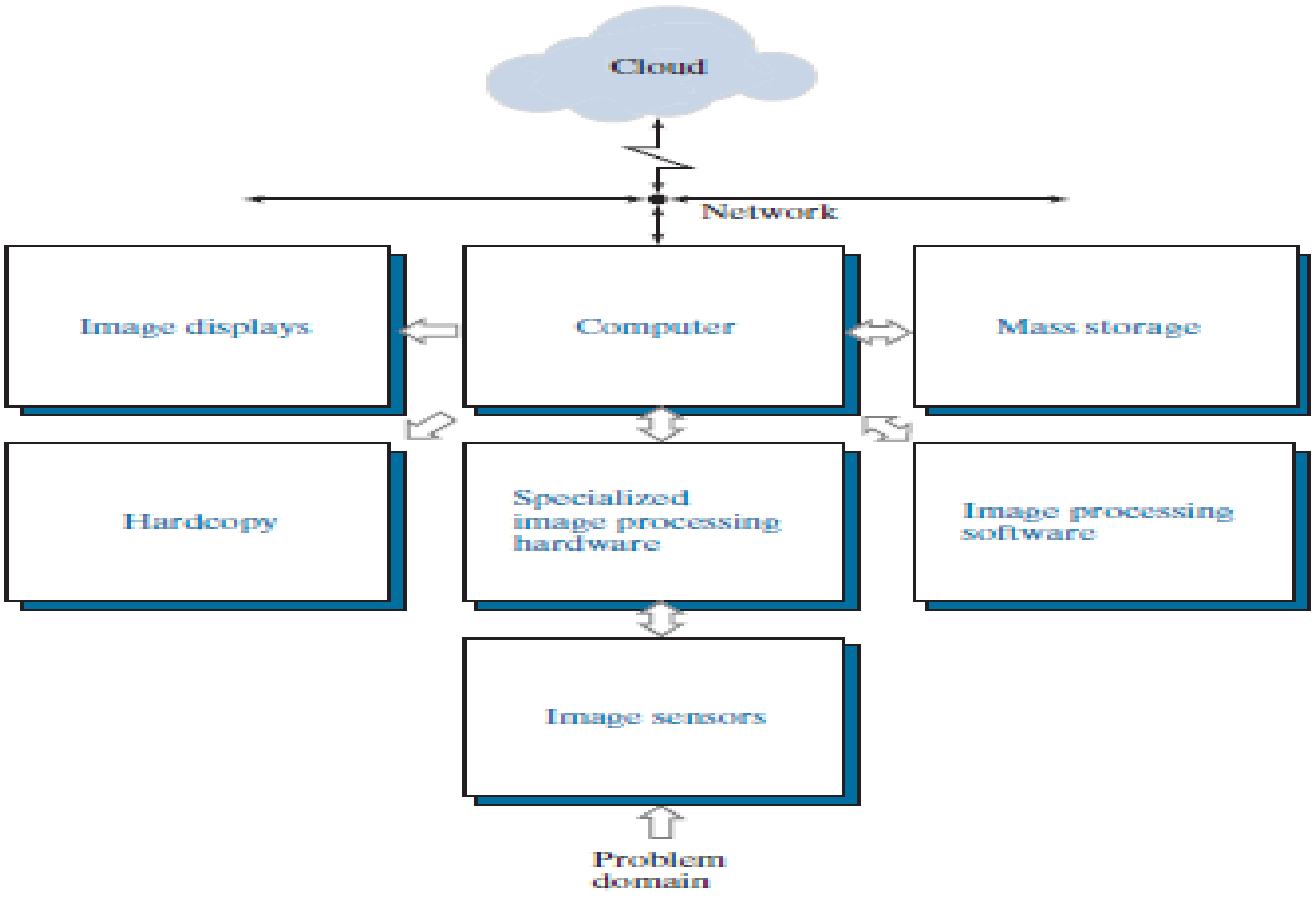


IMAGING IN THE RADIO BAND

- Imaging at the other end of the spectrum (gamma rays)
- The major applications of imaging in the radio band are in medicine and astronomy.
- In medicine, radio waves are used in magnetic resonance imaging (MRI).
- This technique places a patient in a powerful magnet and passes radio waves through the individual’s body in short pulses.
- Each pulse causes a responding pulse of radio waves to be emitted by the patient’s tissues.
- The location from which these signals originate and their strength are determined by a computer.
- Produces a two-dimensional image of a section of the patient.
- MRI can produce images in any plane.



Components of an Image Processing System



i) Image Sensors

- With reference to sensing, two elements are required to acquire digital image.
- The first is a physical device that is sensitive to the energy radiated by the object we wish to image

ii) Specialize image processing hardware

- – It consists of the digitizer just mentioned, plus hardware that performs other primitive operations such as an arithmetic logic unit, which performs arithmetic such addition and subtraction and logical operations in parallel on images

iii) Computer

- It is a general purpose computer and can range from a PC to a supercomputer depending on the application.
- In dedicated applications, sometimes specially designed computer are used to achieve a required level of performance.

iv) Software

- It consist of specialized modules that perform specific tasks a well designed package also includes capability for the user to write code, as a minimum, utilizes the specialized module.
- More sophisticated software packages allow the integration of these modules.

v) Mass storage

- This capability is a must in image processing applications.
- An image of size 1024 x1024 pixels, in which the intensity of each pixel is an 8- bit quantity requires one megabytes of storage space if the image is not compressed.
- Image processing applications falls into three principal categories of storage

    i) Short term storage for use during processing

    ii) On line storage for relatively fast retrieval

    iii) Archival storage such as magnetic tapes and disks

vi) Image displays

- Image displays in use today are mainly color TV monitors.
- These monitors are driven by the outputs of image and graphics displays cards that are an integral part of computer system

vii) Hardcopy devices

- The devices for recording image includes laser printers, film cameras, heat sensitive devices inkjet units and digital units such as optical and CD ROM disk.
- Films provide the highest possible resolution, but paper is the obvious medium of choice for written applications.

viii) Networking

- It is almost a default function in any computer system in use today because of the large amount of data inherent in image processing applications.
- The key consideration in image transmission bandwidth.

Sample Questions

1) Explain the applications and fields where image processing is used.
2) Describe the components of Image processing with neat diagram.

MCQ

1) The infrared system operates in the band:

A) 10.0 to 13.4 mm

B)10.0 to 12.0 mm

C)8.0 to 10.0 mm

D)10.0 to 11.0 mm

2) The principal application of imaging in the microwave band is:

a)X-ray

b) Radar

c)Gamma ray

d) Infra red

3.Which imaging is for weather forecasting

a)Ultraviolet

b)X-ray

c)MRI

d)Near Infrared

Elements of visual perception

- Eye characteristics
    - nearly spherical
    - approximately 20 mm in diameter
    - three membranes
- cornea (transparent) & sclera (opaque) outer cover
- choroid contains a network of blood vessels, heavily pigmented to reduce amount of extraneous light entering the eye. Also contains the iris diaphragm (2-8 mm to allow variable amount of light into the eye)
- retina is the inner most membrane, objects are imaged on the surface

Imaging in the eye

- Variable thickness lens: thick for close focus, thin for distant focus
- Distance of focal center of the lens to the retina (14-17 mm)
- Image of a 15m tree at 100m
  - 15/100 = X/17 or approximately 2.55 mm
- Image is almost entirely on the fovea

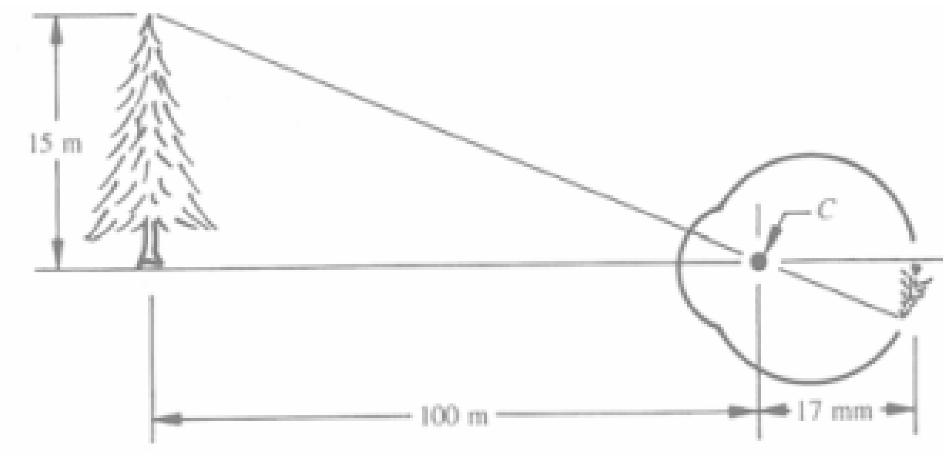


Image Formation

- First step in understanding Image formation is to known about Physical Illumination
- Second is Reflectance Model

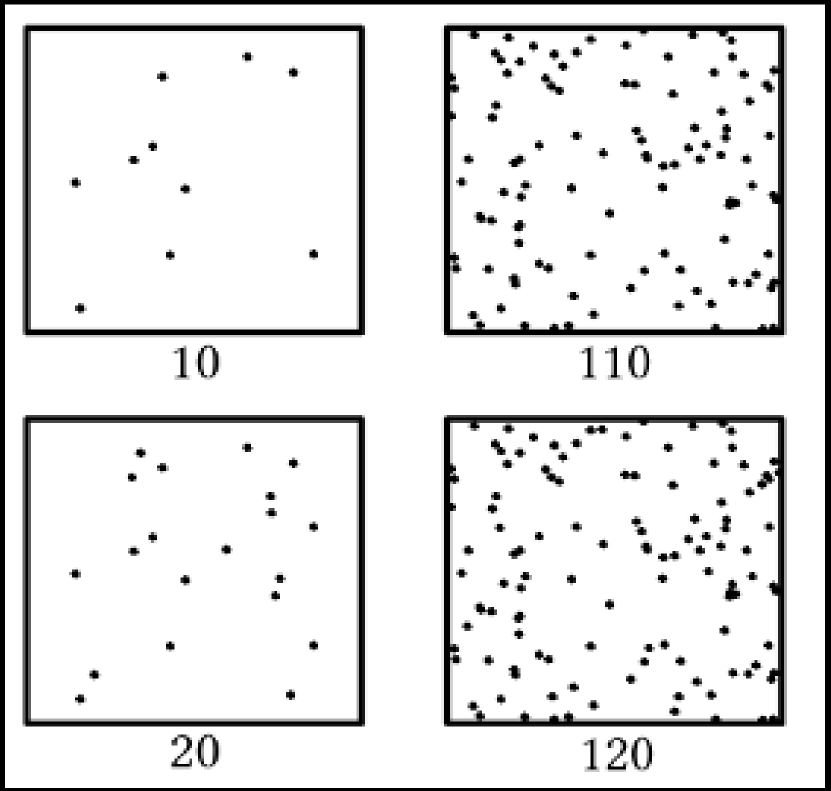
1)Illumination

- Fundamental components of Image formation process which generates sense in our visual organs.
- The strength of Sensation which is the sensation of brightness can be quantified by averaging the responses of many human observers.
- The average response ,i.e. the psychovisual sensation is determined at different spectral wavelength.
- The peak spectral sensitivity of a human observer happens at 555 nm Wavelengths

1)Illumination

- Equal amounts of Luminous flux produce equal brightness, which is proportional to the logarithm of luminous flux.
- Fechner's law defines the brightness by the relation

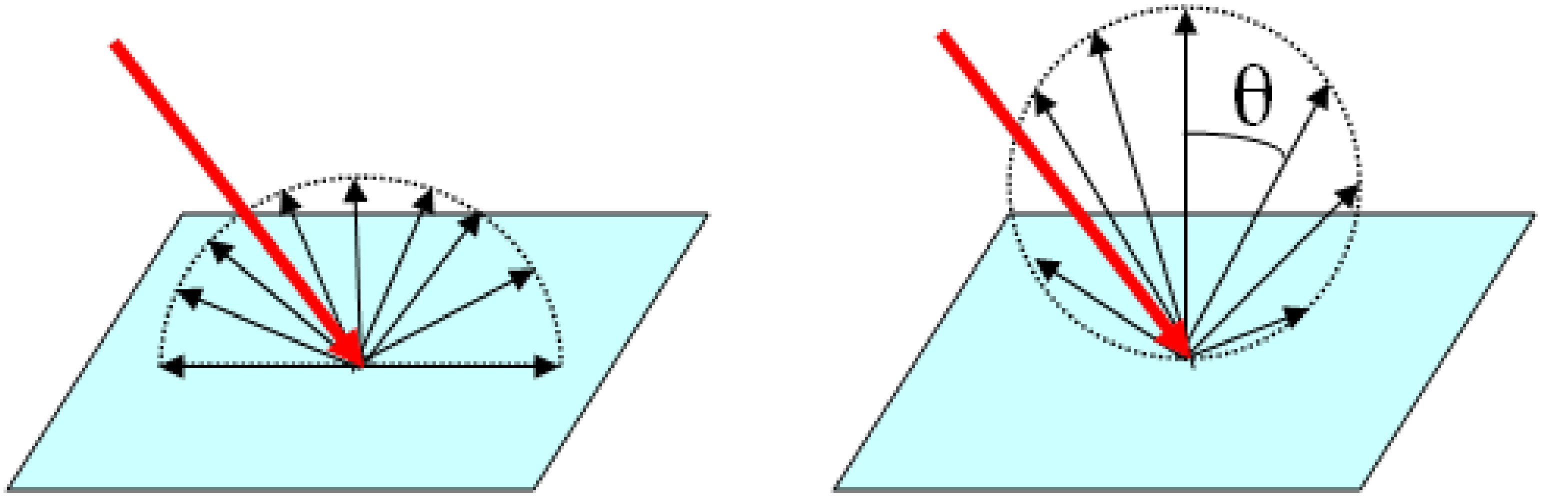
$$B = K \log\left(\frac{F}{F_0}\right)$$


10
110
20
120

2) Reflectance Model

- Depending on the nature reflection
- Three categories :
    1. Lambertian
    2. Specular
    3. Hybrid

1.Lambertian reflection



1.Lambertian reflection

- Lambertian reflectance usually refers to the reflection of light by an object
- Light are reflected in all directions and diffused one
- It can be used to refer to the reflection of any wave
- The reflectance from the wall paint with flat paints, papers , fabrics, ground surface
- For example, in ultrasound imaging, "rough" tissues are said to exhibit Lambertian reflectance.

- Entire incident light in all directions covering solid angle 2π radians
- Equally bright in all directions
- The reflectance map of Lambertian surface may be modelled as

$$I_L = E_0 A \cos\theta$$

Where E_0 is the strength of the incident light source

A is the surface area of the Lambertian patch

θ is the angle of Incidence

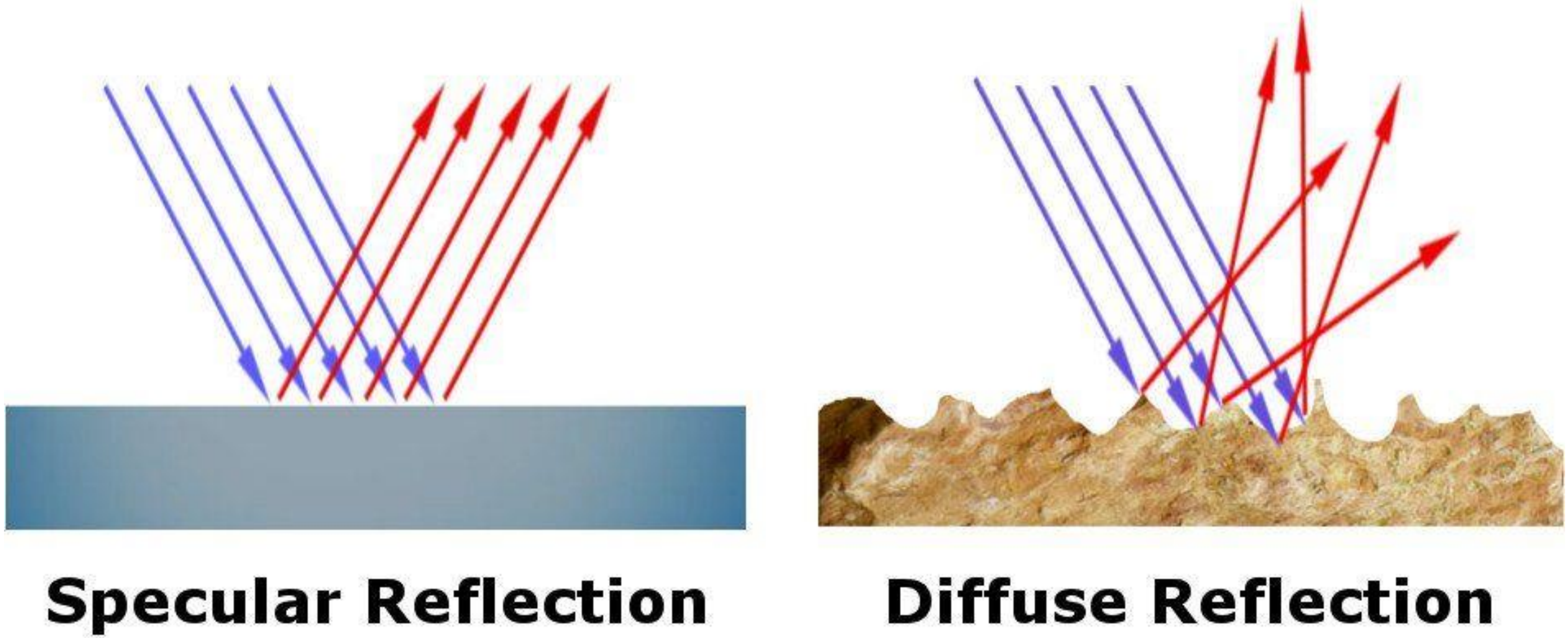
For an Image

- The reflectance relationship for a
- Lambertian model of image $E(x,y)$

$$E(x,y) = A\,(n \cdot s)$$

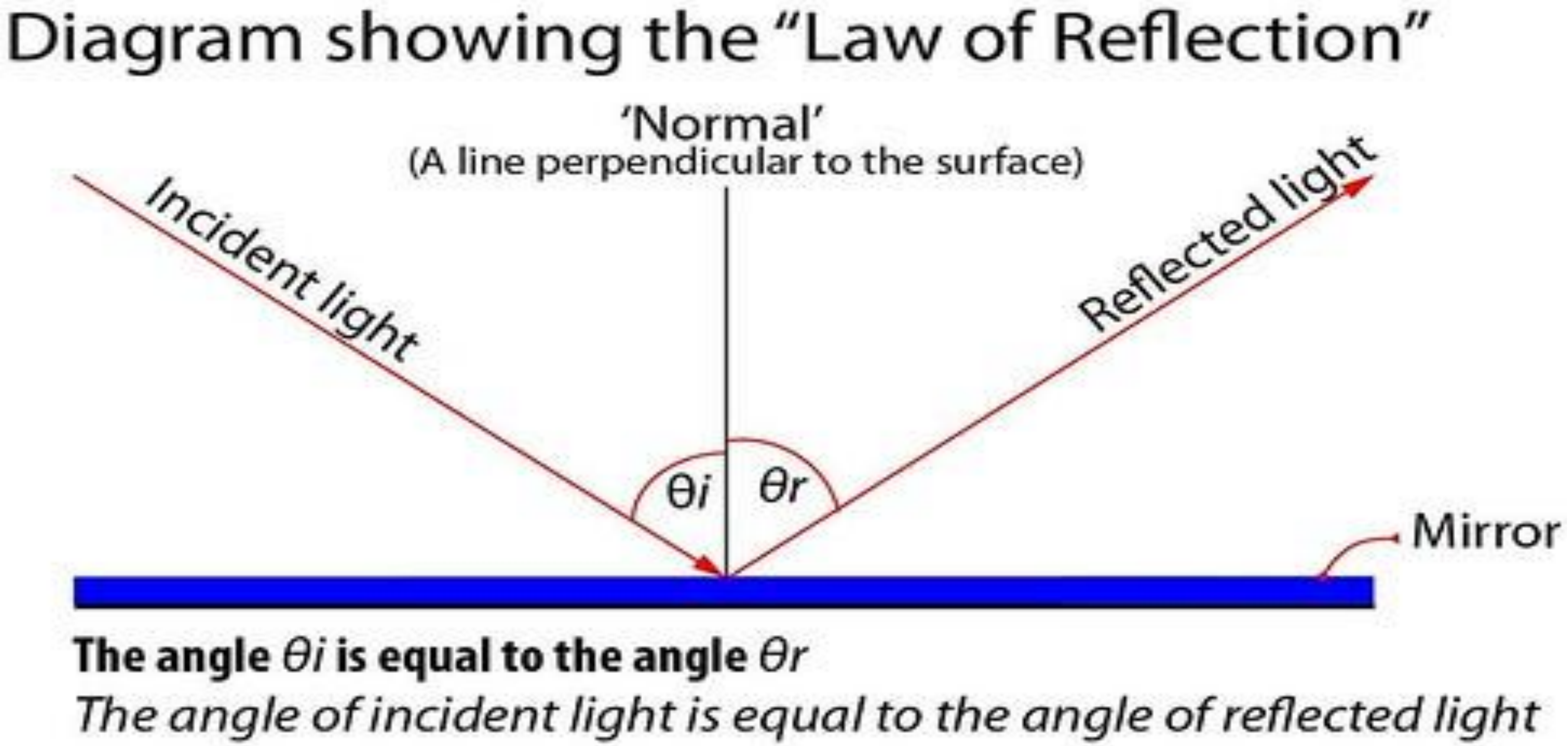
  - n = surface normal (unit vector)
  - s = source direction (unit vector)
  - A = constant related to illumination intensity and surface

2.Specular reflectance



- In specular reflection a mirror surface reflects a beam of light so that the angle of reflection is equal to the angle of incidence
- Eg. the angle of the incoming light is the same as the angle of the outgoing/reflected light

- The diagram shows how the incoming (incident) light is reflected off the mirror at the same angle to the perpendicular line (which in geometry is called the ‘normal’).



Hybrid Reflectance

- Mostly found in Display devices
- Known as Hazes
- In real world ,neither Lambertian nor specular
- Mixture of Lambertian and Specular reflectance
- The reflectance surface of model can described as:

$$I = wI_S + (1 - w)I_L$$

Where I_S&I_L specular and Lambertian intensities

Face Image processing

Sample Questions

- Describe various reflectance model
- Draw a diagram that show how image is formed in the eyes
- Define Fechner’s law

MCQ

1) Mixture of Lambertian and Specular reflectance is called as

a)Diffuse Model

b)Hyper Model

c)Hybrid Model

d)None of above

2)Lambertian model of image $E(x,y)$ can be:

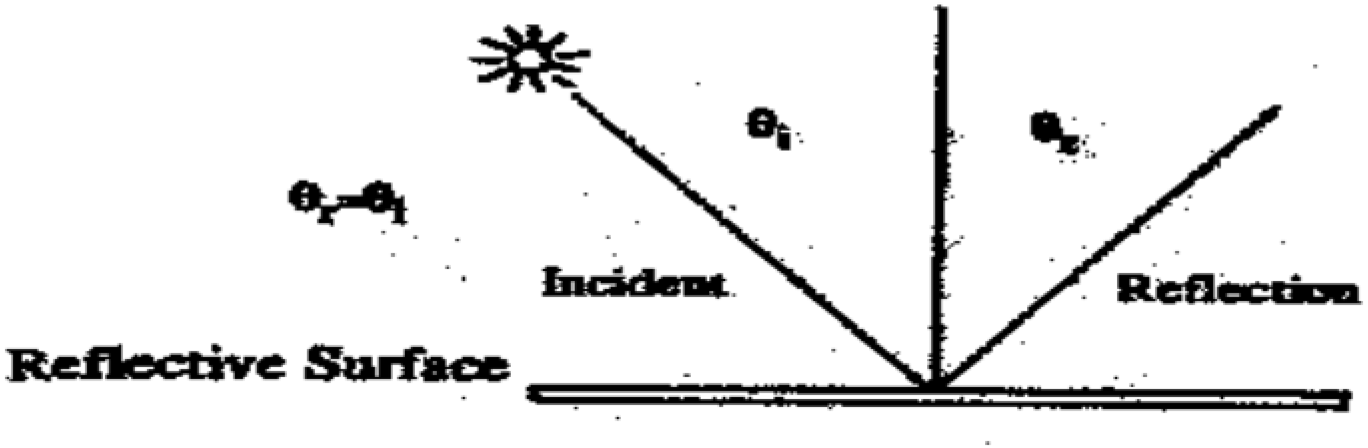
a)$E(x,y) = A\ (n\ .\ s)$

b)$E(x,y) = A\ (s)$

c)$E(x,y) = nA\ (s)$

d)$E(x,y) = A\ (n\ )$

3)The below diagram is represent which reflectance model



a)Diffuse Model
b)Hyper Model
c)Hybrid Model
d)Specular Model

References

- Tinku Acharya and Ajoy K. Ray, "*Image Processing Principles and Applications*", John Wiley and Sons publishers.

Image Sampling and Quantization

- The output of most of the image sensors is an analog signal, and we can not apply digital processing on it because we can not store it. We can not store it because it requires infinite memory to store a signal that can have infinite values.
- So we have to convert an analog signal into a digital signal.
- To create an image which is digital, we need to covert continuous data into digital form. There are two steps in which it is done.
  1. **Sampling**
  2. **Quantization**
- We will discuss sampling now, and quantization will be discussed later on but for now on we will discuss just a little about the difference between these two and the need of these two steps.

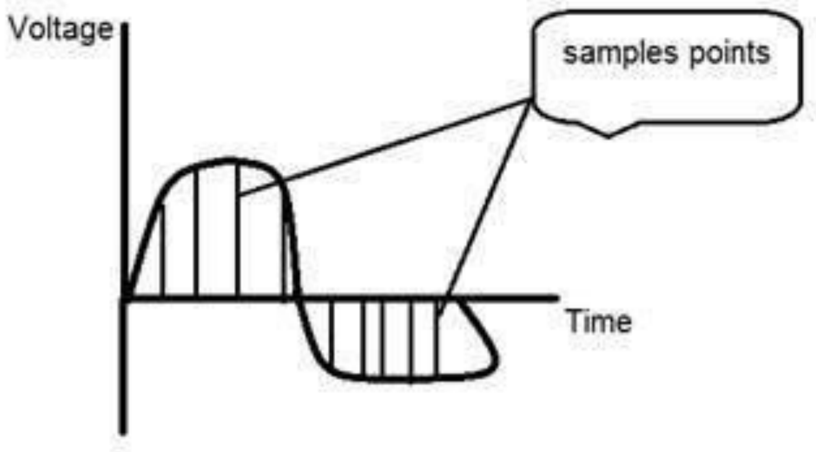
Basic idea:

- The basic idea behind converting an analog signal to its digital signal is

- To convert both of its axis (x,y) into a digital format.
- Since an image is continuous not just in its co-ordinates (x axis), but also in its amplitude (y axis), so the part that deals with the digitizing of co-ordinates is known as sampling.
- And the part that deals with digitizing the amplitude is known as quantization.

Sampling

- The term sampling refers to take samples
- We digitize x axis in sampling
- It is done on independent variable
- It is further divided into two parts , up sampling and down sampling

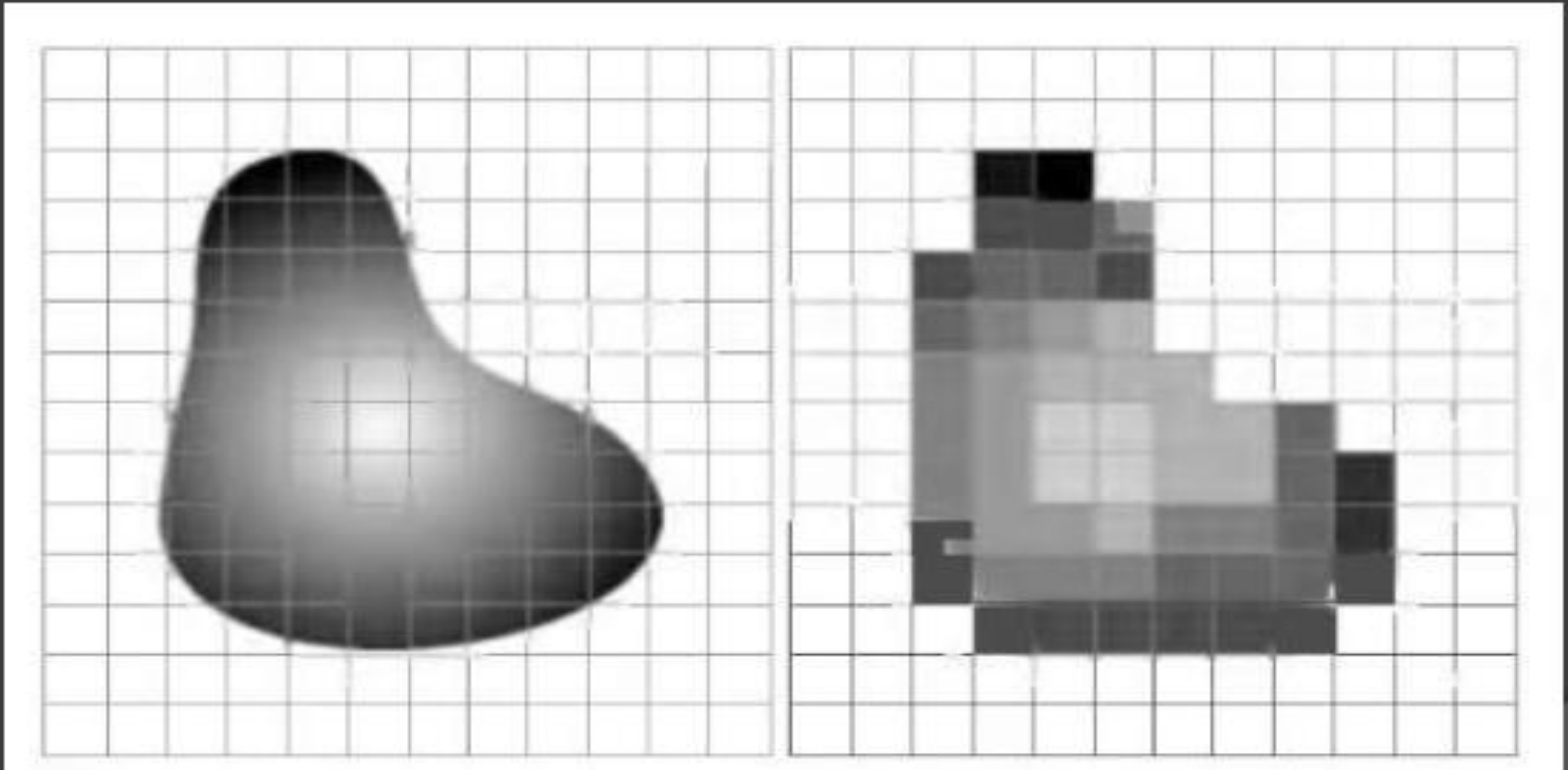


- If you will look at the above figure, you will see that there are some random variations in the signal.
- These variations are due to noise. In sampling we reduce this noise by taking samples.
- It is obvious that more samples we take, the quality of the image would be more better, the noise would be more removed and same happens vice versa.
- However, if you take sampling on the x axis, the signal is not converted to digital format, unless you take sampling of the y-axis too which is known as quantization.
- The more samples eventually means you are collecting more data, and in case of image, it means more pixels.

Image Sampling & Quantization

Sampling: Digitizing the coordinate value.

Quantization: Digitizing the amplitude value.



Recall: a pixel is a point…

- It is NOT a box, disc or teeny wee light
- It has no dimension
- It occupies no area
- It can have a coordinate
- *More* than a point, it is a *SAMPLE*

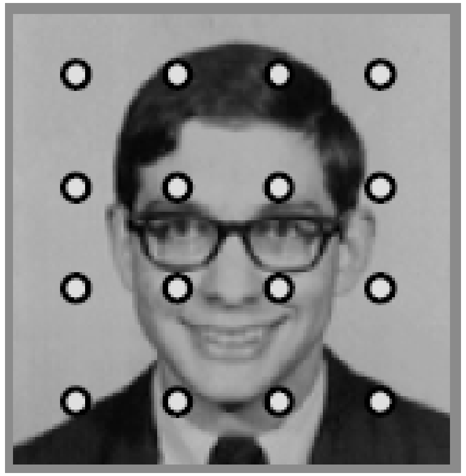
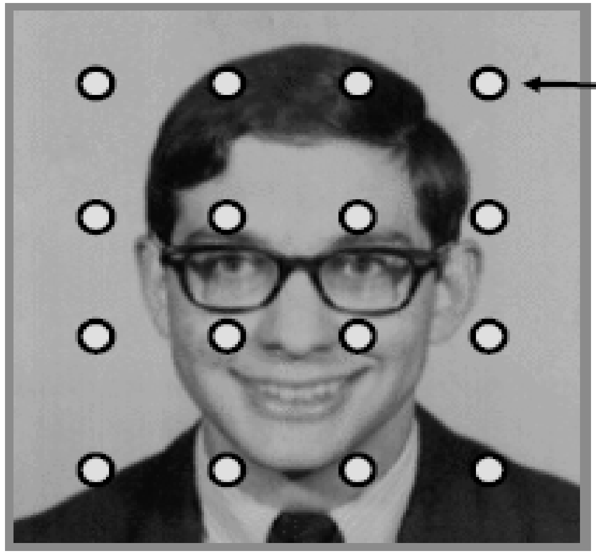


Image Sampling

- An image is a 2D rectilinear array of samples
  - Quantization due to limited intensity resolution
  - Sampling due to limited spatial and temporal resolution



Pixels are infinitely small point samples

Sampling and Reconstruction

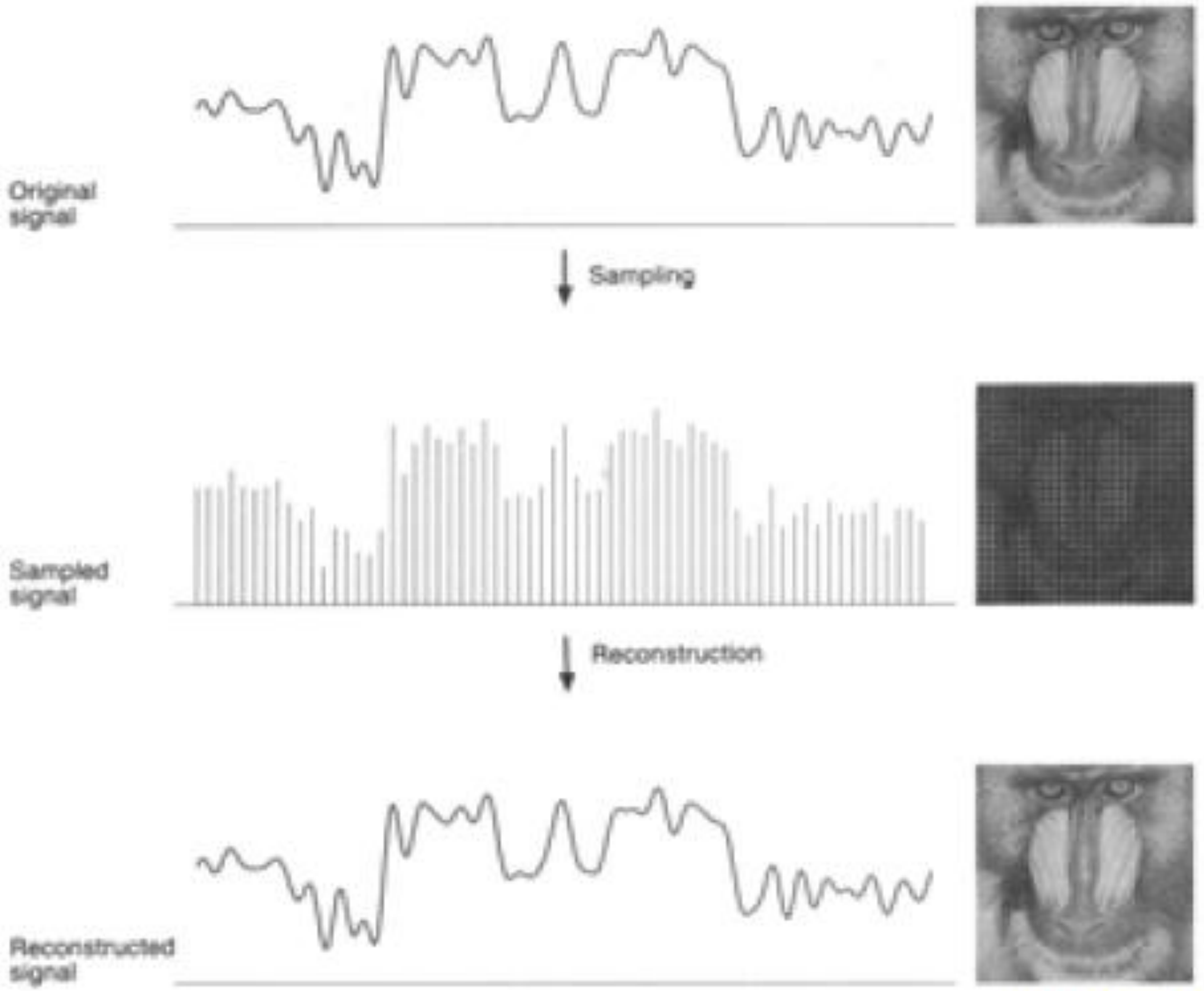


Figure 19.9 FvDFH

Image Sampling

- A static image is a two dimensional spatially varying signal.
- A sampling period should be smaller than or at the most equal to half of the period of the finest detail in the image according to Nyquist rate.
- This implies that sampling frequency along x axis $\omega_x \geq 2\omega_x^L$ and along y axis $\omega_y \geq 2\omega_y^L$

  where ω_x^L and ω_y^L are the limiting factors along x and y axis

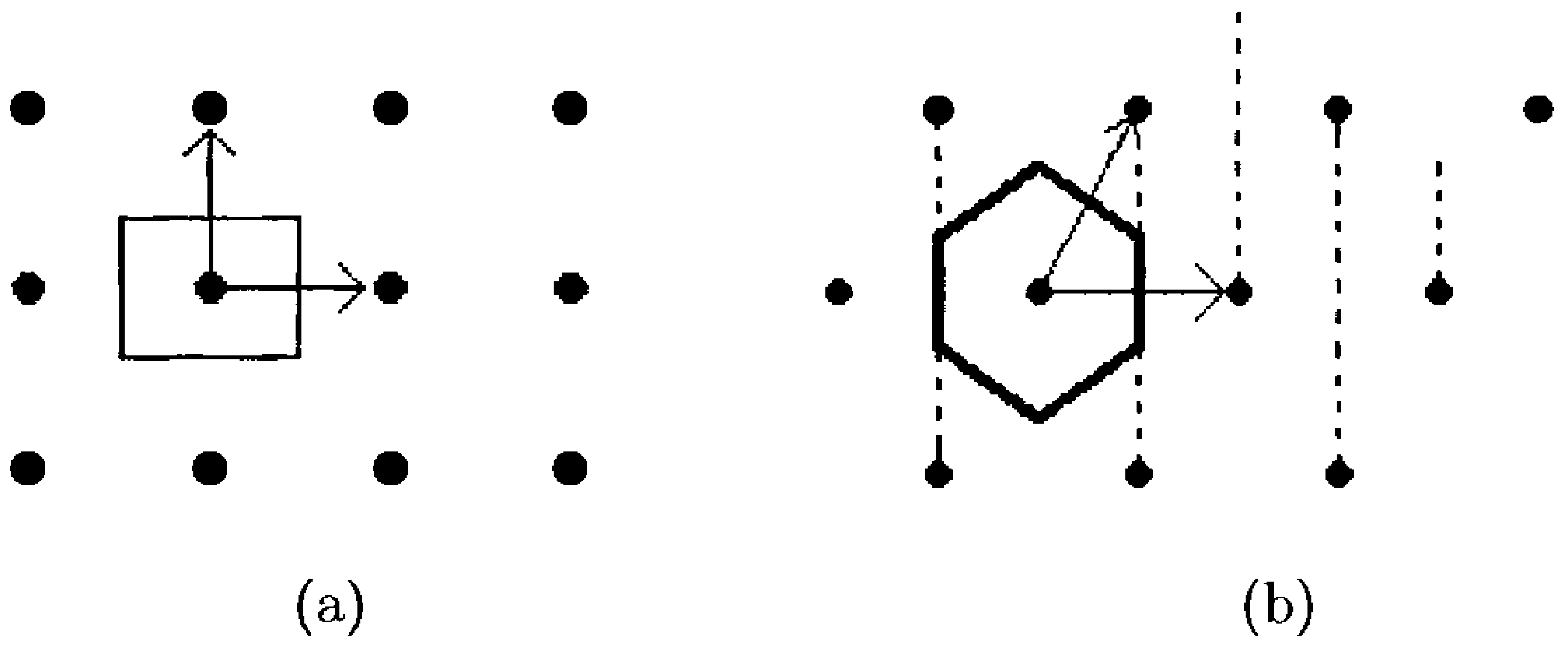


Fig. 2.5 (a) Rectangular and (b) hexagonal lattice structure of the sampling grid.

- $\Delta x \ is$ chosen sampling along x-axis then,

$$\Delta x \leq \frac{\pi}{\omega_x^L}$$

- $\Delta y \ is$ chosen sampling along y-axis then,

$$\Delta y \leq \frac{\pi}{\omega_y^L}$$

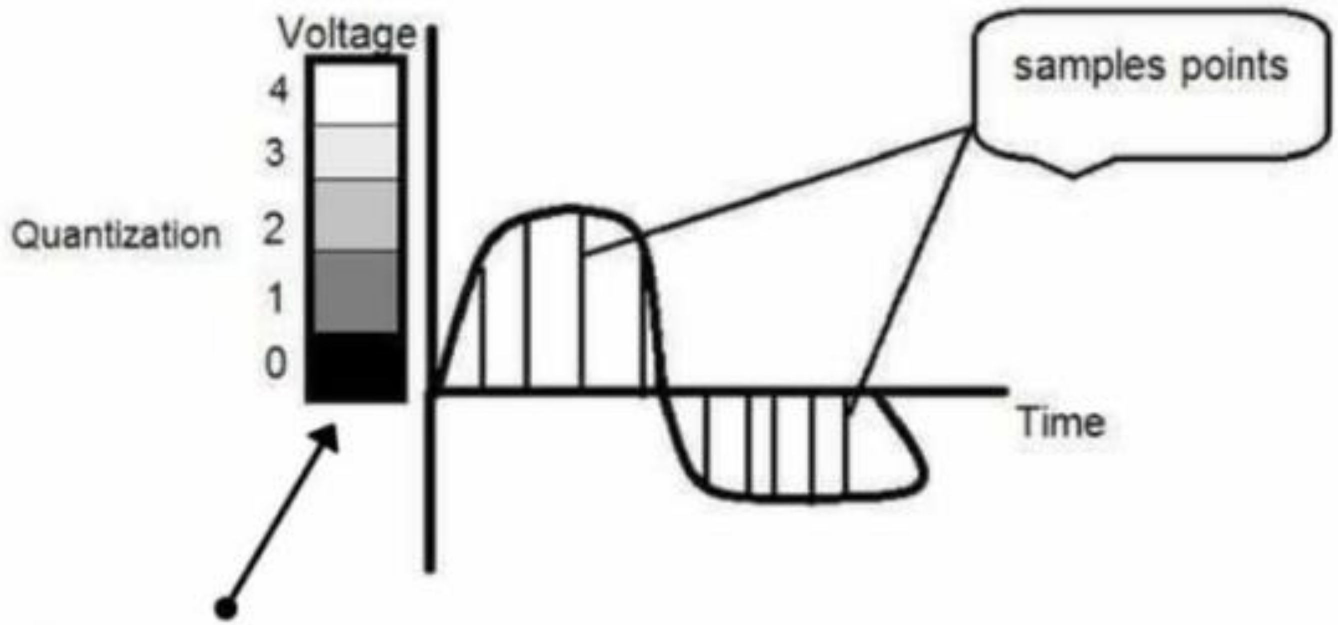
If $\Delta x \ and \ \Delta y$ are smaller, its called oversampling and $\Delta x \ and \ \Delta y$ are larger then it is called undersampling.

- If images are oversampled or exactly sampled, it is possible to reconstruct the band limited image
- If images are undersampled , there will be spectral overlapping which results in aliasing effect
- This aliasing error can be reduced by substantially by using a presampling filter

Fig. Images sampled at 256×256, 128×128 , 64×64, 32×32, and 16×16 rectangular sampling grids.

Image Quantization

- It is opposite side of Sampling
- As sampling is done in x-axis whereas Quantization is done on the y-axis
- Digitizing the amplitudes is called Quantization
- Quantization involves in assigning a single value to each samples
- We divide signal amplitudes into quanta(partitions)



Vertically ranging values have been quantized into 5 different levels or partitions.

Relation of Quantization and gray level resolution:

Number of quantas (partitions) = Number of gray levels

- Number of gray levels here means number of different shades of gray.
- To improve image quality, we number of gray levels or gray level resolution up.
- If we increase this level to 256, it is known as the grayscale image.

$$\boxed{L = (2^k)}$$

Where,

L = gray level resolution

k = gray level

Types of Quantization

- Uniform Quantization
- Random Quantization

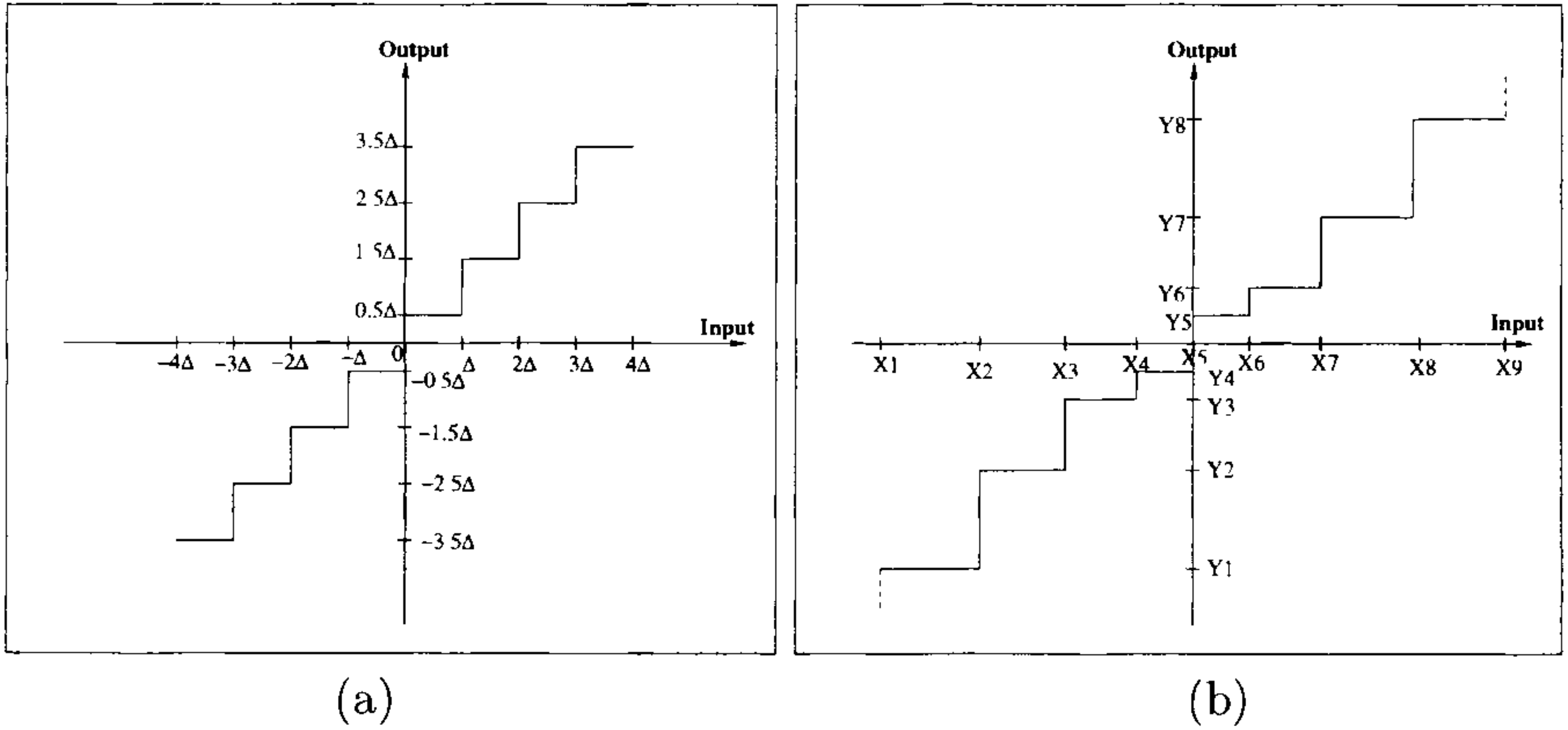


Fig. 2.7 Two-dimensional (a) uniform quantization (b) nonuniform quantization.

- As the number of quantization levels increases, the quantized image will be approximately to the original image with less error
- When quantization levels are chosen equally spaced at equal interval, it is known Uniform Quantization
- If levels are spaced at different intervals, it is called Random Quantization or Non-uniform Quantization
- When sample intensity values are equally like to occur at different intervals, then Uniform Quantization is followed
- If samples assumes values in a small range quite frequently and other values infrequently,then Non-uniform Quantization is used


Original 8bit
3bit Quantized

Quantification IV

Relationship with pixels

- Since a pixel is a smallest element in an image. The total number of pixels in an image can be calculated as

  Pixels = total no of rows * total no of columns.

- Lets say we have total of 25 pixels, that means we have a square image of 5 X 5.
- Then as we have discussed above in sampling, that more samples eventually result in more pixels. So it means that of our continuous signal, we have taken 25 samples on x axis. That refers to 25 pixels of this image.

MCQ

1) 1. A continuous image is digitised at ________ points.
a) random
b) vertex
c) contour
d) sampling

- 1. A continuous image is digitised at _______ points.
  a) random
  b) vertex
  c) contour
  d) sampling

2. The transition between continuous values of the image function and its digital equivalent is called _______________

a) Quantisation

b) Sampling

c) Rasterisation

d) None of the Mentioned

2. The transition between continuous values of the image function and its digital equivalent is called _______________

a) Quantisation

b) Sampling

c) Rasterisation

d) None of the Mentioned

3.Quantitatively, spatial resolution cannot be represented in which of the following ways

a) line pairs

b) pixels

c) dots

d) none of the Mentioned

3.Quantitatively, spatial resolution cannot be represented in which of the following ways

a) line pairs

b) pixels

c) dots

d) none of the Mentioned

1)Write in detail about Image Sampling and Quantization

2)Identify the different types of Quantization in Images

Reference

- T1. Tinku Acharya and Ajoy K. Ray, "*Image Processing Principles and Applications*", John Wiley and Sons publishers.

Binary Image Processing

Binary Images

- Images only consist of two colors (tones): white or black

Binary Images

- Images with only two values (0 or 1)
- Simple to process and analyze
- Very useful for industrial applications

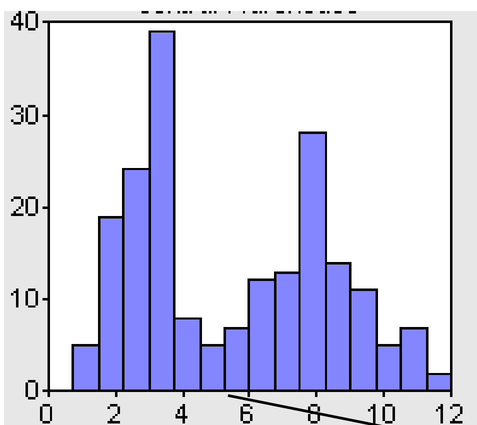
Binary Images

- Obtained from gray-level (or color) image g(x, y) by Thresholding

- Characteristic Function

$$b(x, y) = \begin{cases} 1 & \text{if } g(x, y) > T \\ 0 & \text{if } g(x, y) <= T \end{cases}$$

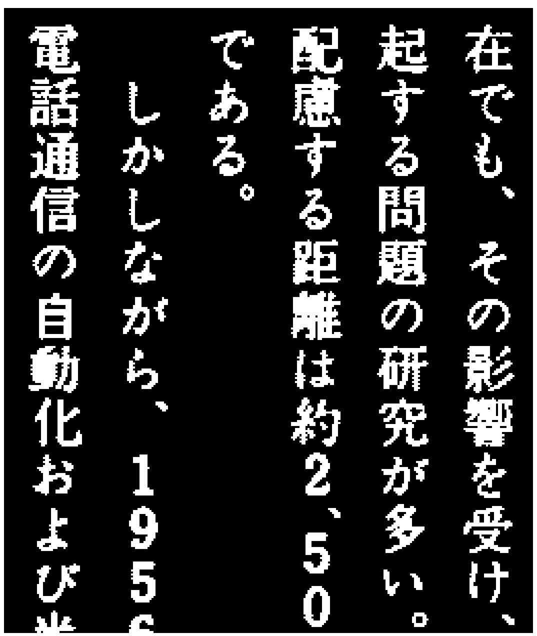
Selecting a Threshold

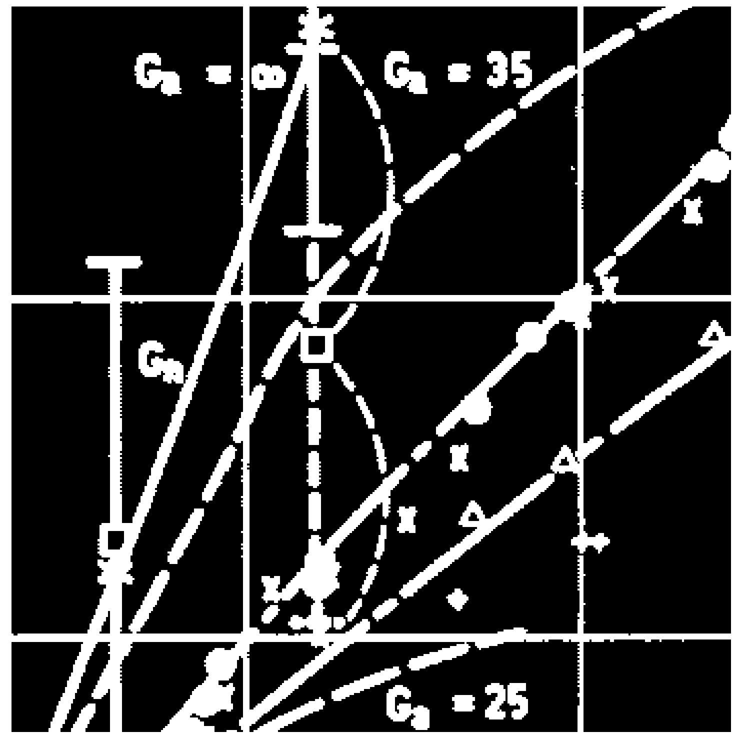


Threshold

Bimodal Histogram

Binary Image Examples


在でも、その影響を受け、
起する問題の研究が多い。
配慮する距離は約2、50
である。
しかしながら、195
電話通信の自動化および



Why are binary images special?

- Since pixels are either white or black, the locations of white(black) pixels carry ALL information of binary images

<u>Example</u>

$$\begin{array}{cccc} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 255 & 255 \\ 0 & 0 & 255 & 255 \end{array} \quad \Longleftrightarrow \quad L=\{(3,3),(3,4),(4,3),(4,4)\}$$

f(m,n) ⟷ location of white pixels

matrix representation ⟷ set representation

It is often more convenient to consider the set representation than the matrix representation for binary images

- Binary images are least expensive since its requires least storage and also less processing requirements.
- E.g line drawings, printed text in White papers
- This images have enough information about the objects in the images
- The gray images can be converted to binary using thersolding

Image Example (Con't)

Binary fingerprint image

Skeleton image

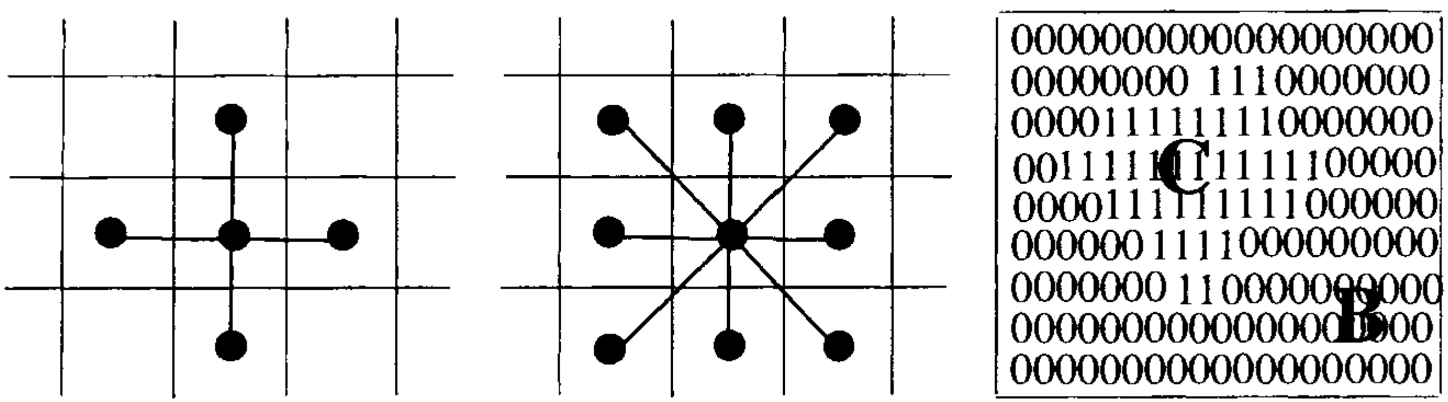
- The binary is quantified in two levels. The grey level can increased based on applications
- As number of intensity increased, we get better approximation images.
- Although the storage requirements also increases approximately

Geometric properties of the Images

- Connectivity
- Projection
- Area
- Perimeter

Connectivity

- A pixel P_0 at (i_0, j_0) is connected to another pixel P_n at (i_n, j_n)
- If and only if there exists a path from P_0 to P_n,which is a sequence of points (i_0, j_0) , (i_1, j_1) ……., (i_n, j_n)
- (i_k, j_k) is a neighboring pixel at (i_{k+1}, j_{k+1})



(a) (b) (c)

Fig. 2.9 Examples of (a) 4-connected pixels, (b) 8-connected pixels, and (c) connected component and background.

- **4-connected:** When a pixel at location (i, j) has four immediate neighbors at $(i+1, j)$, $(i-1, j)$, $(i, j+1)$, and $(i, j-1)$, they are known as *4-connected*. Two four connected pixels share a common boundary as shown in Figure 2.9(a).

- **8-connected:** When the pixel at location (i, j) has, in addition to above four immediate neighbors, a set of four corner neighbors at $(i+1, j+1)$, $(i+1, j-1)$, $(i-1, j+1)$, and $(i-1, j-1)$, they are known as *8-connected*. Thus two pixels are eight neighbors if they share a common corner. This is shown in Figure 2.9(b).

- **Connected component:** A set of connected pixels (4 or 8 connected) forms a *connected component*. Such a connected component represents an object in a scene as shown in Figure 2.9(c).
- **Background:** The set of connected components of 0 pixels forms the *background* as shown in Figure 2.9(c).

AREA

Once an object is identified, some of the attributes of the object may be defined as follows.

- *Area of an object*: The area of a binary object is given by

$$A = \sum_i \sum_j O[i, j],$$

where $O[i, j]$ represents the object pixels (binary 1). The area is thus computed as the total number of object pixels in the object.

- *Location of object*: The location of the object is usually given by the center of mass and is given as

$$x_c = \frac{\sum_i \sum_j [i\,O(i,j)]}{A}, \qquad y_c = \frac{\sum_i \sum_j [j\,O(i,j)]}{A}$$

where x_c and y_c are the coordinates of the centroid of the object and A is the area of the object. In effect thus the location of the object is given by the first-order moment.

Fig.3 Occluded car

- *Orientation of an object*: When the objects have elongated shape, the axis of elongation is the orientation of the object. The axis of elongation is a straight line so that the sum of the squared distances of all the object points from this straight line is minimum. The distance here implies the perpendicular distance from the object point to the line.

- *Perimeter of an object*: To compute the perimeter of an object, we identify the boundary object pixels covering an area. Perimeter is defined by the sum of these boundary object pixels.

Projection of Object

- The projections of a binary image provide good information about the image
- Computed along horizontal, vertical or diagonal lines
- The horizontal projection is obtained by counting the number of object pixels in column wise
- Total no. each rows will give vertical projection

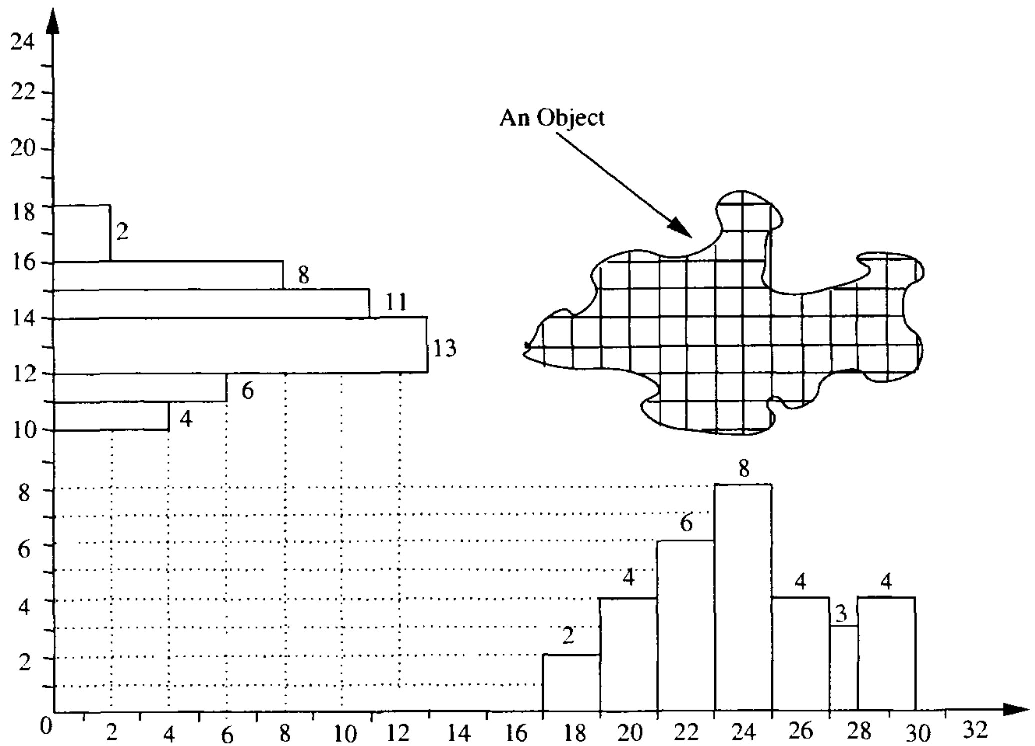
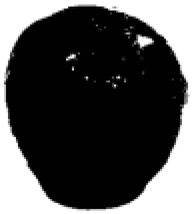


Fig. 2.10 Histogram of a binary object along horizontal and vertical axes.

Sample Questions

- How the Geometric properties are helpful for processing binary images?
- What is the procedure for converting gray image to binary Image?

The process of converting grey image to binary is called as



a) Grey scale inversion (negative of the original image);
b) Binary thresholding;
c) Histogram equalization;
d) Some grey scale slicing

1)The process of converting grey image to binary is called as

a) Grey scale inversion (negative of the original image);
b) Binary thresholding;
c) Histogram equalization;
d) Some grey scale slicing

2)Validate the statement "When in an Image an appreciable number of pixels exhibit high dynamic range, the image will have high contrast."

a) True
b) False

3)The area of object can be defined as

- a) $A = \sum_i \sum_j O(i,j)$
- b) $A = \sum_i O(i)$
- c) $A = \sum_i \sum_j O(i,j,k)$
- d) $A = \sum_j O(j)$

3)The area of object can be defined as

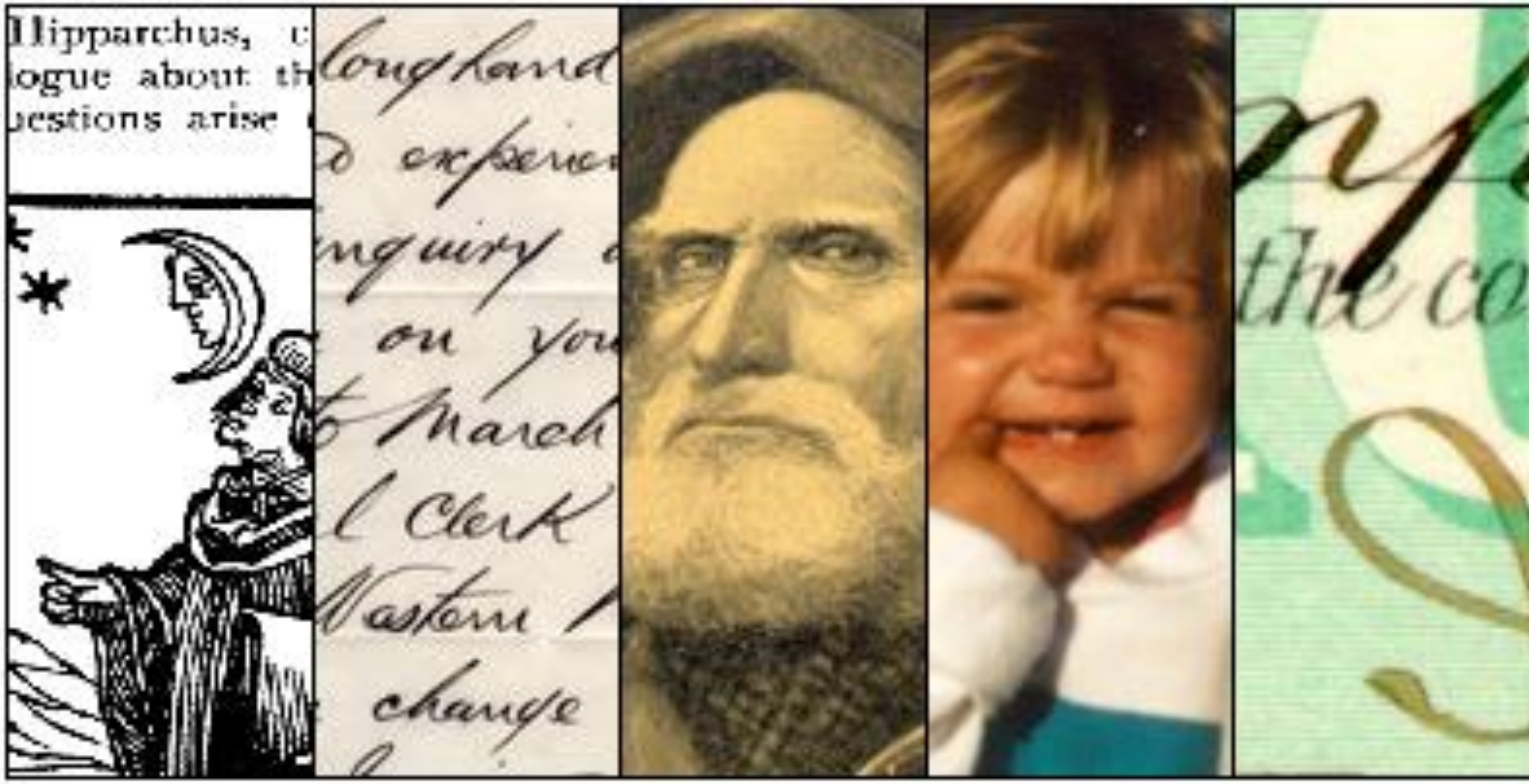
a) $\boldsymbol{A = \sum_i \sum_j O(i,j)}$

b) $A = \sum_i O(i)$

c) $A = \sum_i \sum_j O(i,j,k)$

d) $A = \sum_j O(j)$

T1. Tinku Acharya and Ajoy K. Ray, "*Image Processing Principles and Applications*", John Wiley and Sons publishers.


Hipparchus,
logue about th
uestions arise
March
Clerk
change

RAW (UNPROCESSED CAMERA IMAGE CAPTURING DATA)

- **A camera raw image file contains minimally processed data from the image sensor of a digital camera. Raw files are named so because they are not yet processed and therefore are not ready to be printed or edited. Normally, the image is processed by a raw converter where precise adjustments can be made before conversion to a file format such as a TIFF or JPEG for storage, printing, or further manipulation. There are hundreds, of raw formats in use by different models of digital equipment.**

PROS

- Format can be used by many applications.
- File size may be smaller than TIFF.
- Saved at the camera's maximum colour bit depth.

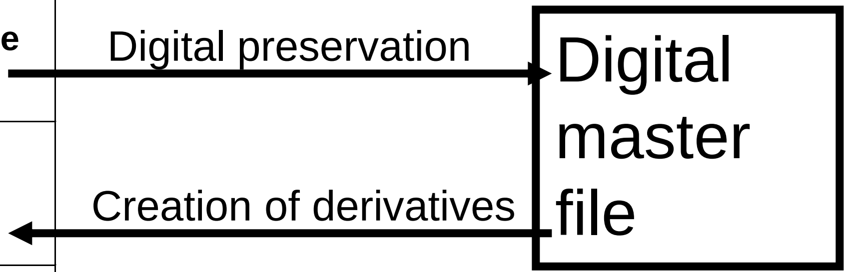
CONS

- Large file size means that it can take longer to save an image to the memory card, i.e. less images captured per second.
- Difficult to work with images because they need to be converted to something else (like TIFF) before they can be shared and manipulated.

A
Go

Digital master images

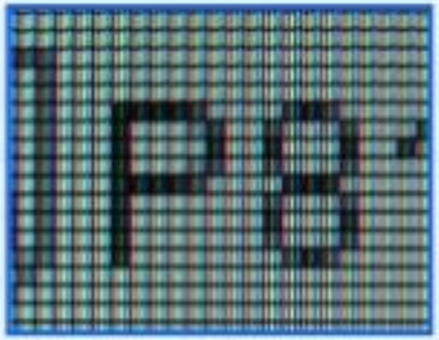
	Conventional photography	Digital photography
step 1. Capture	**'Snapshot'**	**Scanning / digital capture**
step 2. Process	**Chemical film processing**	**Image processing**
step 3. Output	**Imprint**	**Screen view / Printer output**



Three steps in the photographic process

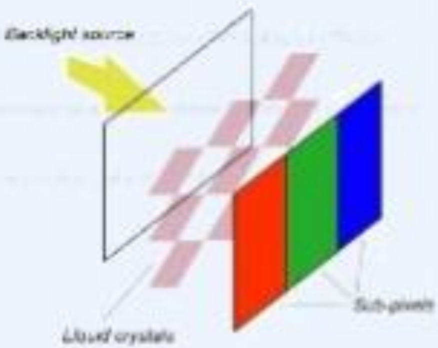
Image Formation

- The primary concept of image formation signify the presence of dots.



- In digital mediums these dots are often called PIXELS (Picture Elements) for 2-D medium or VOXELS (Volumetric Picture Elements) for 3-D images.

- Pixels can be of single colour in an entire image drawing or may be of primary colours in a multi-colour drawing.



- The proximity of pixels (DPI - Dots Per Inch) and the count over a given dimension represent the Image Resolution which is the primary measure of Visual Quality of an Image.

Graphic File Formats

… - PCX – PBM – TGA – TIFF – GIF – JPEG – PSD – DXF - CGM – PNG – SVG – RAW – WPG – FITS – BMP – PCD – RAS – TGA – BPS – EPS – PDF – PCT – WBM – FITS – XBM – VFF – RIB – PCX – DMP – AVS – IMG – ICO – JFIF – IFF – WMF - …

Why are there so many different graphic file formats?

There are a number of fundamental different types of graphical data

- raster data (sampled values)
- geometry data (mathematical description of space)
- latent image data (data transformed into useful images by some algorithmic process)

Types of Digital Images (Based on Drawing Units)

- **RASTER IMAGES:**
  Images made of pixels or dots.
  A Raster means a frame of Screen which is made using scanning of entire screen line by line. Raster images are resolution dependent and can not be scaled up or down without loss of quality.

- **VECTOR IMAGES:**
  Images made using lines and curves that are drawn using mathematical equations. These images are not related to resolution and they can be scaled up or down to any size. While drawing on a medium vector images are also drawn using pixels, but they retain their scaling quality and redrawn again when resized.

> Both Raster and Vector Images can have Colours. In case of Raster Images, colours is a pixel property while in case of Vector Images Colours are given as another mathematical property.

Types of Digital Images (Based On Dimensions)

- **2-D IMAGES:**
  Images that are seen on X and Y axis only.

- **3-D IMAGES on 2-D Medium:**
  Images that are displayed on 2-D medium but still have feeling of depth associated with it. These images might require a viewer to wear special glasses to feel the 3D effect.

- **3-D IMAGES on 3-D Medium:**
  Images that are produced in all 3-Dimensions of space such as 3-D holographic images, 3-D Laser Images.

Features List

- Resolution and DPI
- Colour/Bit Depth
- Compression
- Transparency
- Alpha Channels
- Gamma Correction
- Anti-Aliasing
- Interlacing
- Palletes
- Half Tone/ Duotone
- Animation Support

Colour Depth/Bit Depth

- 2 Colour: This is mostly a black and white image. It may however be any other two colour image also. It requires just 1 bit for colour information.
- 16 Colour: These are very basic image types used on old machines. The colour information here is encoded in 4 bits only.
- 256 Color: These are 8 Bit images often used in BMP and GIF formats.
- 16 Bit: This is also known as HI-COLOR setting. These have more than 64 Thousand colours and are suitable for most picture related work on computers.
- 24 Bit: This is known as TRUE COLOR Setting. These have a better colour depth of more than 16.7 Million Colours and are visually excellent.
- 32 Bit: These have even better picture quality to show excellent picture shading effects and shades of special colours like silver, gold, colours across a glass etc. This quality is also available on modern computers.

Image Compression.

- With the advent of faster computers the technology of reducing the image file size gained momentum.
- It is possible to reduce file size of a pixel based image to the tune of 1/10 using modern compression techniques without much loss in image quality.
- Image compression can be either completely lossless like in case of GIF and PNG standards, while in case of lossy compression even more size reduction can be achieved as in the case of JPG formats (commonly used for photographs).

Watch the minor loss of image quality near the Cat's nose.

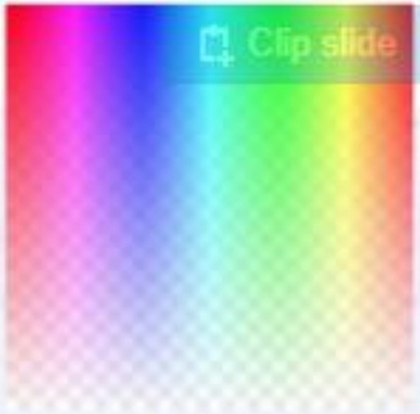
Image Transparency.

- Transparency is a feature of image where a certain colour of image can be replaced by the background.
- Image Transparency feature is available with certain file formats only. Most common one with transparency features are GIF, PNG and TIFF formats.
- In some formats multiple levels of transparency is supported by adding additional byte for transparency level. So instead of RGB colours it becomes RGBA colours. Here A stands for Alpha Channel. Typical example of this is the PNG file format.

White Background Colour has been made transparent in this case.

More About Alpha Channel

- It is a way to produce partial transparency.
- This often provides perfect smoothening of edges which is otherwise difficult due to rectangular nature of pixels.
- The drop shadow effect is also correctly possible due to partial transparency feature.

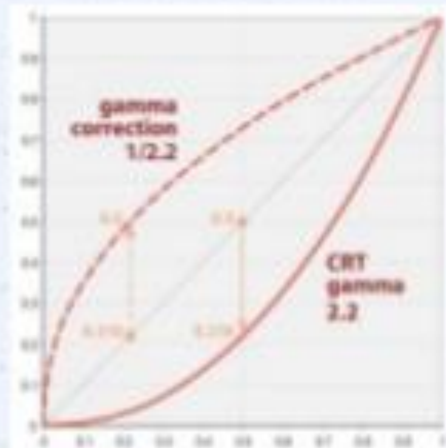


Gamma Correction

- If the intensity element of image is encoded in a linear fashion then the image will not look correct. This is due to the non-linear behaviour of displays devices like CRT, LCD etc. The intensity value with respect to impulse applied does not change linearly.

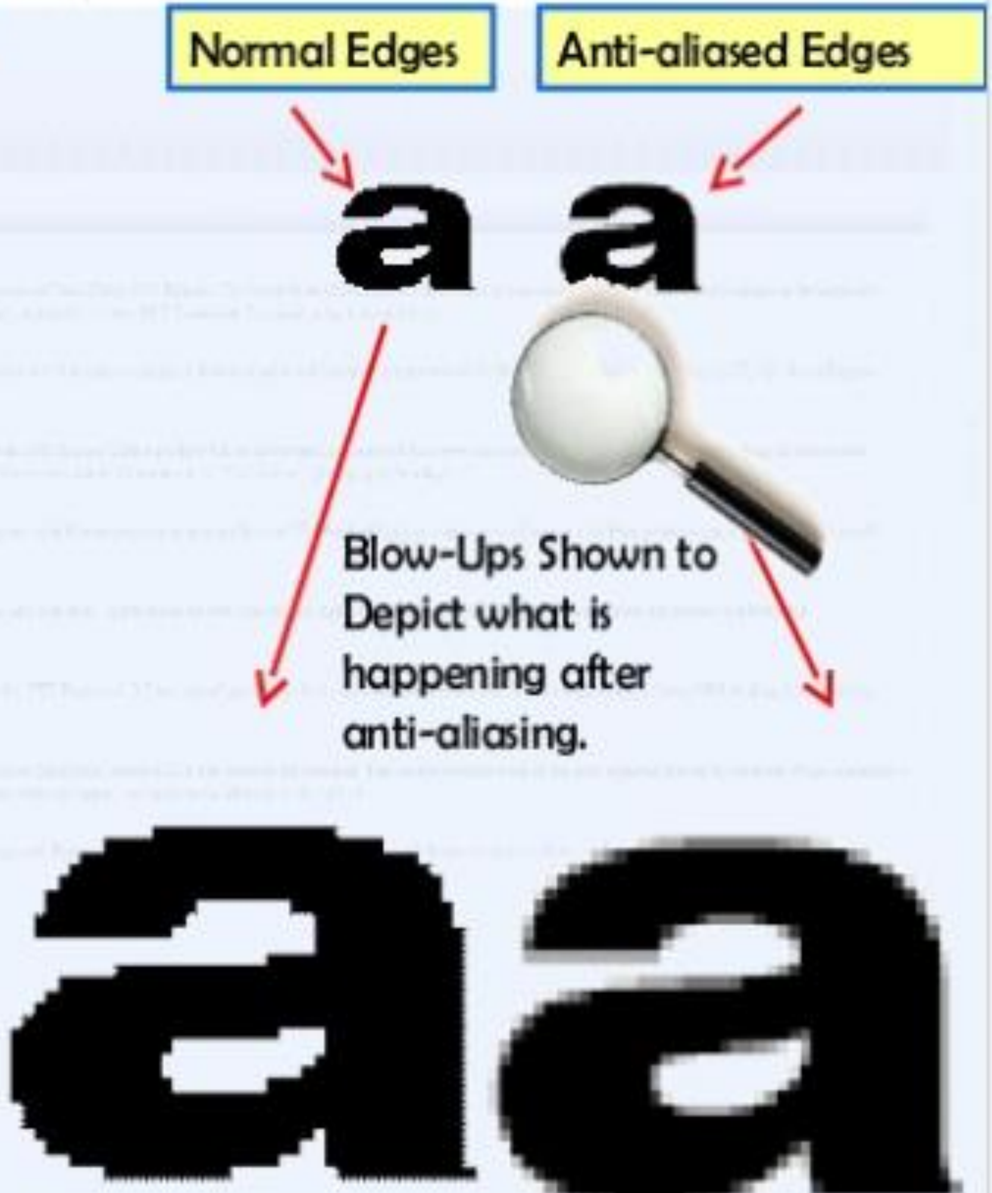
- Due to this nonlinear behaviour intensity value is pre-encoded in image files itself to show it correctly on various displays.

- As an image might be displayed on different mediums and makes of computers one may need to adjust the value of this encoding for different devices. This is called GAMMA CORRECTION. Some image formats like PNG allow this correction in a straight forward manner.



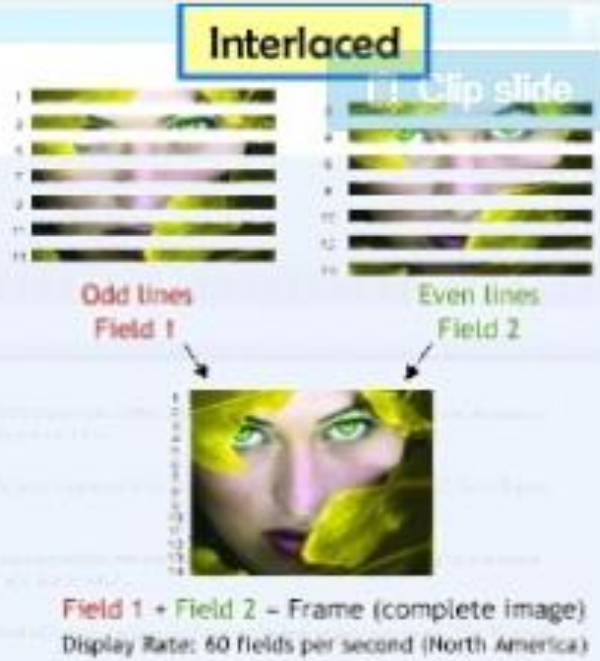
Anti-Aliasing

- Anti-Aliasing is a way to give a smoother perception of edges of an image.
- Anti-aliasing is done by using mathematical calculations to calculate grey shades of existing pixels or by addition/deletion of pixels near the edges.
- Microsoft's Clear-type Technology is an advanced form of anti-aliasing using colored pixels on edges.
- Anti-aliasing algorithms may be applied to full screens for better edge smoothening on the entire picture scenes. This is often done in graphics cards for better look of 3-D effect games.



Interlacing

- Interlacing indicates the way an image is drawn on the screen.
- Interlaced Image: When the image is drawn in a way like it is done on a TV where ODD frame is drawn first and then EVEN frame is drawn, it is called an Interlaced image. In this case the whole image frame is drawn at once and then gradually the other interpolated frames are drawn to give a feel of improving quality.
- Non-Interlaced Image: In this type the image is drawn from top to bottom pixel by pixel and line by line. The rest portion of image looks blank. Non-Interlacing is also termed as "Progressive Scan".
- Image Formats Like GIF, JPG and TIFF support interlacing.



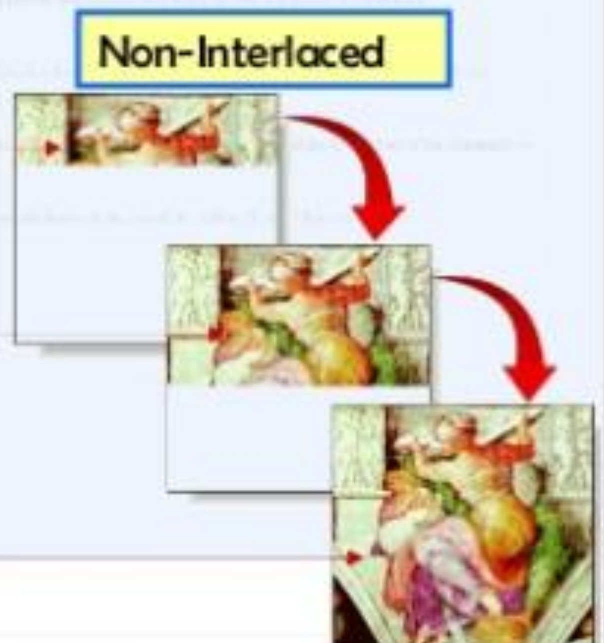
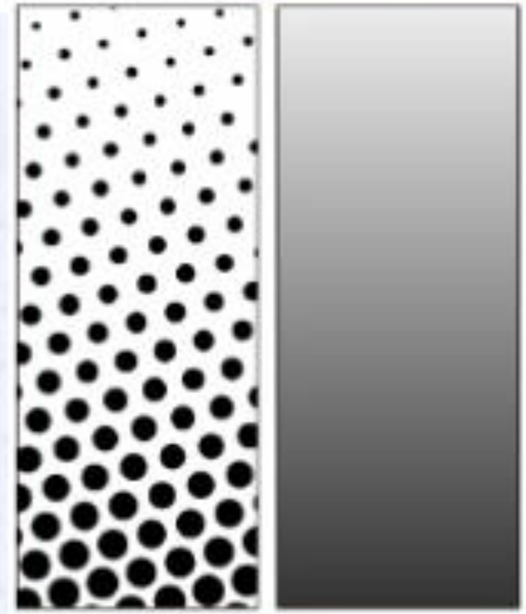


Image Palettes

- The set of colour an image is made of is called image palette.
- A typical digital image may contain an 8 bit palette (256 colours) or a set of more colours like 64K colours or 16.7 Million Colours.
- A palette based image has an advantage of changing the entire colour set in one go by just switching the palettes.
- 8-Bit BMP and GIF images are examples of palette based images.

Half Tone / Duo Tone



- Half tone is a method where continuous tone perception is generated with the use of dots pitched far from regular dots density.
- Duotone is produced by superimposing another contrasting colour halftone over halftone drawing in another colour.

Popular 2-D Digital Image Formats

Categorisation of 2-D Image Formats

- RASTER IMAGE FORMATS
  - Non-Proprietary:
    JPG, GIF, PNG, TIFF, BMP
  - Proprietary:
    PSD, PSP
- VECTOR IMAGE FORMATS
  - Non-Proprietary:
    CGM, SVG, WMF/EMF, EPS
  - Proprietary:
    CDR, AI, PDF, SWF

RASTER FORMATS

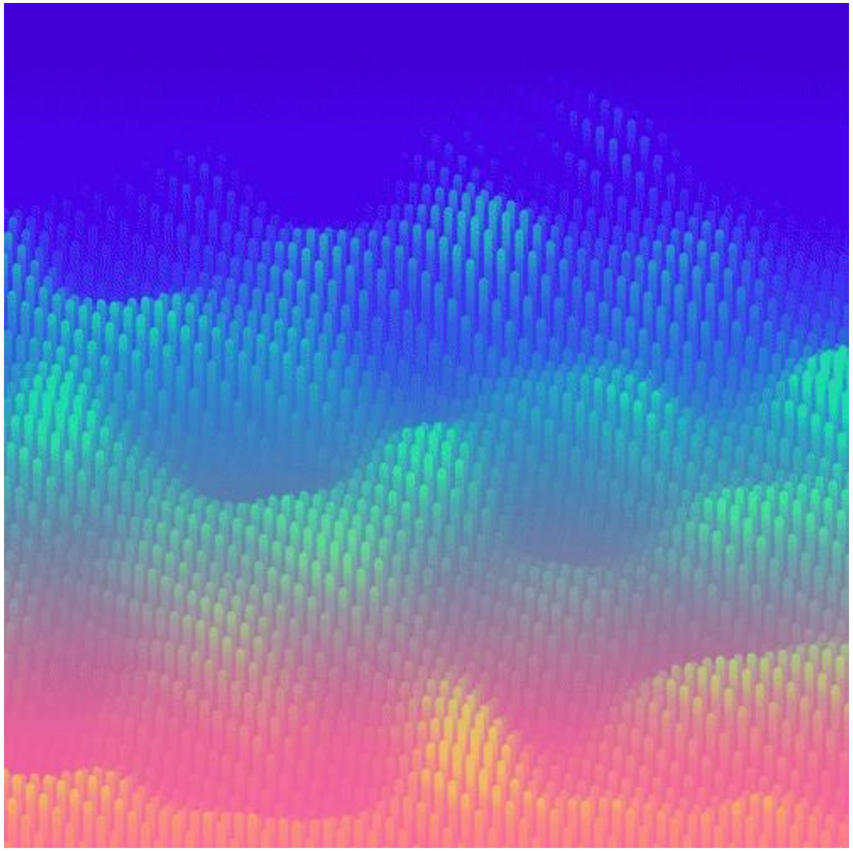
BMP – Bitmap Format

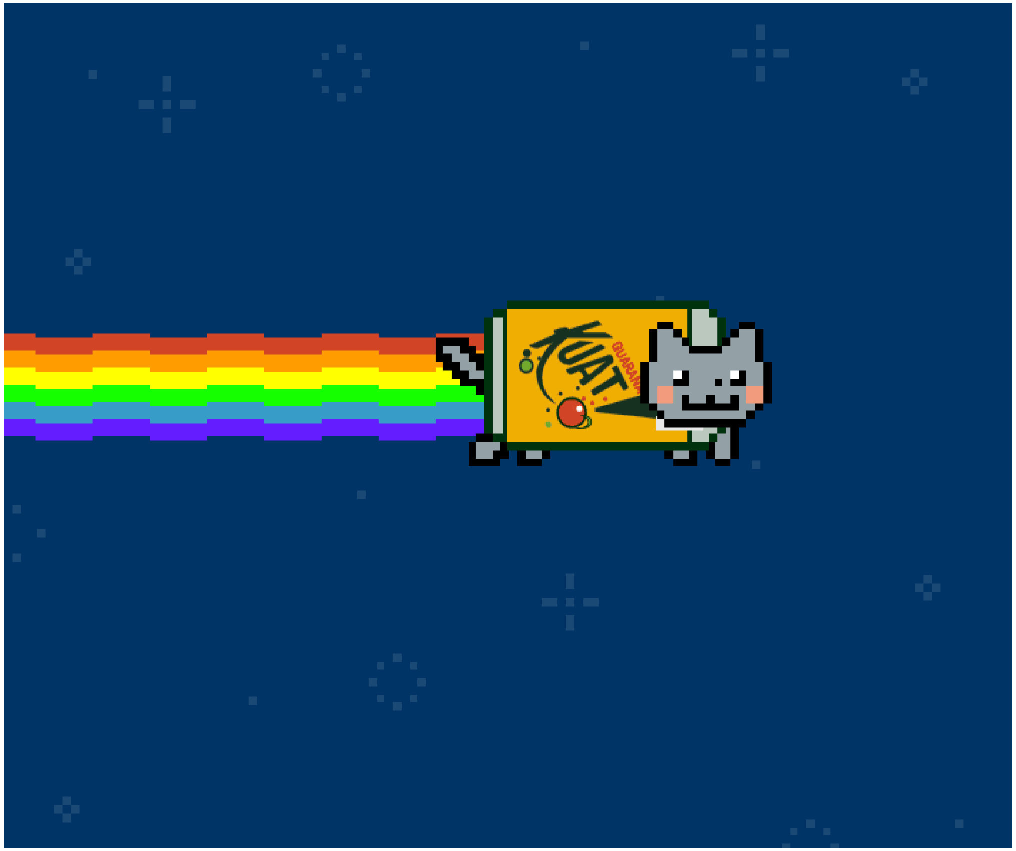
- Used to store direct pixel colour information.
- It is mainly used on Windows family of OS.
- One of its variations is DIB (device independent bitmaps).
- It has file extensions BMP and DIB.
- Its 8 bit version can store only 256 colours.
- It creates a very large file-size as it has no major compression technique in use.
- Sometimes low compression ratio techniques like RLE (Run Length Encoding) can be used along with BMPs.
- BMP files may be zipped to reduce file sizes but still BMP format is not suitable for internet transfer.
- BMP format is however useful for standalone applications and creation of a base file that stores entire image information without any quality loss.

GIF – Graphics Interchange Format

- This is also a pixel based format with a good image compression technique called LZW compression.
- The image quality is not reduced while using this compression.
- It supports upto 256 colours.
- It is good for images with lines, curves and solid colours.
- It is most widely supported on internet and other software.
- It can support animated images with different set of colours for each frame.
- It also supports transparency.


uploading




KUAT

GIF (GRAPHICS INTERCHANGE FORMAT)

- **A GIF is a lossless file format for image files that supports both animated and static images.**

PROS

- 256 number of colours.
- Uses lossless compression.
- Support for transparency.
- Small file format.

CONS

- The oldest format for web – 1989.
- In most cases it has a bigger file size than PNG.
- Loss of colour variation.

JPG/JPEG – Joint Photographic Expert Group

- It has been designed under the banner of ISO (International standard Organisation) by Joint Photographic Experts Group.
- It is a highly compressed raster image format best suited for photographs.
- It allows for adjustment of degree of compression.
- It is a lossy compression. Once compressed perfect reproduction of original is impossible.
- For very little image loss 1:10 compression is often possible.
- It has an advanced version called JPEG 2000 which is still less used as it is a licensed version.
- Progressive JPGs allow multipass drawing when loaded.

Original
1.5 MB

High
Lossy
Compression
92 KB

Compression

- Lossless

RLE (Run Length Encoding) – Windows bitmap files (bmp, ico)

LZW (Lempel-Ziv-Welch) – GIF & TIFF files

ZIP – TIFF files

- Lossy

JPEG (Joint Photographic Experts Group)

Best suited to photos and paintings of realistic scenes with smooth variations of tone and colour

JPEG (JOINT PHOTOGRAPHIC EXPERTS GROUP)

- **A JPEG is an image file format used for compressing image files. The degree of compression can be adjusted, allowing a selectable tradeoff between storage size and image quality.**

PROS

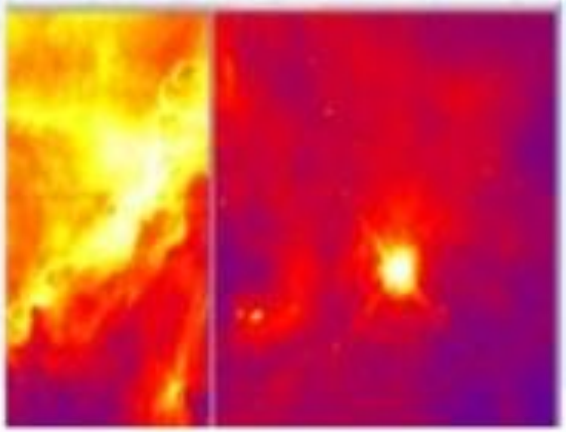
- Retains up to 16,000,000 colours.
- Suitable for images, high details & quality pictures.
- It is the most used graphic file format.
- Approved as standard in 1994.

CONS

- It does not support transparency.
- File size larger than GIF because of colour information.

TIFF – Tagged Image File Format

- This format was designed for images for Desktop Publishing Purposes.
- This format is often the default format in which a scanner saves the file.
- It can work as an image container along with its editing/cropping status.
- It can support compression without any loss of quality.
- It is highly recommended for archival images so that every thing can remain intact along with the image.
- It can even act as container of lossy JPEG files.
- Adobe Corp. holds the copyright of this format but for usage purpose license is not required.
- It is also useful for high precision scientific images. The other option for high precision scientific images such as astronomical images is FITS (Flexible Image Transport System)



TIFF (TAGGED IMAGE FILE FORMAT)

- **Tagged Image File Format (TIFF) is a computer file format for storing raster images, popular among the publishing industry and photographers. The TIFF format is widely supported by image manipulation applications and publishing and page layout applications.**

PROS

- No image data is lost.
- Better image quality than even the JPEG fine quality.
- Good for images that will be heavily manipulated in a photo editing program.

CONS

- File size is very large.
- Still need to make sure that exposure, white balance and colour saturation are properly set because fixing these in the photo editing program will degrade the image to a certain degree.

Extension	Colour	Compression	Common Uses
JPG, JPEG	24-bit	Lossy	Photos, web pics
GIF	8-bit	Lossless	Web graphics – buttons, icons, etc
PNG	up to 24-bit	Lossless	Web – replacement for GIF
TIF, TIFF	24-bit	Lossless	Professional Photos etc

PSD – Photoshop Document

- It is a application specific proprietary format for Adobe Photoshop.
- Application specific formats support layered image storage, editing marks, clipping, padding and position storage.
- It supports colour modes like RGB, CMYK, LAB, GREY, PALLETTED etc.
- It supports unlimited colours.
- It produces native bitmap format with RLE compression.

VECTOR FORMATS

WMF/EMF – Windows Metafile/Enhanced Meta File

- It can store both vector and bitmap components.
- It is the native format for applications like Word, Power-point, Publisher etc.
- The EMF enhancement has commands for printer graphics also.
- WMF/EMF have direct function calls for windows GDI – Graphics Device Interface.
- WMF produces very small size files and is quite suitable for usage in form of clipart libraries.
- WMZ and EMZ are compressed formats of WMF and EMF respectively.

CDR - CorelDraw

- It is native Vector Based Format for Corel Applications.
- It has capability to store both vector based and bitmap images.
- It can store multiple pages of data.
- It stores all editing status and other image configuration data.
- It produces an extremely low file size.
- Every Version of CorelDraw has different formats and it is essentially required to convert files to a lower version while transferring to previous version of Corel Application.

EPS – Encapsulated Postscript

- This format is frequently used for production quality drawing in printing.
- This is a vector based format that can contain PostScript Style Description of Drawing.
- Its purpose is for printing only and EPS files are not meant for Editing.
- Converted EPS files may only be viewed by special viewers. Regular graphics applications are not able to open these file.

PPM-Portable Pixmap Image

- A PPM file is a 24-bit color image formatted using a text format.
- It stores each pixel with a number from 0 to 65536, which specifies the color of the pixel.
- PPM files also store the image height and width, whitespace data, and the maximum color value.
- Either P3(ASCII form) or P6(Binary form)

```
P3
# feep.ppm
8 8
255
255 255 0   255 255 0   255 255 0   255 255 0  255 255 0   255 255 0
255 255 0   255 255 0
255 255 0   255 255 0   255 255 0   255 255 0  255 255 0   255 255 0
255 255 0   255 255 0
0  0  0     0  0  0     0  0  0     255 0 255  0  0  0     0  0  0
0  0  0     255  0 255
0  0  0     0 255 127   0  0  0     0  0  0    0  0  0     0 255 127
0  0  0     0  0  0
0  0  0     0  0  0     0 255 127   0  0  0    0  0  0     0  0  0
0 255 127   0  0  0
255  0 255  0  0  0     0  0  0     0  0  0    255  0 255  0  0  0
0  0  0     0  0  0
255 255 0   255 255 0   255 255 0   255 255 0  255 255 0   255 255 0
255 255 0   255 255 0
255 255 0   255 255 0   255 255 0   255 255 0  255 255 0   255 255 0
255 255 0   255 255 0
```

PGM

- A **PGM** file is a grayscale **image** file saved in the portable gray map (**PGM**) format and encoded with one or two bytes (8 or 16 bits) per pixel.
- It contains header information and a grid of numbers that represent different shades of gray from black (0) to white (up to 65,536)

PBM

- A file with the PBM file extension is mostly likely a Portable Bitmap Image file.

- These files are text-based, black and white image files that contain either a 1 for a black pixel or a 0 for a white pixel.

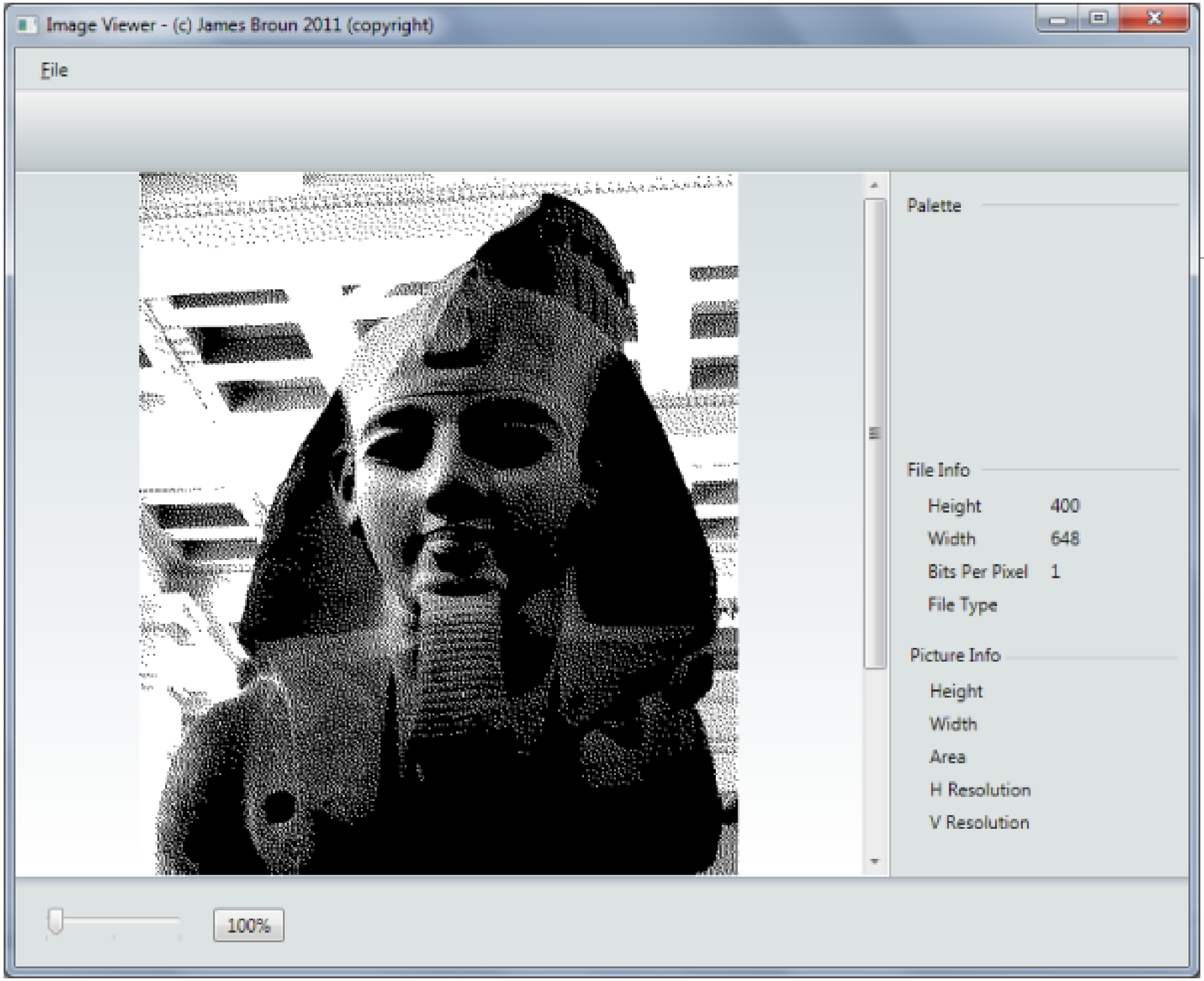


Image Viewer - (c) James Broun 2011 (copyright)
File
Palette
File Info
Height 400
Width 648
Bits Per Pixel 1
File Type
Picture Info
Height
Width
Area
H Resolution
V Resolution
100%

OTHER FORMATS

ICO - ICON

- It is a file format for Windows Icons.
- One can produce 16x16 16 colour icon to 48x48 16.7 Million Colour Icons using this format.
- Technically ICO file can even store a 1x1 pixel image.
- Vista and above supports even the 256x256 pixel icons.
- Modern systems also supports PNG files to be used as icons.
- One may require to use a special pixels based editor to create icons.

SVG – Scalable Vector Graphics

- It is a modern XML based file for vector graphics, that can be used on internet also.
- It is an standard from W3C (World Wide Web Consortium) that created standards for HTML, XML etc.
- It supports standard compression techniques and is saved as SVGZ when compressed.
- It supports dynamic, interactive drawing using Javascript.
- It supports Vector Graphics, Raster Graphics and Normal Text.

Introduction to Mathematical Operations in DIP

- **Array vs. Matrix Operation**

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \qquad B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

Array product operator

$$A \;.*\; B = \begin{bmatrix} a_{11}b_{11} & a_{12}b_{12} \\ a_{21}b_{21} & a_{22}b_{22} \end{bmatrix}$$

Array product

Matrix product operator

$$A * B = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{bmatrix}$$

Matrix product

Introduction to Mathematical Operations in DIP

- **Linear vs. Nonlinear Operation**

$$H\left[f(x,y)\right] = g(x,y)$$

$$H\left[a_i f_i(x,y) + a_j f_j(x,y)\right]$$

$$= H\left[a_i f_i(x,y)\right] + H\left[a_j f_j(x,y)\right]$$

Additivity

$$= a_i H\left[f_i(x,y)\right] + a_j H\left[f_j(x,y)\right]$$

Homogeneity

$$= a_i g_i(x,y) + a_j g_j(x,y)$$

H is said to be a **linear operator;**

H is said to be a **nonlinear operator** if it does not meet the above qualification.

Arithmetic Operations

- Arithmetic operations between images are array operations. The four arithmetic operations are denoted as

$$s(x,y) = f(x,y) + g(x,y)$$

$$d(x,y) = f(x,y) - g(x,y)$$

$$p(x,y) = f(x,y) \times g(x,y)$$

$$v(x,y) = f(x,y) \div g(x,y)$$

Example: Addition of Noisy Images for Noise Reduction

Noiseless image: f(x,y)

Noise: n(x,y) (at every pair of coordinates (x,y), the noise is uncorrelated and has zero average value)

Corrupted image: g(x,y)

$$g(x,y) = f(x,y) + n(x,y)$$

Reducing the noise by adding a set of noisy images, $\{g_i(x,y)\}$

$$\overline{g}(x,y) = \frac{1}{K}\sum_{i=1}^{K} g_i(x,y)$$

Example: Addition of Noisy Images for Noise Reduction

$$\bar{g}(x,y) = \frac{1}{K}\sum_{i=1}^{K} g_i(x,y)$$

$$E\{\bar{g}(x,y)\} = E\left\{\frac{1}{K}\sum_{i=1}^{K} g_i(x,y)\right\}$$

$$= E\left\{\frac{1}{K}\sum_{i=1}^{K}[f(x,y)+n_i(x,y)]\right\}$$

$$= f(x,y) + E\left\{\frac{1}{K}\sum_{i=1}^{K} n_i(x,y)\right\}$$

$$= f(x,y)$$

$$\sigma^2_{\bar{g}(x,y)} = \sigma^2_{\frac{1}{K}\sum_{i=1}^{K} g_i(x,y)}$$

$$= \sigma^2_{\frac{1}{K}\sum_{i=1}^{K} n_i(x,y)} = \frac{1}{K}\sigma^2_{n(x,y)}$$

PRESIDENCY UNIVERSITY
GAIN MORE KNOWLEDGE REACH GREATER HEIGHTS
Private University Estd. in Karnataka State by Act No. 41 of 2013

Example: Addition of Noisy Images for Noise Reduction

- In astronomy, imaging under very low light levels frequently causes sensor noise to render single images virtually useless for analysis.

- In astronomical observations, similar sensors for noise reduction by observing the same scene over long periods of time. Image averaging is then used to reduce the noise.

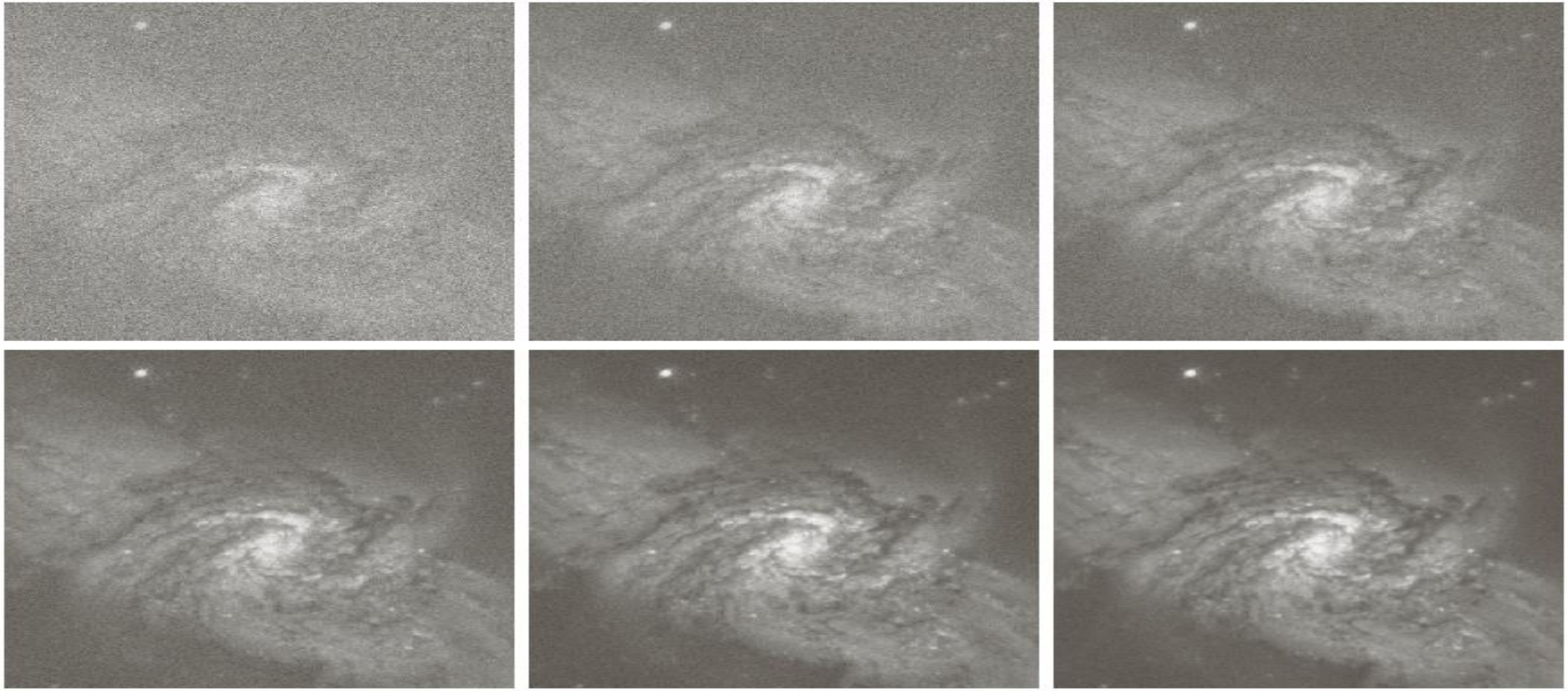


FIGURE 2.26 (a) Image of Galaxy Pair NGC 3314 corrupted by additive Gaussian noise. (b)–(f) Results of averaging 5, 10, 20, 50, and 100 noisy images, respectively. (Original image courtesy of NASA.)

An Example of Image Subtraction: Mask Mode Radiography

Mask h(x,y): an X-ray image of a region of a patient's body

Live images f(x,y): X-ray images captured at TV rates after injection of the contrast medium

Enhanced detail g(x,y)

$$g(x,y) = f(x,y) - h(x,y)$$

The procedure gives a movie showing how the contrast medium propagates through the various arteries in the area being observed.

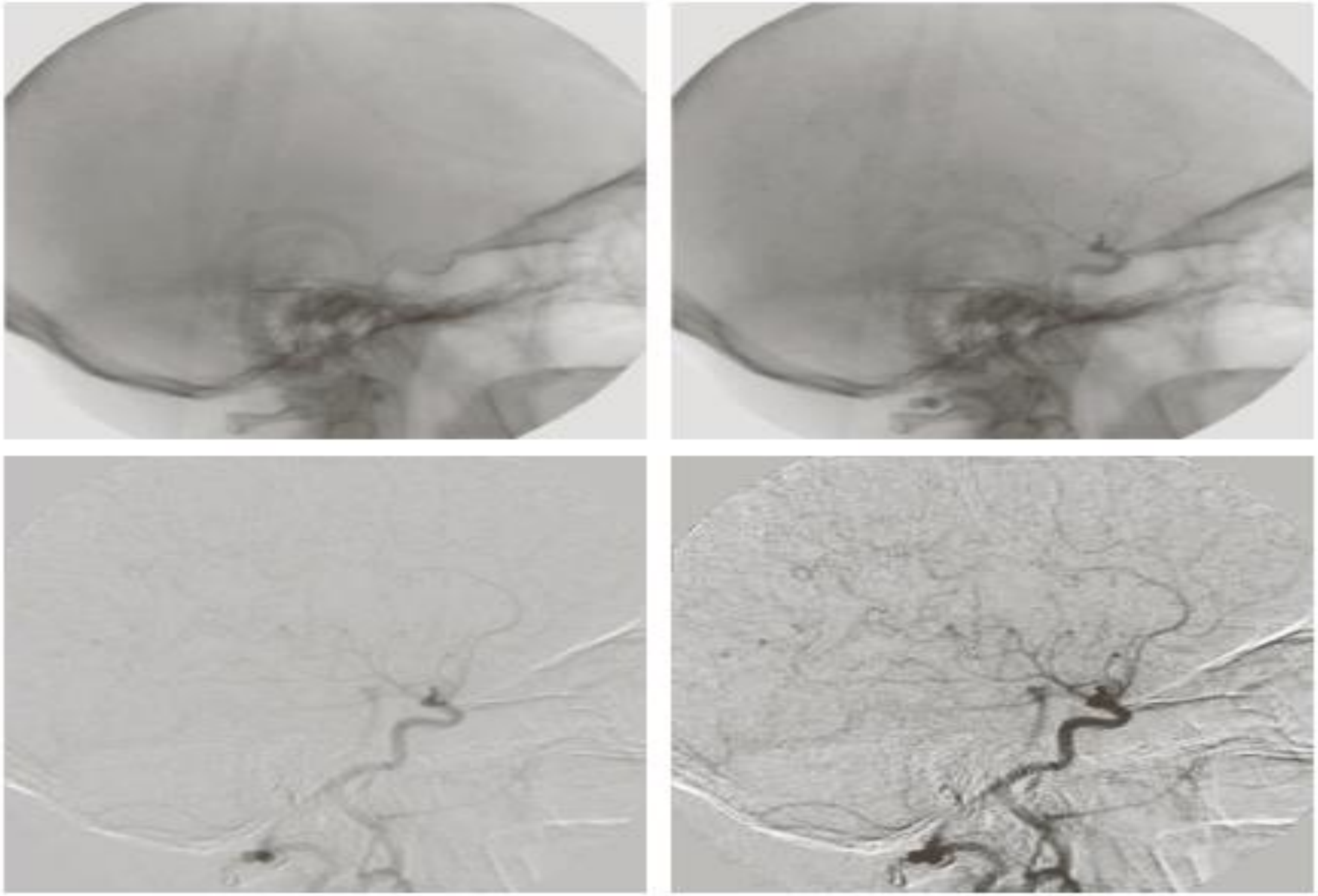


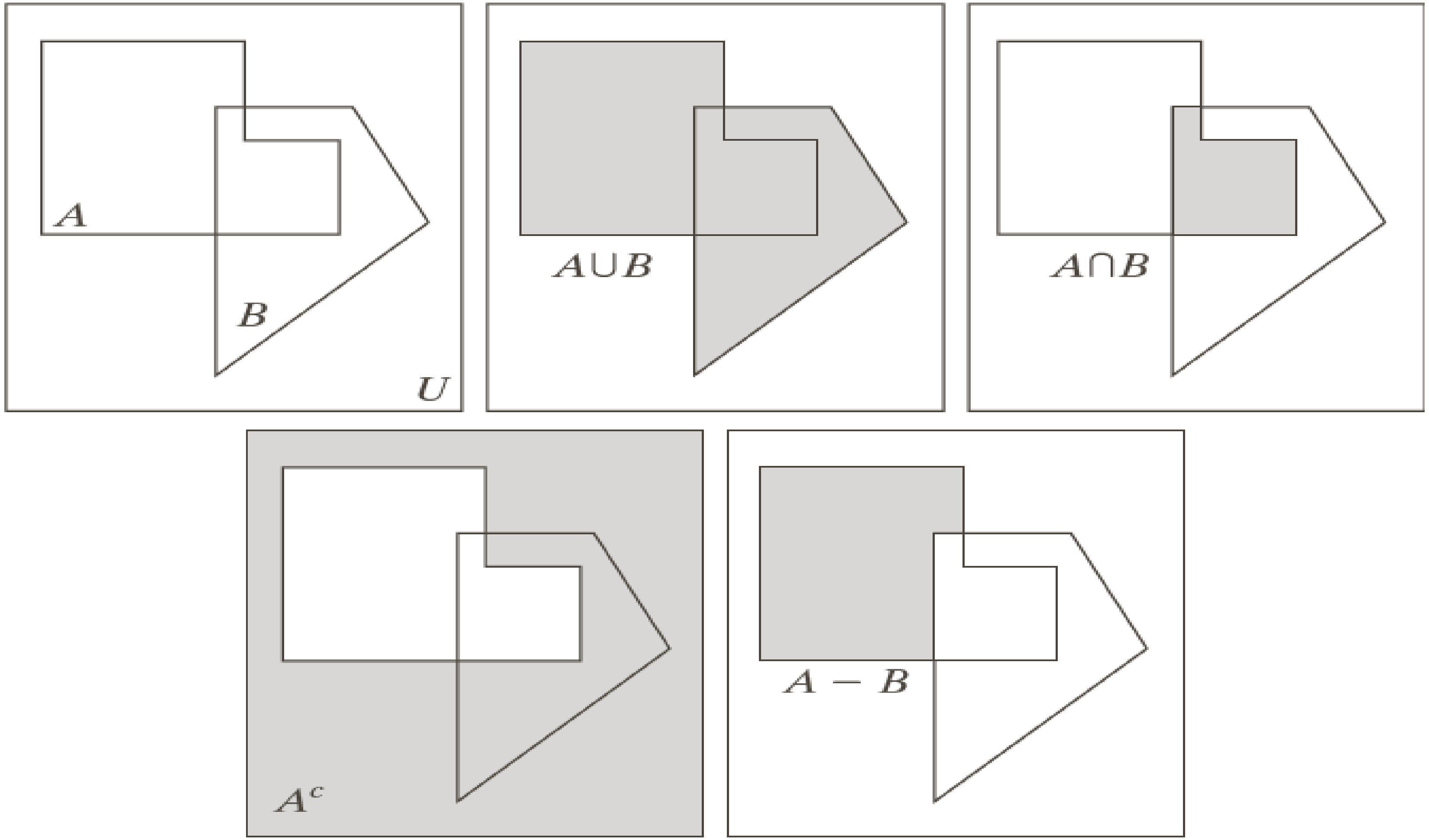
FIGURE 2.28 Digital subtraction angiography. (a) Mask image. (b) A live image. (c) Difference between (a) and (b). (d) Enhanced difference image. (Figures (a) and (b) courtesy of The Image Sciences Institute, University Medical Center, Utrecht, The Netherlands.)

An Example of Image Multiplication

a b c

FIGURE 2.29 Shading correction. (a) Shaded SEM image of a tungsten filament and support, magnified approximately 130 times. (b) The shading pattern. (c) Product of (a) by the reciprocal of (b). (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)

Set and Logical Operations



a b c
d e

FIGURE 2.31
(a) Two sets of coordinates, A and B, in 2-D space. (b) The union of A and B. (c) The intersection of A and B. (d) The complement of A. (e) The difference between A and B. In (b)–(e) the shaded areas represent the member of the set operation indicated.

Set and Logical Operations

- Let A be the elements of a gray-scale image

  The elements of A are triplets of the form (x, y, z), where x and y are spatial coordinates and z denotes the intensity at the point (x, y).

$$A = \{(x, y, z) \mid z = f(x, y)\}$$

- The complement of A is denoted A^c

$$A^c = \{(x, y, K - z) \mid (x, y, z) \in A\}$$

$K = 2^k - 1$; k is the number of intensity bits used to represent z

Set and Logical Operations

- The union of two gray-scale images (sets) A and B is defined as the set

$$A \cup B = \{\max_{z}(a,b) \mid a \in A, b \in B\}$$

Set and Logical Operations

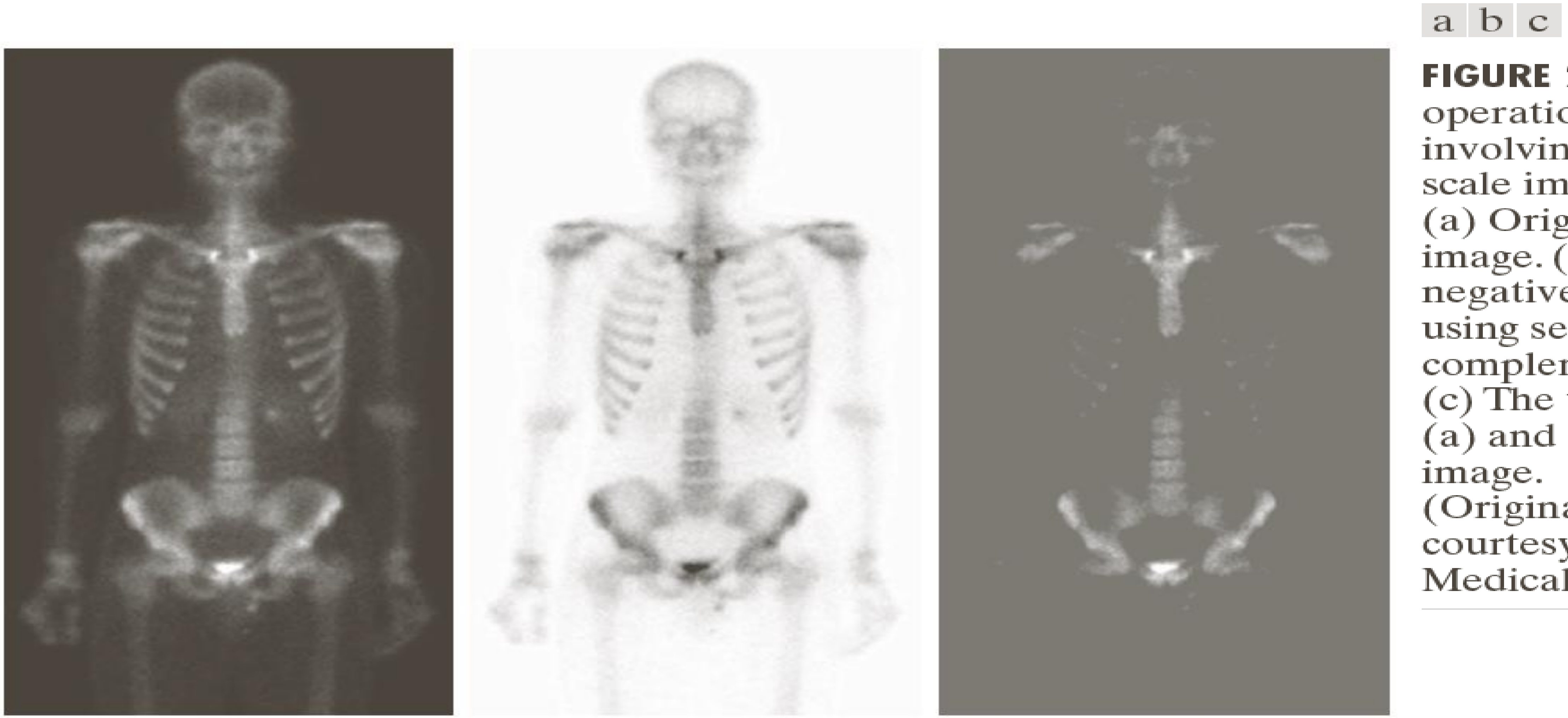


FIGURE 2.32 Set operations involving gray-scale images. (a) Original image. (b) Image negative obtained using set complementation. (c) The union of (a) and a constant image. (Original image courtesy of G.E. Medical Systems.)

Set and Logical Operations

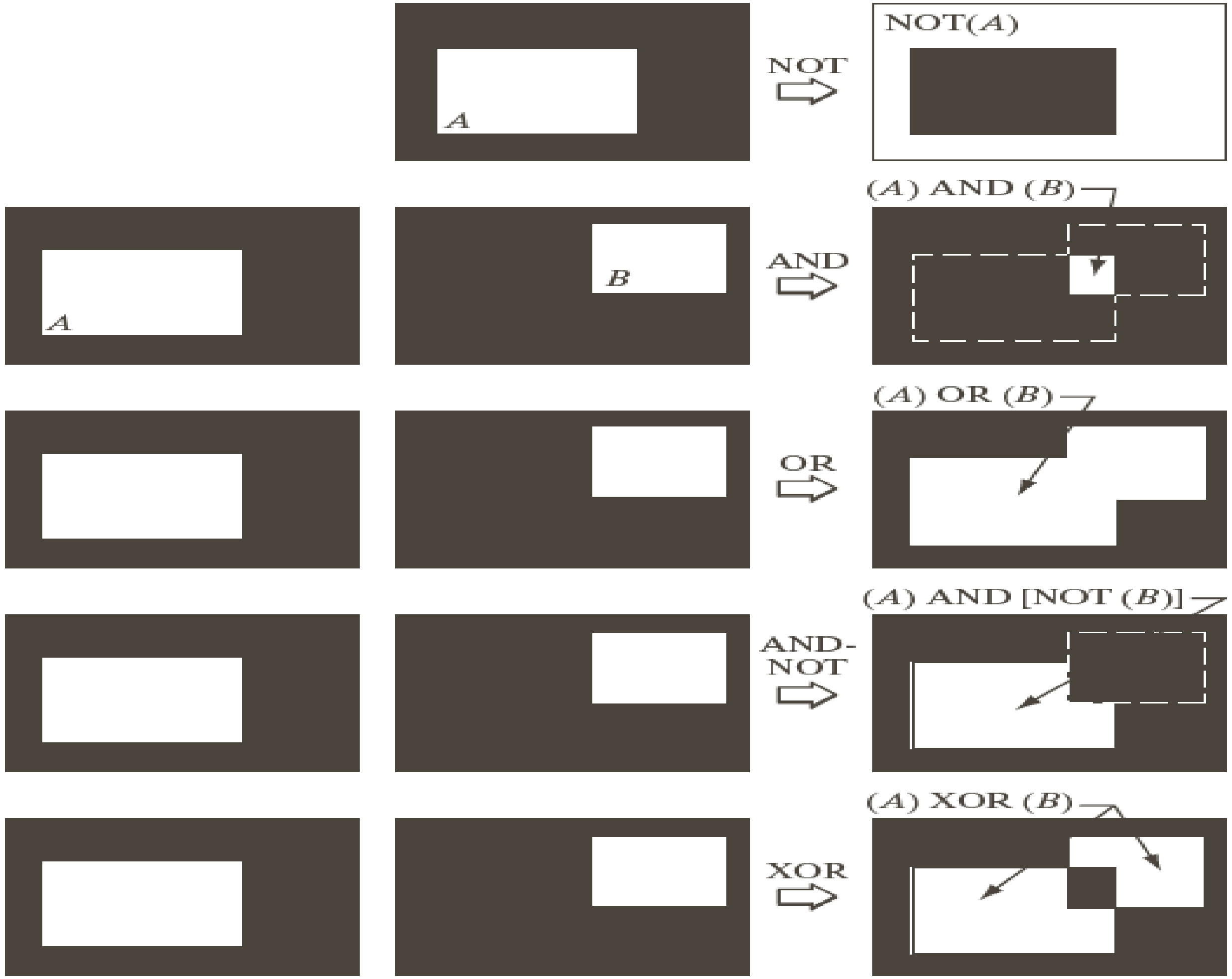


FIGURE 2.33 Illustration of logical operations involving foreground (white) pixels. Black represents binary 0s and white binary 1s. The dashed lines are shown for reference only. They are not part of the result.

Spatial Operations

- Single-pixel operations

  Alter the values of an image's pixels based on the intensity.

$$s = T(z)$$

e.g.,

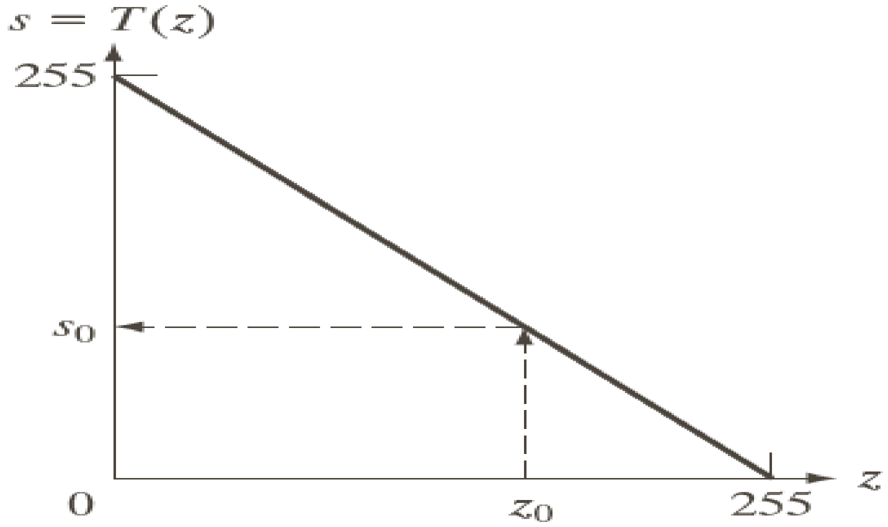
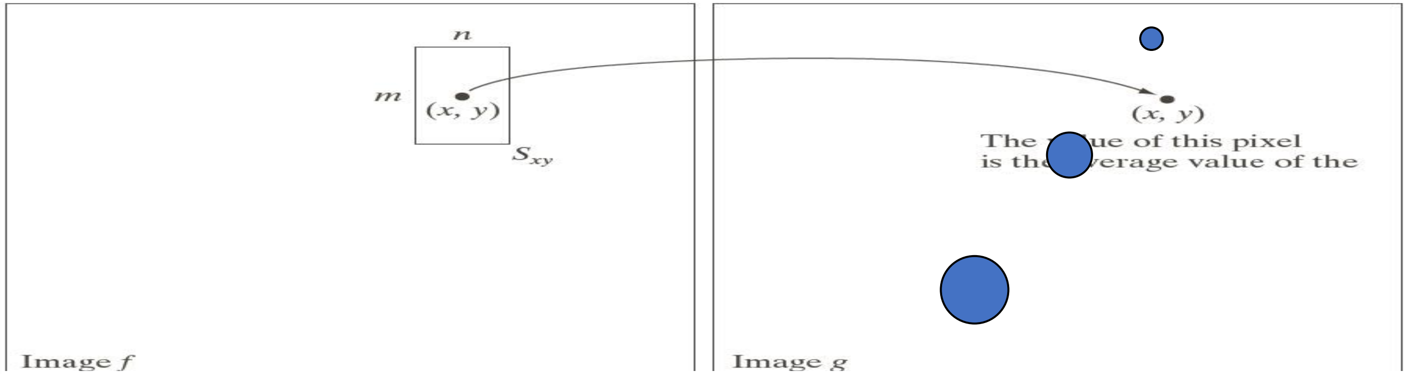


FIGURE 2.34 Intensity transformation function used to obtain the negative of an 8-bit image. The dashed arrows show transformation of an arbitrary input intensity value z_0 into its corresponding output value s_0.

Spatial Operations

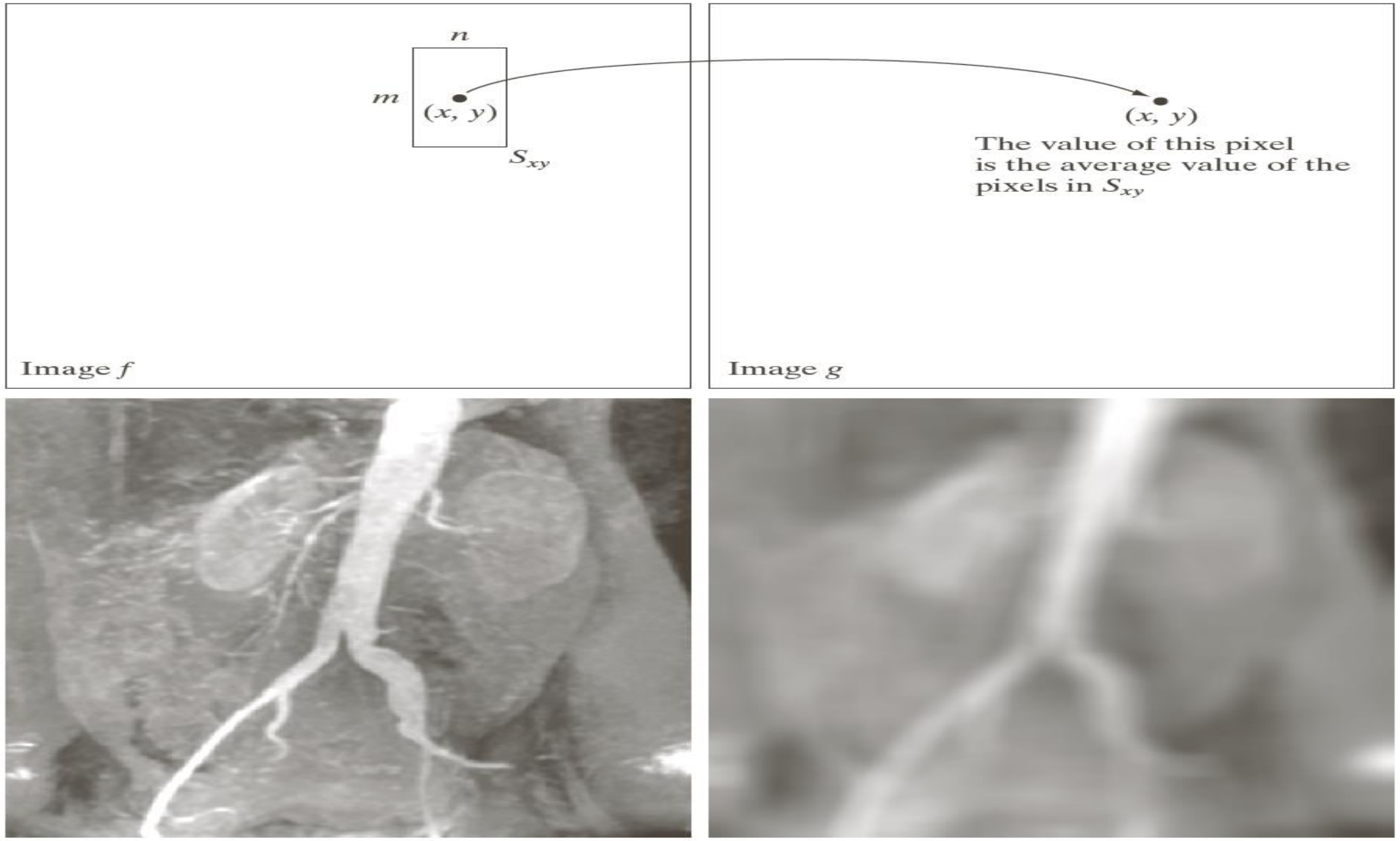
- Neighborhood operations



The value of this pixel is determined by a specified operation involving the pixels in the input image with coordinates in S_{xy}

Spatial Operations

- Neighborhood operations



Geometric Spatial Transformations

- Geometric transformation (rubber-sheet transformation)

  — A spatial transformation of coordinates

$$(x, y) = T\{(v, w)\}$$

  — intensity interpolation that assigns intensity values to the spatially transformed pixels.

- Affine transform

$$[x \quad y \quad 1] = [v \quad w \quad 1]\begin{bmatrix} t_{11} & t_{12} & 0 \\ t_{21} & t_{22} & 0 \\ t_{31} & t_{32} & 1 \end{bmatrix}$$

TABLE 2.2
Affine transformations based on Eq. (2.6.–23).

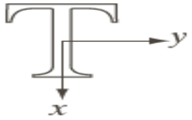
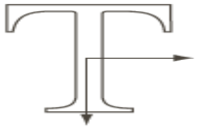
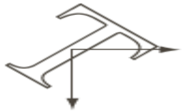
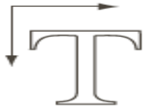
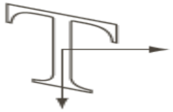
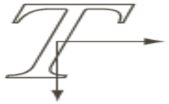
Transformation Name	Affine Matrix, T	Coordinate Equations	Example
Identity	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = w$	
Scaling	$\begin{bmatrix} c_x & 0 & 0 \\ 0 & c_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = c_x v$ $y = c_y w$	
Rotation	$\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v\cos\theta - w\sin\theta$ $y = v\cos\theta + w\sin\theta$	
Translation	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix}$	$x = v + t_x$ $y = w + t_y$	
Shear (vertical)	$\begin{bmatrix} 1 & 0 & 0 \\ s_v & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v + s_v w$ $y = w$	
Shear (horizontal)	$\begin{bmatrix} 1 & s_h & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = s_h v + w$	

Image Registration

- Input and output images are available but the transformation function is unknown.

  Goal: estimate the transformation function and use it to register the two images.

- One of the principal approaches for image registration is to use ***tie points*** (also called ***control points***)

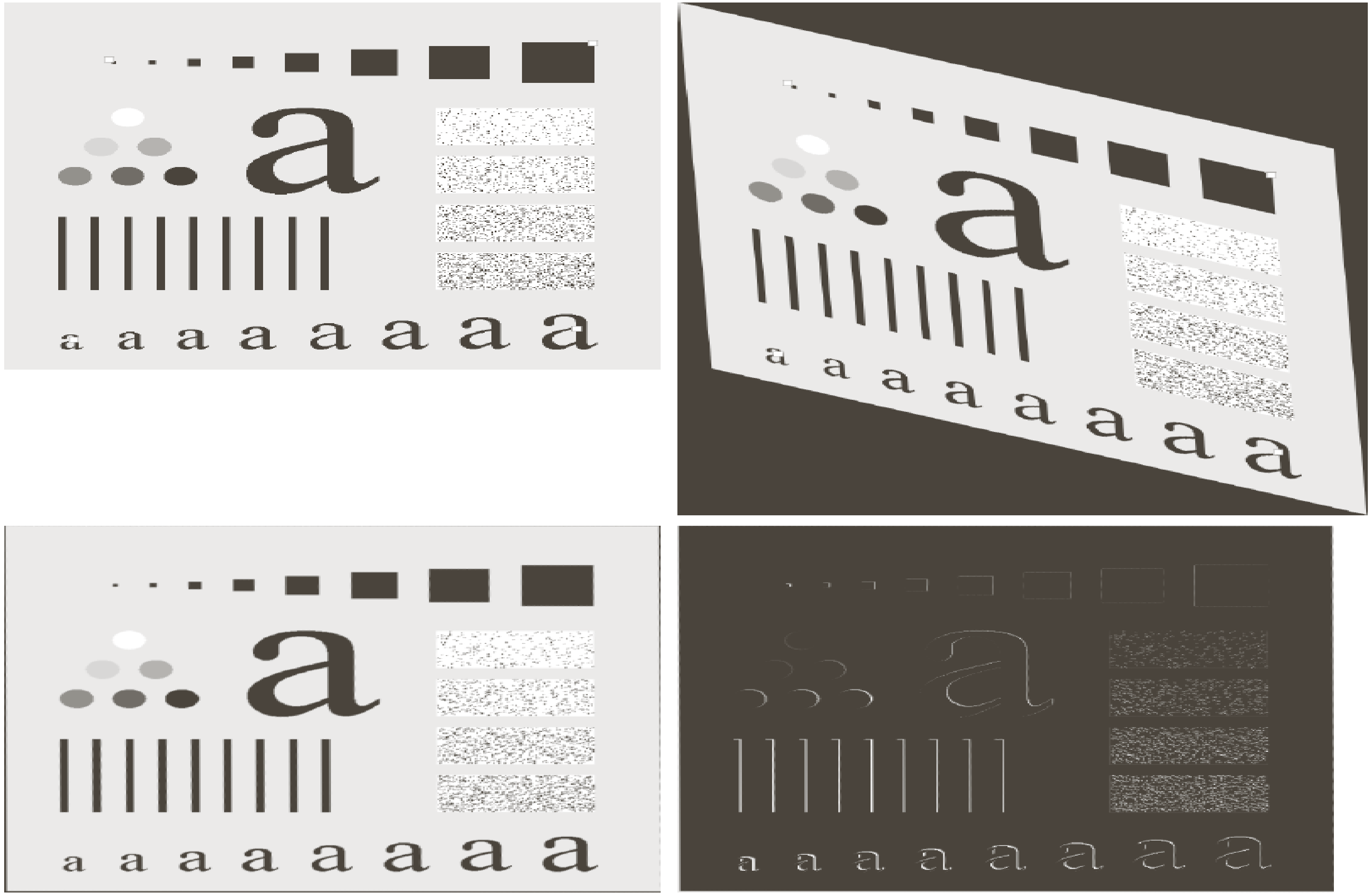
➢ The corresponding points are known precisely in the input and output (**reference**) images.

Image Registration

- A simple model based on bilinear approximation:

$$\begin{cases} x = c_1 v + c_2 w + c_3 vw + c_4 \\ y = c_5 v + c_6 w + c_7 vw + c_8 \end{cases}$$

Where (v, w) and (x, y) are the coordinates of tie points in the input and reference images.



a b
c d

FIGURE 2.37 Image registration. (a) Reference image. (b) Input (geometrically distorted image). Corresponding tie points are shown as small white squares near the corners. (c) Registered image (note the errors in the borders). (d) Difference between (a) and (c), showing more registration errors.

Image Transformation

- Enhancement Techniques
  - Spatial
    Operates on pixels
  - Frequency Domain
    Operates on FT of Image

Image Enhancement Definition

- **Image Enhancement:** is the process that improves the quality of the image for a specific application

Image Enhancement Methods

- **Spatial Domain Methods (Image Plane)**

  Techniques are based on direct manipulation of pixels in an image

- **Frequency Domain Methods**

  Techniques are based on modifying the Fourier transform of the image.

- **Combination Methods**

  There are some enhancement techniques based on various combinations of methods from the first two categories

Spatial Domain Methods

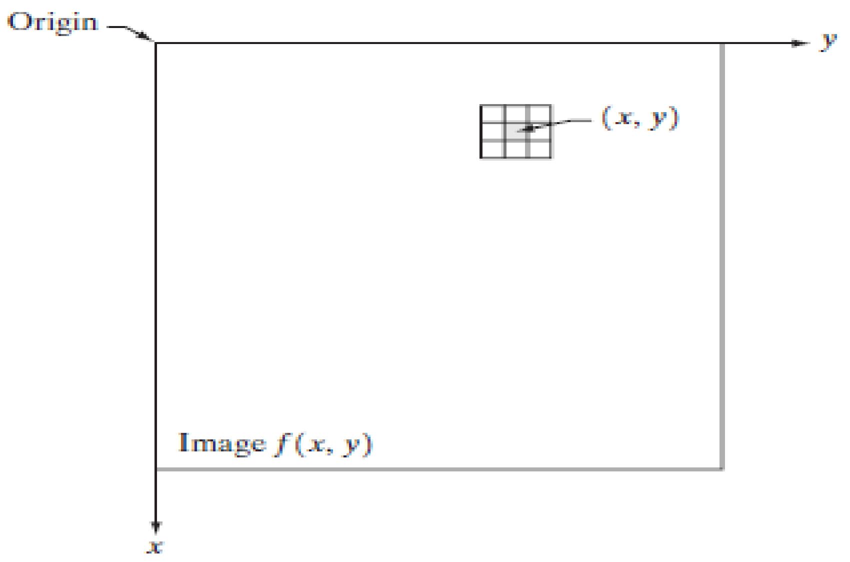
- As indicated previously, the term *spatial domain* refers to the aggregate of pixels composing an image. Spatial domain methods are procedures that operate directly on these pixels. Spatial domain processes will be denoted by the expression:

  $g(x,y) = \boldsymbol{T}\,[f(x,y)]$

  Where f(x,y) in the input image, g(x,y) is the processed image and ***T*** is as operator on f, defined over some neighborhood of (x,y)

- In addition, ***T*** can operate on a set of input images.

FIGURE 3.1 A 3×3 neighborhood about a point (x, y) in an image.



- The simplest form of ***T***, is when the neighborhood of size 1X1 (that is a single pixel). In this case, g depends only on the value of f at (x,y), and ***T*** becomes a *grey-level* (also called *intensity* or *mapping*) *transformation function* of the form:

$$s = T\,(r)$$

Where, for simplicity in notation, r and s are variables denoting, respectively, the grey level of f(x,y) and g(x,y) at any point (x,y)

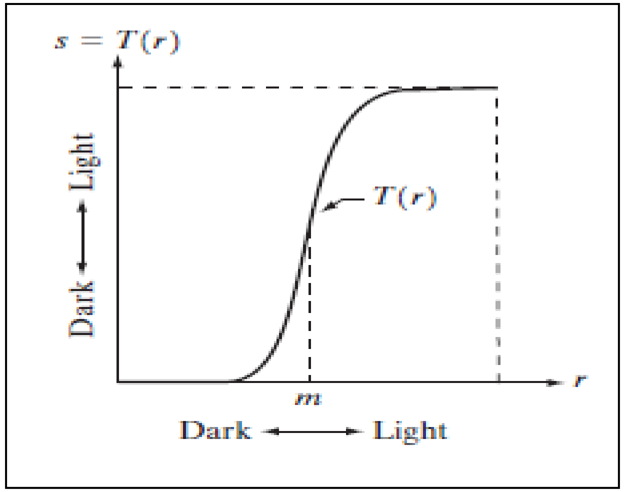
Examples of Enhancement Techniques

- **Contrast Stretching**:

If T(r) has the form as shown in the figure below, the effect of applying the transformation to every pixel of f to generate the corresponding pixels in g would:

Produce higher contrast than the original image, by:

- Darkening the levels below m in the original image
- Brightening the levels above m in the original image

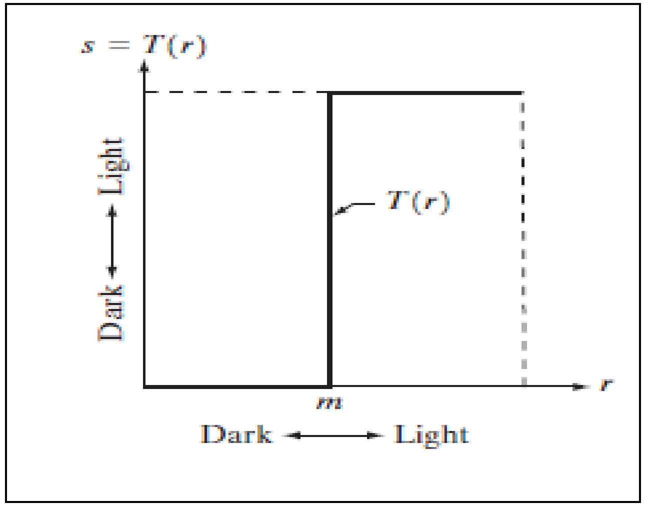


So, Contrast Stretching: is a simple image enhancement technique that improves the contrast in an image by 'stretching' the range of intensity values it contains to span a desired range of values. Typically, it uses a linear function

Examples of Enhancement Techniques

- **Thresholding**

Is a limited case of contrast stretching, it produces a two-level (binary) image.



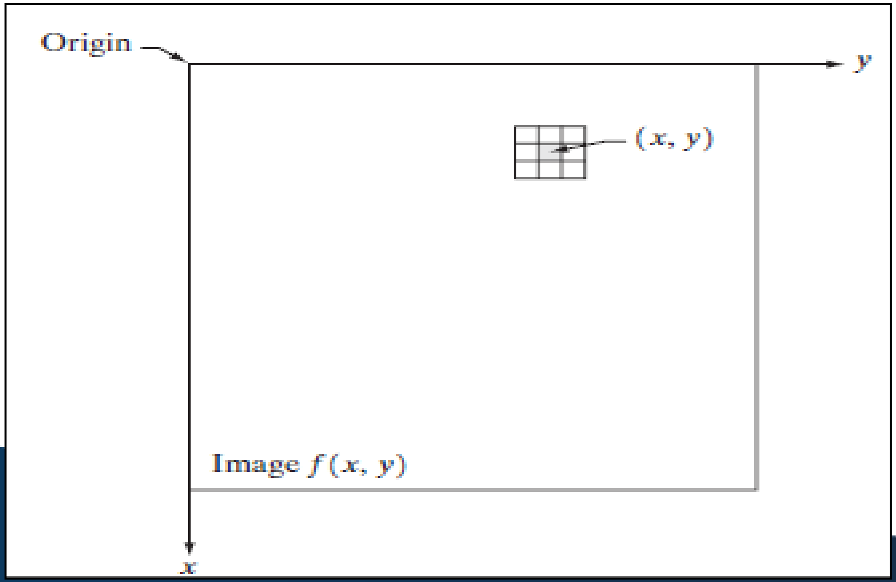
Some fairly simple, yet powerful, processing approaches can be formulated with grey-level transformations. Because enhancement at any point in an image depends only on the gray level at that point, techniques in this category often are referred to as *point processing*.

Examples of Enhancement Techniques

Larger neighborhoods allow considerable more flexibility. The general approach is to use a function of the values of *f* in a predefined neighborhood of (x,y) to determine the value of *g* at (x,y).

One of the principal approaches in this formulation is based on the use of so-called *masks* (also referred to as *filters*)

So, a mask/filter: is a small (say 3X3) 2-D array, such as the one shown in the figure, in which the values of the mask coefficients determine the nature of the process, such as *image sharpening*. Enhancement techniques based on this type of approach often are referred to as *mask processing* or *filtering*.



Some Basic Intensity (Gray-level) Transformation Functions

- Grey-level transformation functions (also called, intensity functions), are considered the simplest of all image enhancement techniques.
- The value of pixels, before an after processing, will be denoted by *r* and *s*, respectively. These values are related by the expression of the form:

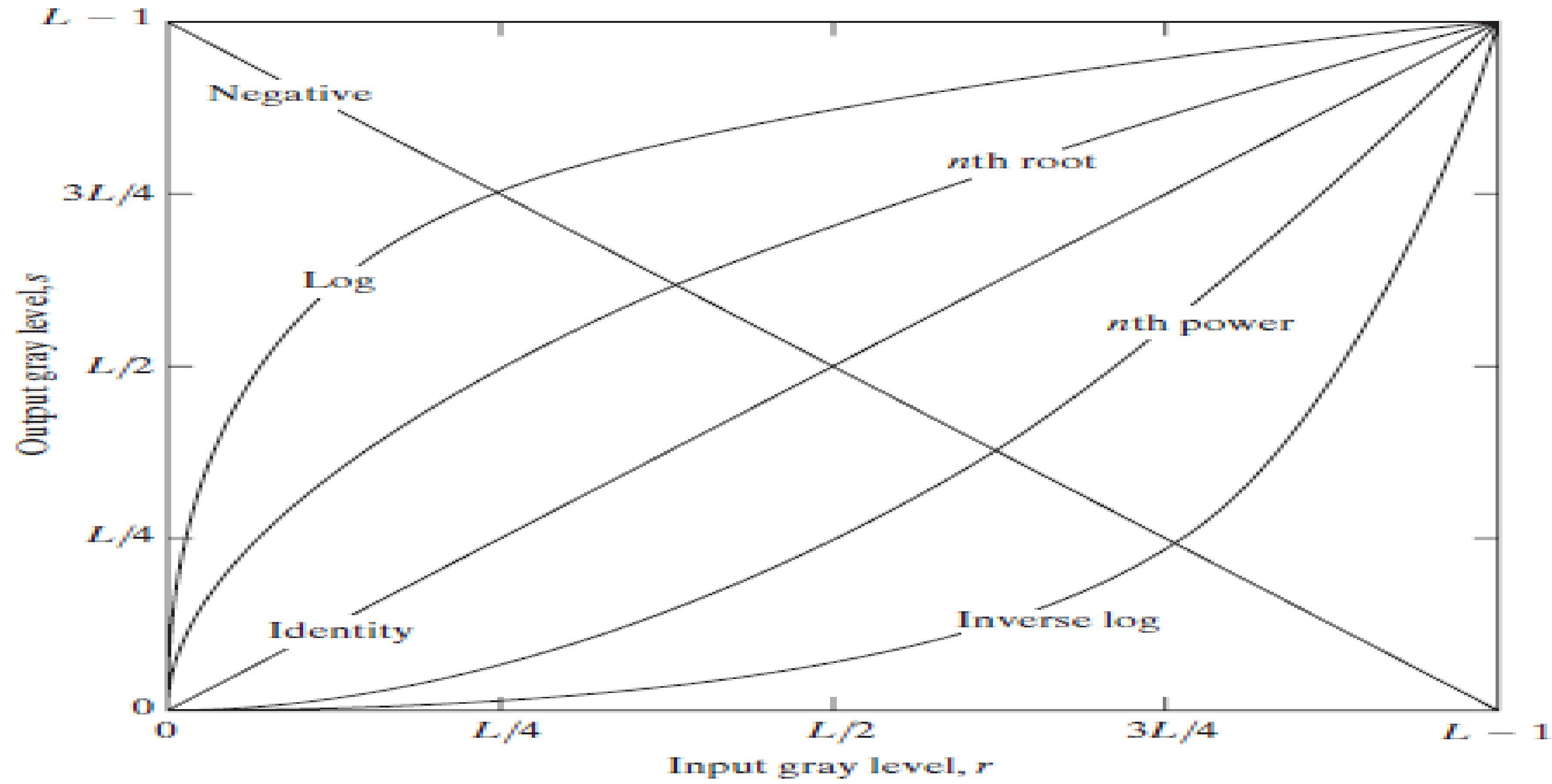
$$s = T(r)$$

where T is a transformation that maps a pixel value r into a pixel value s.

Some Basic Intensity (Gray-level) Transformation Functions

Consider the following figure, which shows three basic types of functions used frequently for image enhancement:

FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.



Some Basic Intensity (Gray-level) Transformation Functions

- The three basic types of functions used frequently for image enhancement:
  - Linear Functions:
    - Negative Transformation
    - Identity Transformation
  - Logarithmic Functions:
    - Log Transformation
    - Inverse-log Transformation
  - Power-Law Functions:
    - n^{th} power transformation
    - n^{th} root transformation

Linear Functions

- **Identity Function**
  - Output intensities are identical to input intensities
  - This function doesn't have an effect on an image, it was included in the graph only for completeness
  - Its expression:

    $\mathbf{s = r}$

Linear Functions

- **Image Negatives (Negative Transformation)**
  - The negative of an image with gray level in the range [0, L-1], where L = Largest value in an image, is obtained by using the negative transformation's expression:

$$s = L - 1 - r$$

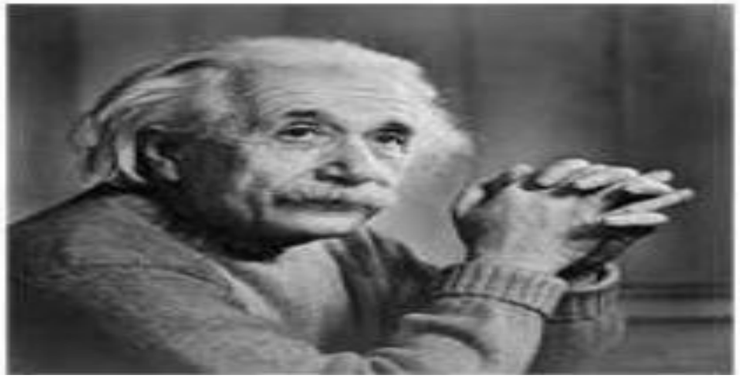
  Which reverses the intensity levels of an input image, in this manner produces the equivalent of a photographic negative.

  - The negative transformation is suitable for enhancing white or gray detail embedded in dark regions of an image, especially when the black area are dominant in size

NEGATIVE TRANSFORMATION EXAMPLE

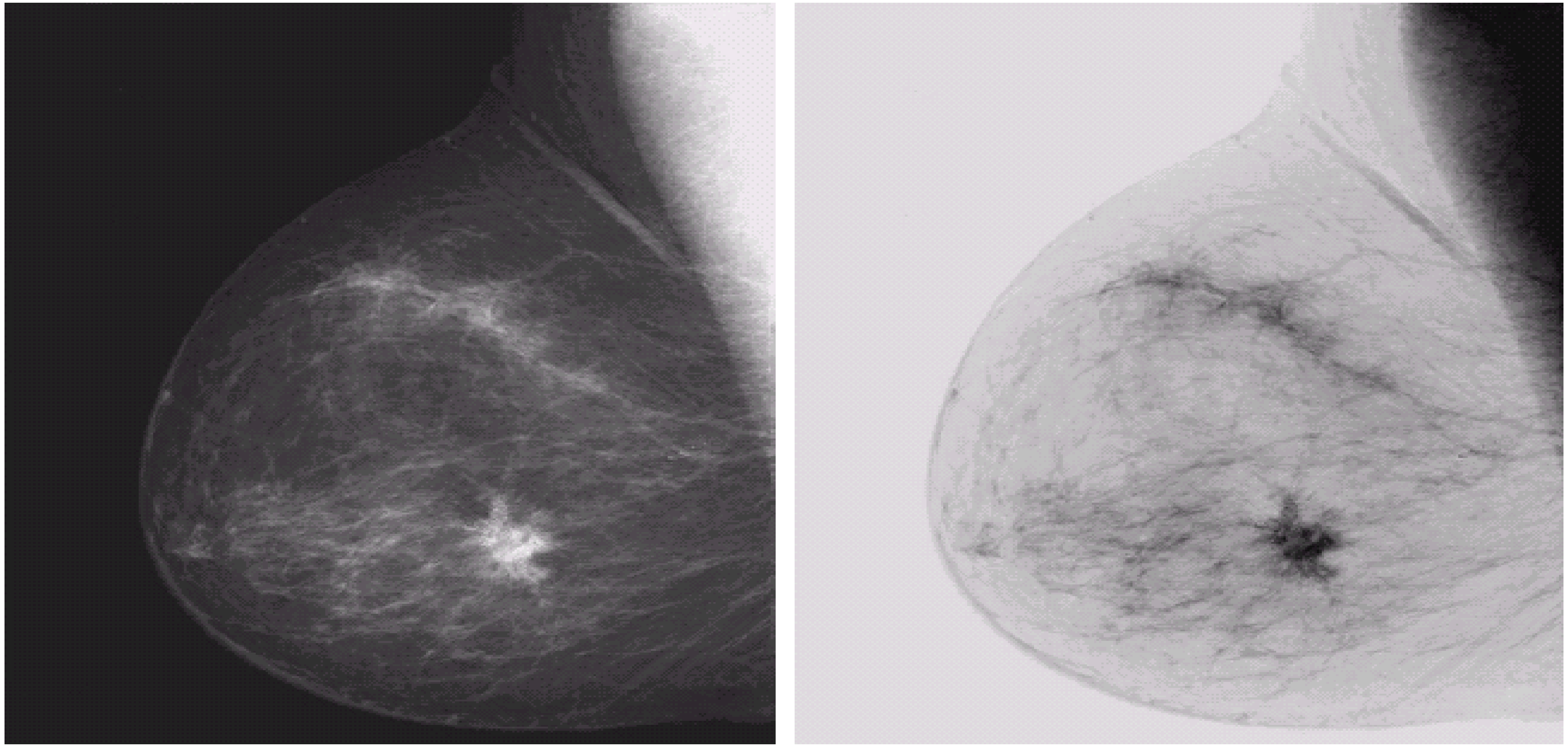
Graph representation

Input image



Output image

Image Negative



a b

FIGURE 3.4
(a) Original digital mammogram.
(b) Negative image obtained using the negative transformation in Eq. (3.2-1).
(Courtesy of G.E. Medical Systems.)

Image Negative: $s = L - 1 - r$

Logarithmic Transformations

- **Log Transformation**

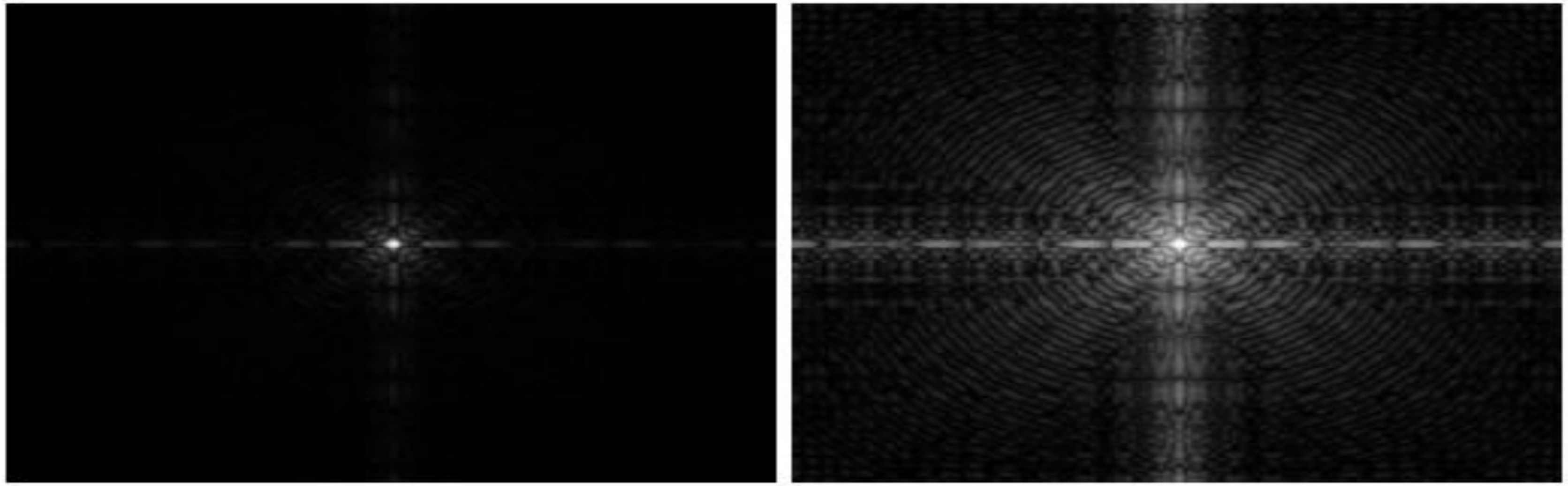
  The general form of the log transformation:

  $$s = c \log (1+r)$$

  Where c is a constant, and $r \geq 0$

  - Log curve maps a narrow range of low gray-level values in the input image into a wider range of the output levels.
  - Used to expand the values of dark pixels in an image while compressing the higher-level values.
  - It compresses the dynamic range of images with large variations in pixel values.

Logarithmic Transformations



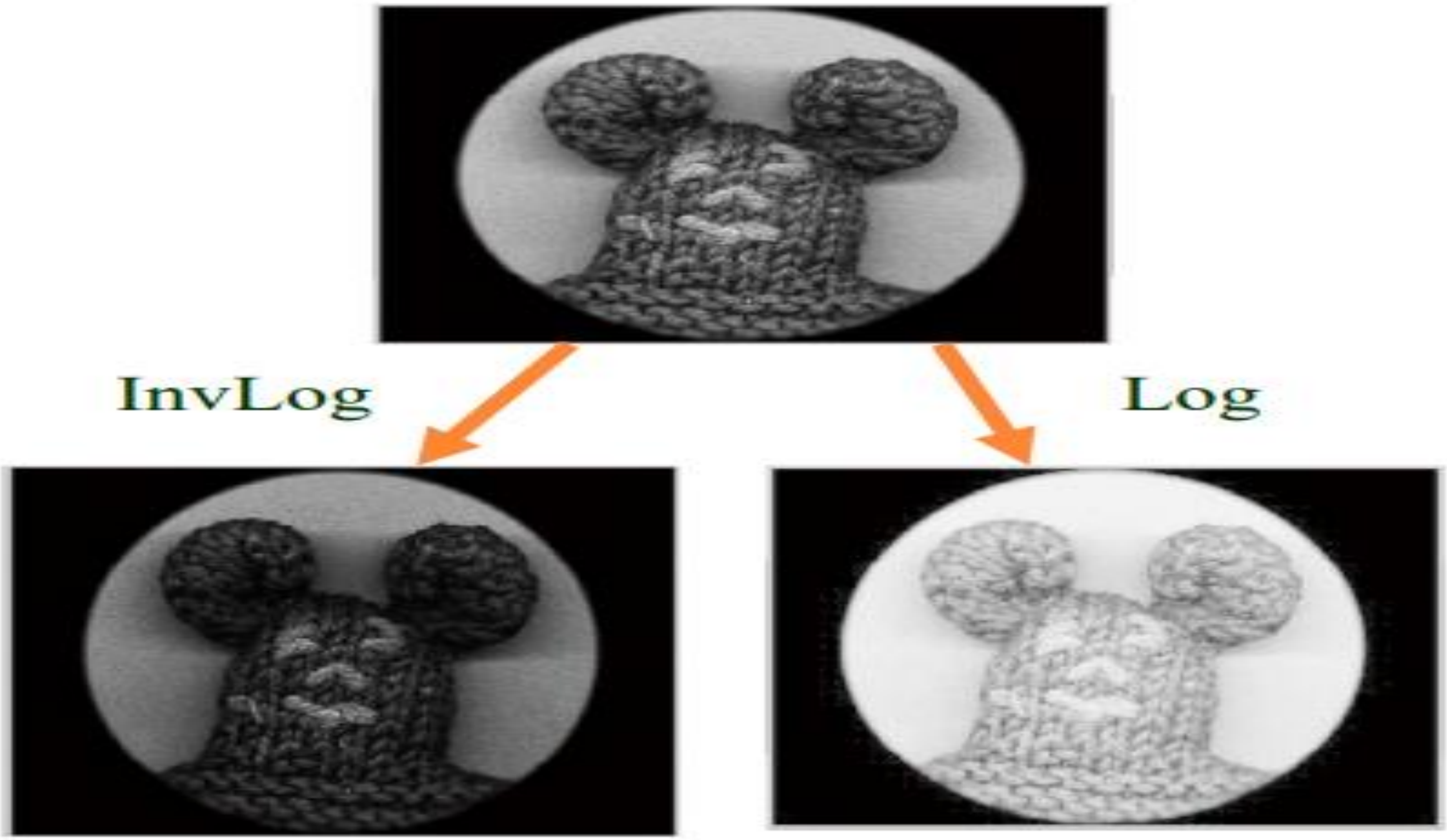
a b

FIGURE 3.5 (a) Fourier spectrum. (b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.

Logarithmic Transformations

- **Inverse Logarithm Transformation**
  - Do opposite to the log transformations
  - Used to expand the values of high pixels in an image while compressing the darker-level values.

LOG TRANSFORMATION EXAMPLE



Power-Law Transformations

- Power-law transformations have the basic form of:

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

  Where c and γ are positive constants

Power-Law Transformations

- Different transformation curves are obtained by varying γ (gamma)

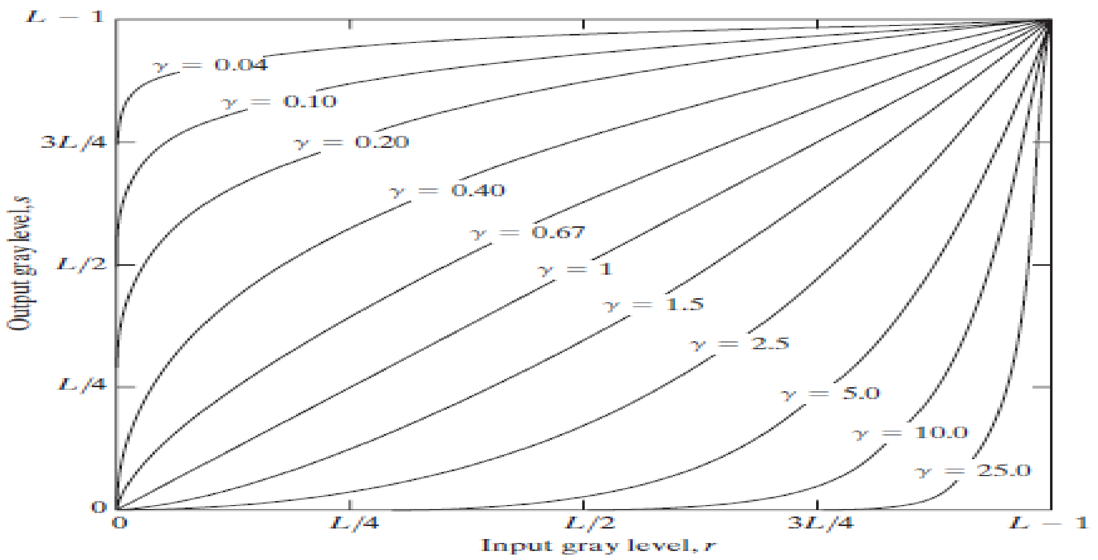


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

Power-Law Transformations

- Variety of devices used for image capture, printing and display respond according to a power law. The process used to correct this power-law response phenomena is called ***gamma correction***.

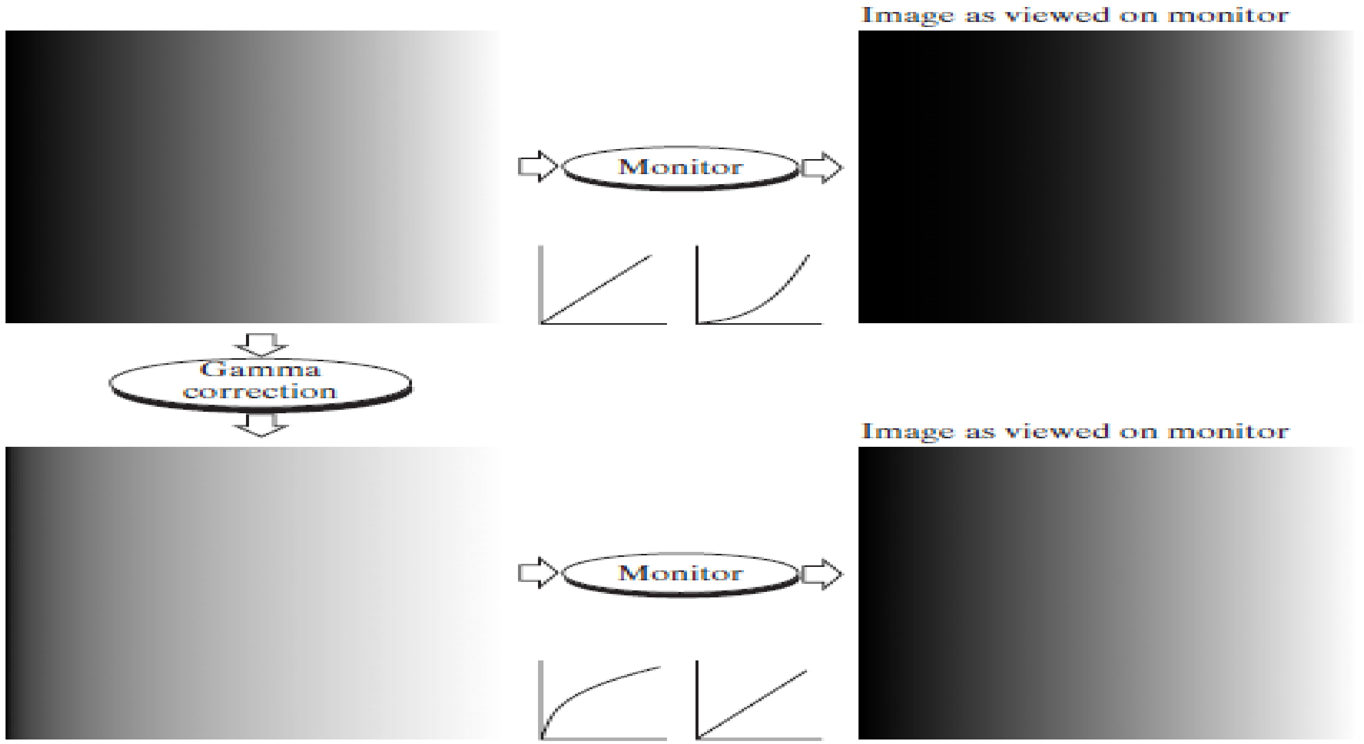
  For example, cathode ray tube (CRT) devices have an intensity-to-voltage response that is a power function, with exponents varying from approximately 1.8 to 2.5.With reference to the curve for g=2.5 in Fig. 3.6, we see that such display systems would tend to produce images that are darker than intended. This effect is illustrated in Fig. 3.7. Figure 3.7(a) shows a simple gray-scale linear wedge input into a CRT monitor. As expected, the output of the monitor appears darker than the input, as shown in Fig. 3.7(b). Gamma correction

  in this case is straightforward. All we need to do is preprocess the input image before inputting it into the monitor by performing the transformation. The result is shown in Fig. 3.7(c).When input into the same monitor, this gamma-corrected input produces an output that is close in appearance to the original image, as shown in Fig. 3.7(d).

Power-Law Transformation

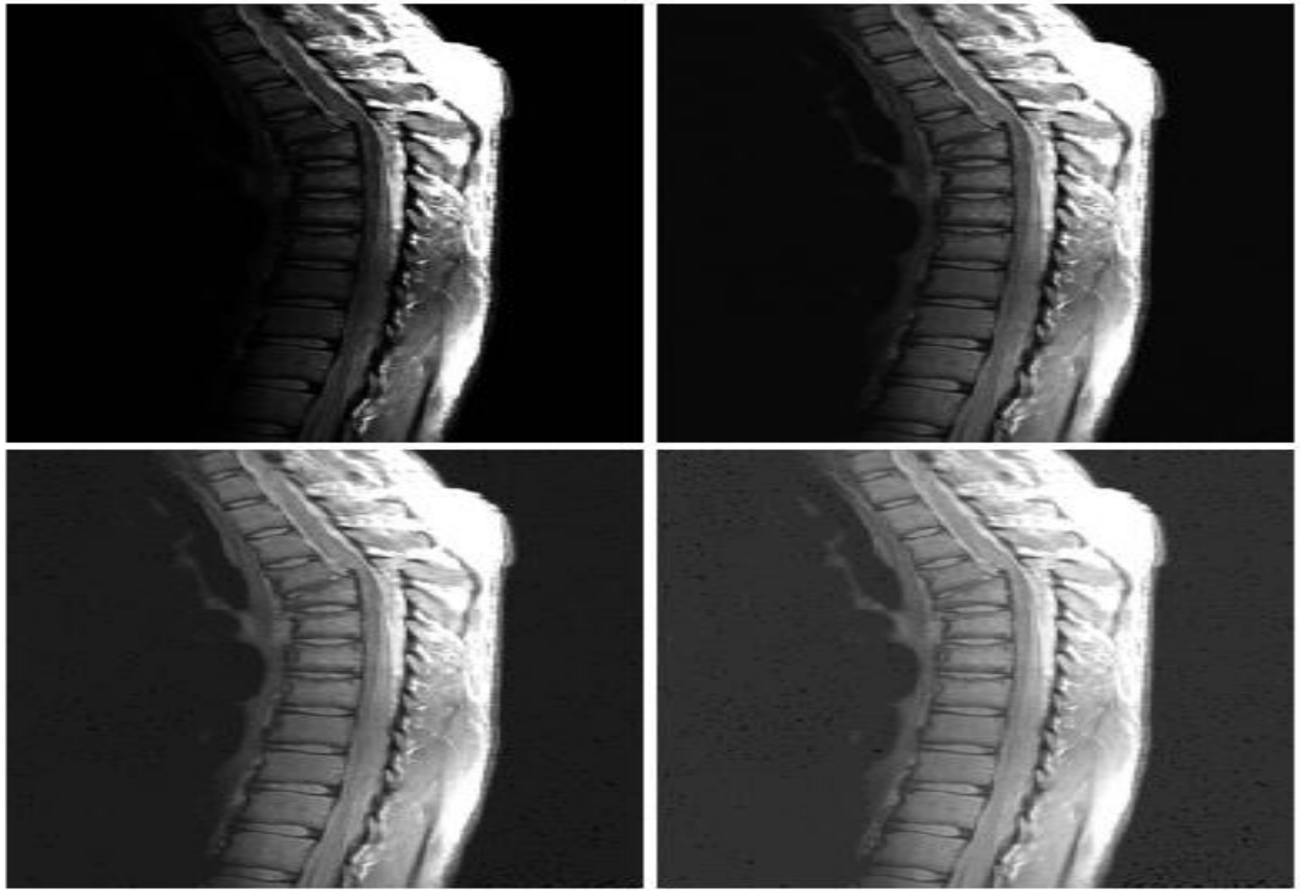
a b
c d

FIGURE 3.7
(a) Linear-wedge gray-scale image.
(b) Response of monitor to linear wedge.
(c) Gamma-corrected wedge.
(d) Output of monitor.



Power-Law Transformation

- In addition to gamma correction, power-law transformations are useful for general-purpose contrast manipulation. See figure 3.8



a b
c d

FIGURE 3.8 (a) Magnetic resonance (MR) image of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4,$ and 0.3, respectively. (Original image for this example courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Power-Law Transformation

- Another illustration of Power-law transformation

a b
c d

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 TRANSFORMATION EXAMPLE

Gamma=10

Gamma=8

Gamma=6

Piecewise-Linear Transformation Functions

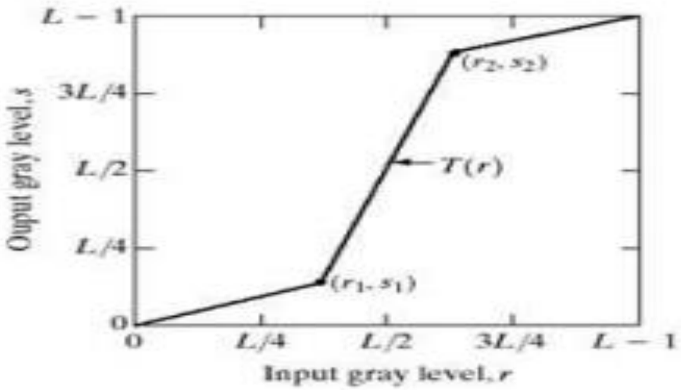
- **Principle Advantage:** Some important transformations can be formulated only as a piecewise function.
- **Principle Disadvantage:** Their specification requires more user input that previous transformations
- **Types of Piecewise transformations are:**
  - Contrast Stretching
  - Gray-level Slicing
  - Bit-plane slicing

Contrast Stretching

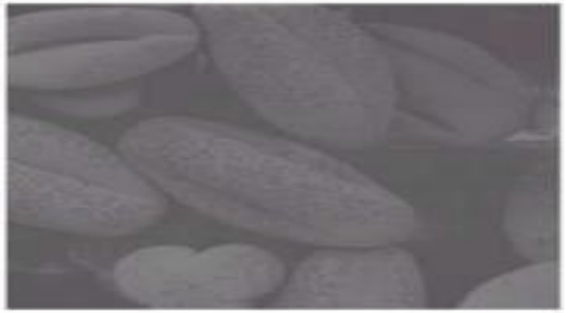
- One of the simplest piecewise linear functions is a contrast-stretching transformation, which is used to enhance the low contrast images.
- Low contrast images may result from:
  - Poor illumination
  - Wrong setting of lens aperture during image acquisition.

CONTRAST STRETCHING EXAMPLE

Transformation function

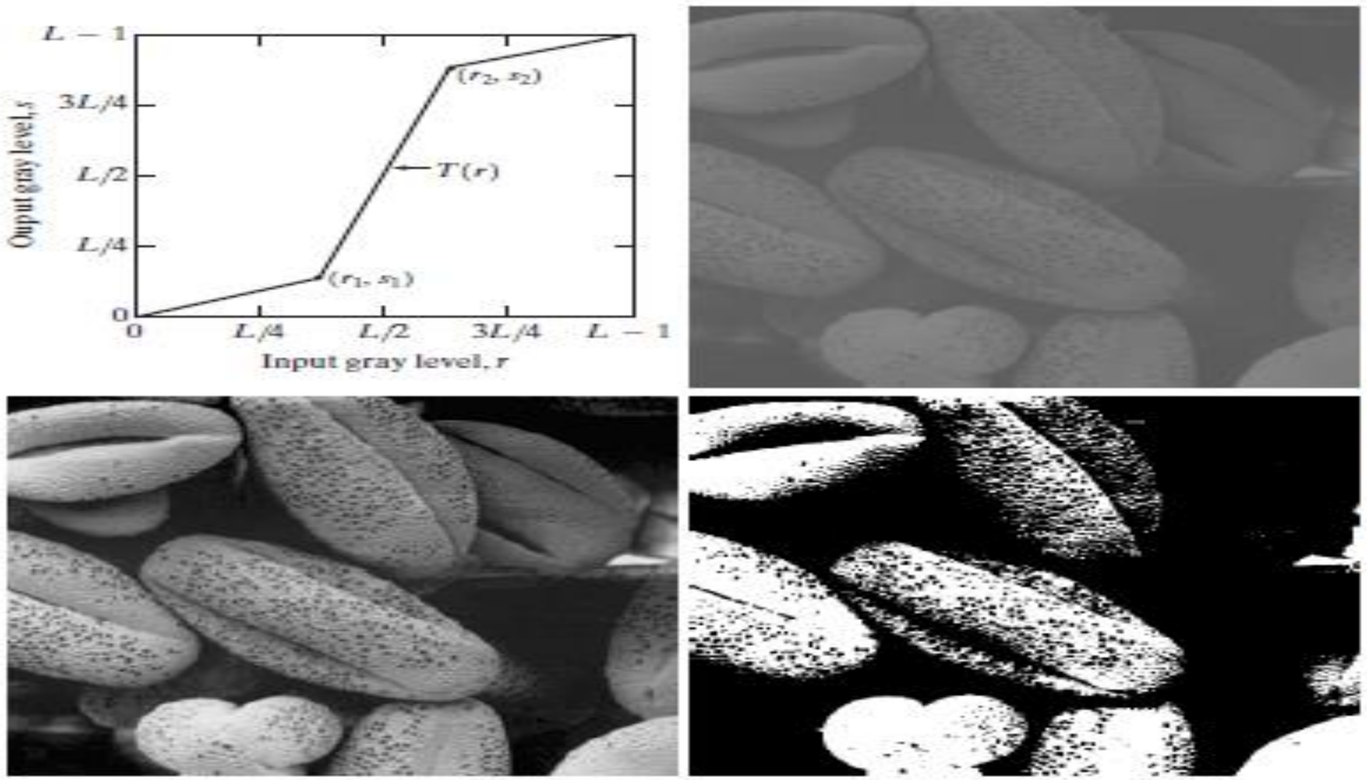


Low contrast image



Contrast stretching image

Contrast Stretching



a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Contrast Stretching

- Figure 3.10(a) shows a typical transformation used for contrast stretching. The locations of points (r1, s1) and (r2, s2) control the shape of the transformation function.
- If r1 = s1 and r2 = s2, the transformation is a linear function that produces no changes in gray levels.
- If r1 = r2, s1 = 0 and s2 = L-1, the transformation becomes a *thresholding function* that creates a binary image. As shown previously in slide 7.
- Intermediate values of (r1, s1) and (r2, s2) produce various degrees of spread in the gray levels of the output image, thus affecting its contrast.
- In general, r1 ≤ r2 and s1 ≤ s2 is assumed, so the function is always increasing.

Contrast Stretching

- Figure 3.10(b) shows an 8-bit image with low contrast.

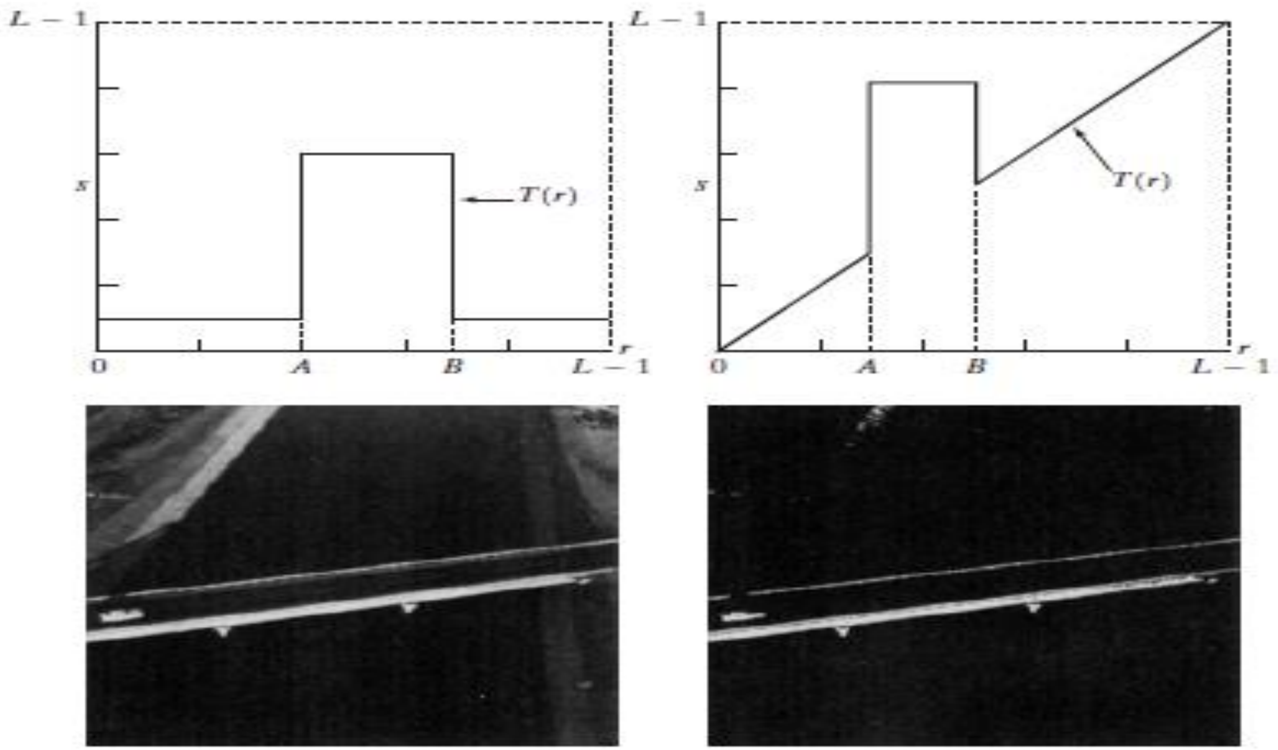
- Fig. 3.10(c) shows the result of contrast stretching, obtained by setting (r1, s1) = (r_{min}, 0) and (r2, s2) = (r_{max},L-1) where r_{min} and r_{max} denote the minimum and maximum gray levels in the image, respectively. Thus, the transformation function stretched the levels linearly from their original range to the full range [0, L-1].

- Finally, Fig. 3.10(d) shows the result of using the *thresholding function* defined previously, with r1=r2=m, the mean gray level in the image.

Gray-level Slicing

- This technique is used to highlight a specific range of gray levels in a given image. It can be implemented in several ways, but the two basic themes are:
  - One approach is to display a high value for all gray levels in the range of interest and a low value for all other gray levels. This transformation, shown in Fig 3.11 (a), produces a binary image.
  - The second approach, based on the transformation shown in Fig 3.11 (b), brightens the desired range of gray levels but preserves gray levels unchanged.
  - Fig 3.11 (c) shows a gray scale image, and fig 3.11 (d) shows the result of using the transformation in Fig 3.11 (a).

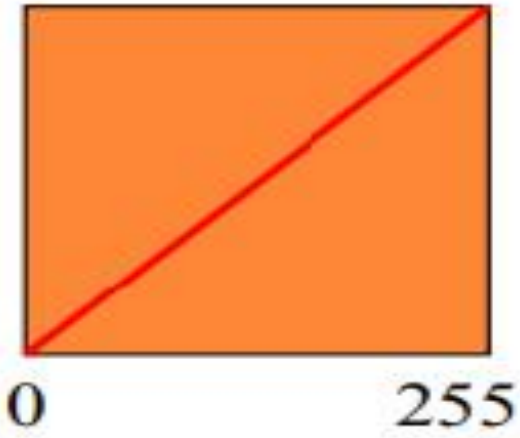
Gray-level Slicing



a b
c d

FIGURE 3.11 (a) This transformation highlights range [A, B] of gray levels and reduces all others to a constant level. (b) This transformation highlights range [A, B] but preserves all other levels. (c) An image. (d) Result of using the transformation in (a).

Input image



Output image

Bit-plane Slicing

- Pixels are digital numbers, each one composed of bits. Instead of highlighting gray-level range, we could highlight the contribution made by each bit.
- This method is useful and used in image compression.

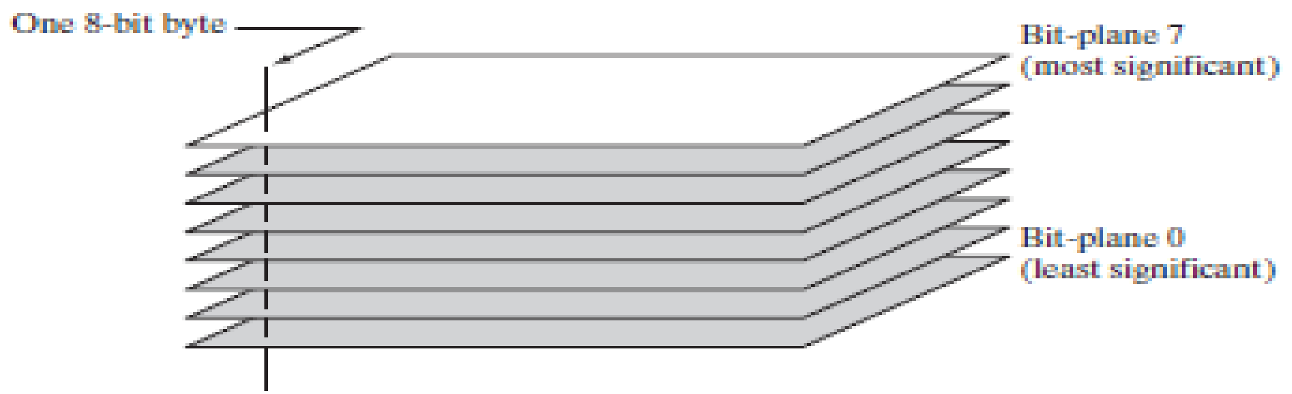


FIGURE 3.12 Bit-plane representation of an 8-bit image.

- Most significant bits contain the majority of visually significant data.

BIT PLANE SLICING EXAMPLE

Original image

Bit plane 7

Bit plane 6

Bit plane 4

Bit plane 1

1. Which of the following expression is used to denote spatial domain process?

a) $g(x,y)=T[f(x,y)]$
b) $f(x+y)=T[g(x+y)]$
c) $g(xy)=T[f(xy)]$
d) $g(x-y)=T[f(x-y)]$

1. Which of the following expression is used to denote spatial domain process?

a) g(x,y)=T[f(x,y)]

b) f(x+y)=T[g(x+y)]

c) g(xy)=T[f(xy)]

d) g(x-y)=T[f(x-y)]

2.Which expression is obtained by performing the negative transformation on the negative of an image with gray levels in the range[0,L-1] ?

a) s=L+1-r

b) s=L+1+r

c) s=L-1-r

d) s=L-1+r

2.Which expression is obtained by performing the negative transformation on the negative of an image with gray levels in the range[0,L-1] ?

a) s=L+1-r

b) s=L+1+r

c) s=L-1-r

d) s=L-1+r

3.What is the general form of representation of log transformation?

a) $s=c\log_{10}(1/r)$

b) $s=c\log_{10}(1+r)$

c) $s=c\log_{10}(1*r)$

d) $s=c\log_{10}(1-r)$

3.What is the general form of representation of log transformation?

a) $s = c\log_{10}(1/r)$

b) $s = c\log_{10}(1+r)$

c) $s = c\log_{10}(1*r)$

d) $s = c\log_{10}(1-r)$

4.What is the general form of representation of power transformation?

a) $s=cr^{\gamma}$

b) $c=sr^{\gamma}$

c) $s=rc$

d) $s=rc^{\gamma}$

4.What is the general form of representation of power transformation?

a) $s=cr^{\gamma}$

b) $c=sr^{\gamma}$

c) $s=rc$

d) $s=rc^{\gamma}$

Image Transform

- A particularly important class of 2-D linear transforms, denoted T(u, v)

$$T(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) r(x,y,u,v)$$

where $f(x,y)$ is the input image,

$r(x,y,u,v)$ is the *forward transformation kernel*,

variables u and v are the transform variables,

u = 0, 1, 2, ..., M-1 and v = 0, 1, ..., N-1.

Image Transform

- Given T(u, v), the original image f(x, y) can be recoverd using the inverse tranformation of T(u, v).

$$f(x,y) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} T(u,v) s(x,y,u,v)$$

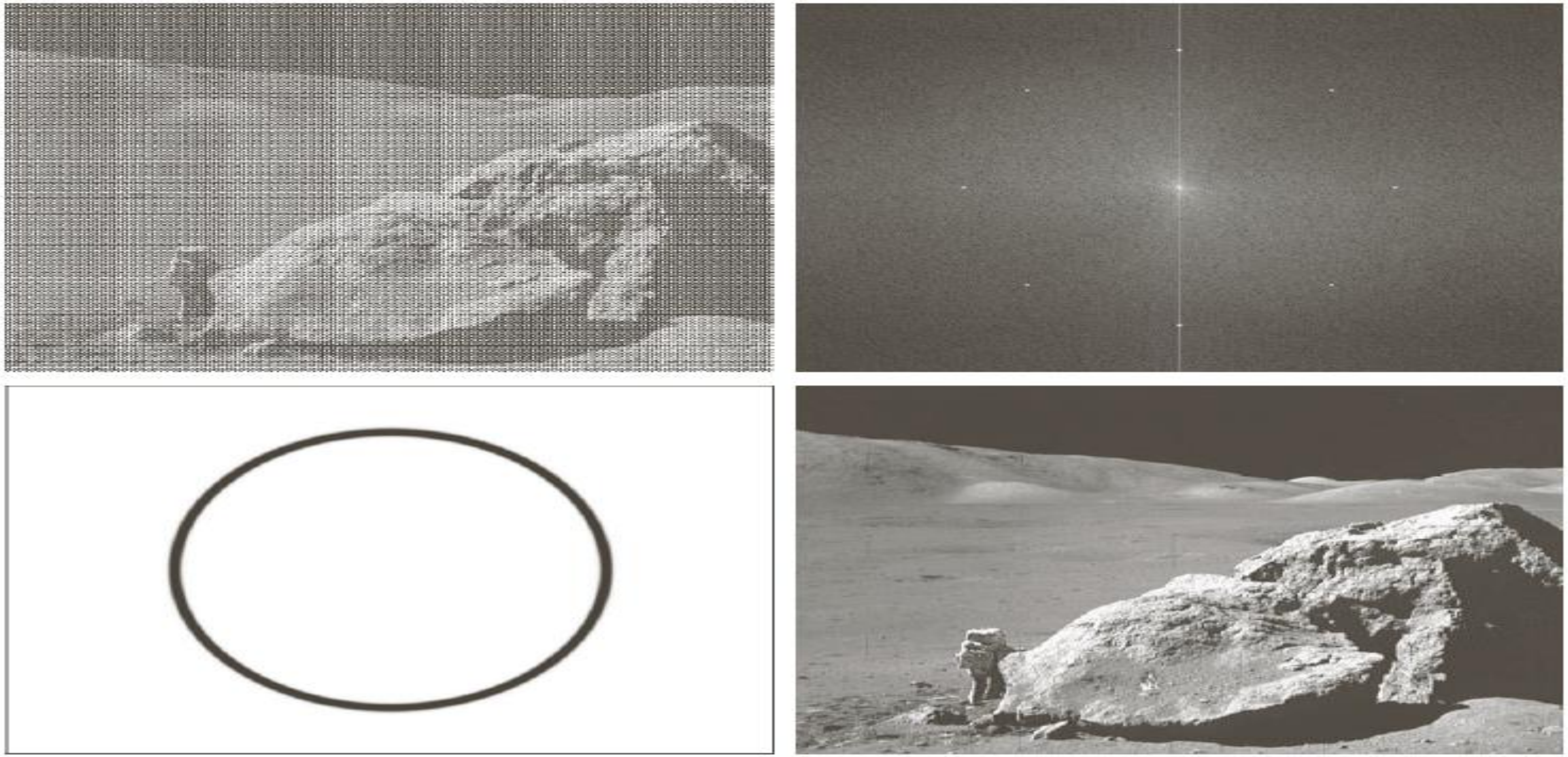
where $s(x, y, u, v)$ is the *inverse transformation* ker*nel*,

x = 0, 1, 2, ..., M-1 and y = 0, 1, ..., N-1.

Image Transform

FIGURE 2.39 General approach for operating in the linear transform domain.

Example: Image Denoising by Using DCT Transform



a b
c d

FIGURE 2.40
(a) Image corrupted by sinusoidal interference. (b) Magnitude of the Fourier transform showing the bursts of energy responsible for the interference. (c) Mask used to eliminate the energy bursts. (d) Result of computing the inverse of the modified Fourier transform. (Original image courtesy of NASA.)

Forward Transform Kernel

$$T(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)r(x,y,u,v)$$

The kernel $r(x,y,u,v)$ is said to be SEPERABLE if

$$r(x,y,u,v) = r_1(x,u)r_2(y,v)$$

In addition, the kernel is said to be SYMMETRIC if $r_1(x,u)$ is functionally equal to $r_2(y,v)$, so that

$$r(x,y,u,v) = r_1(x,u)r_1(y,u)$$

The Kernels for 2-D Fourier Transform

The *forward* kernel

$$r(x, y, u, v) = e^{-j2\pi(ux/M + vy/N)}$$

Where $j = \sqrt{-1}$

The *inverse* kernel

$$s(x, y, u, v) = \frac{1}{MN} e^{j2\pi(ux/M + vy/N)}$$

2-D Fourier Transform

$$T(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-j2\pi(ux/M + vy/N)}$$

$$f(x,y) = \frac{1}{MN} \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} T(u,v) e^{j2\pi(ux/M + vy/N)}$$

Probabilistic Methods

Let z_i, $i = 0, 1, 2, \ldots, L-1$, denote the values of all possible intensities in an $M \times N$ digital image. The probability, $p(z_k)$, of intensity level z_k occurring in a given image is estimated as

$$p(z_k) = \frac{n_k}{MN},$$

where n_k is the number of times that intensity z_k occurs in the image.

$$\sum_{k=0}^{L-1} p(z_k) = 1$$

The mean (average) intensity is given by

$$m = \sum_{k=0}^{L-1} z_k p(z_k)$$

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Probabilistic Methods

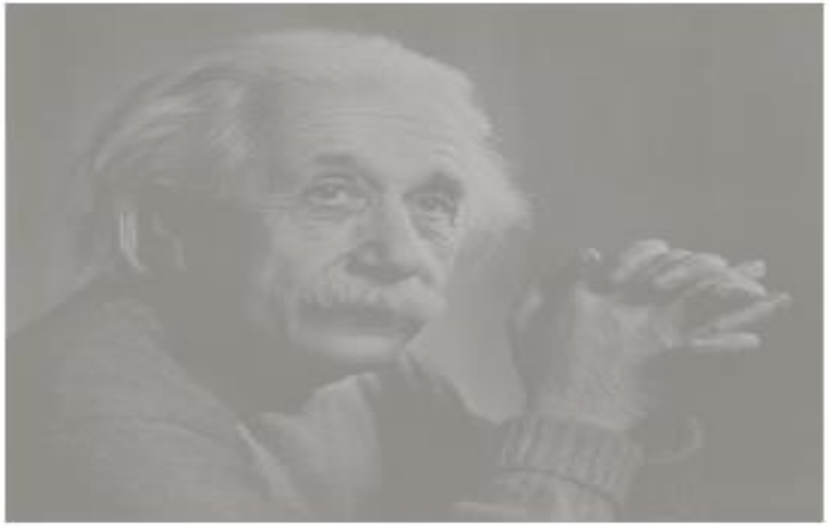
The variance of the intensities is given by

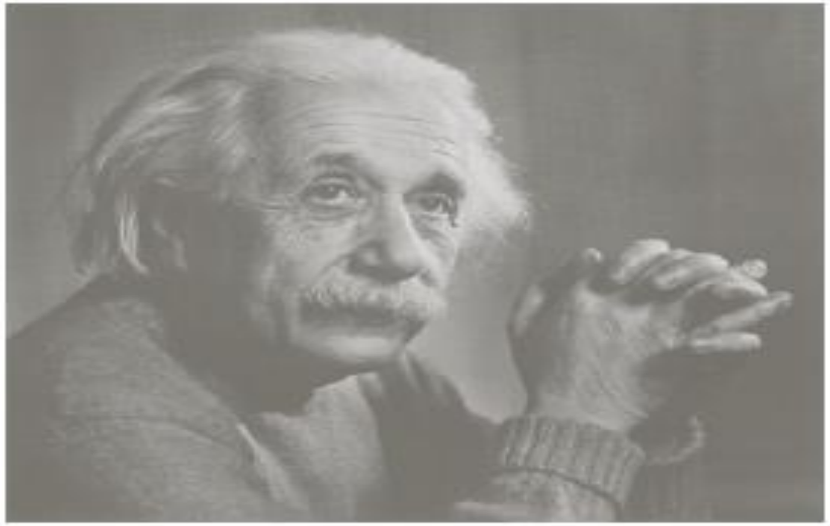
$$\sigma^2 = \sum_{k=0}^{L-1} (z_k - m)^2 p(z_k)$$

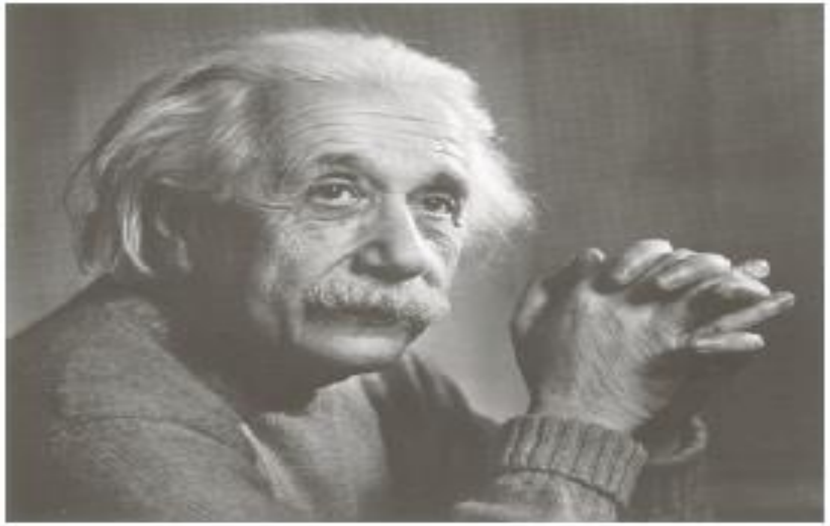
The n^{th} moment of the intensity variable z is

$$u_n(z) = \sum_{k=0}^{L-1} (z_k - m)^n p(z_k)$$

Example: Comparison of Standard Deviation Values







$\sigma = 14.3$ $\sigma = 31.6$ $\sigma = 49.2$