
Marwadi
University

Marwadi University

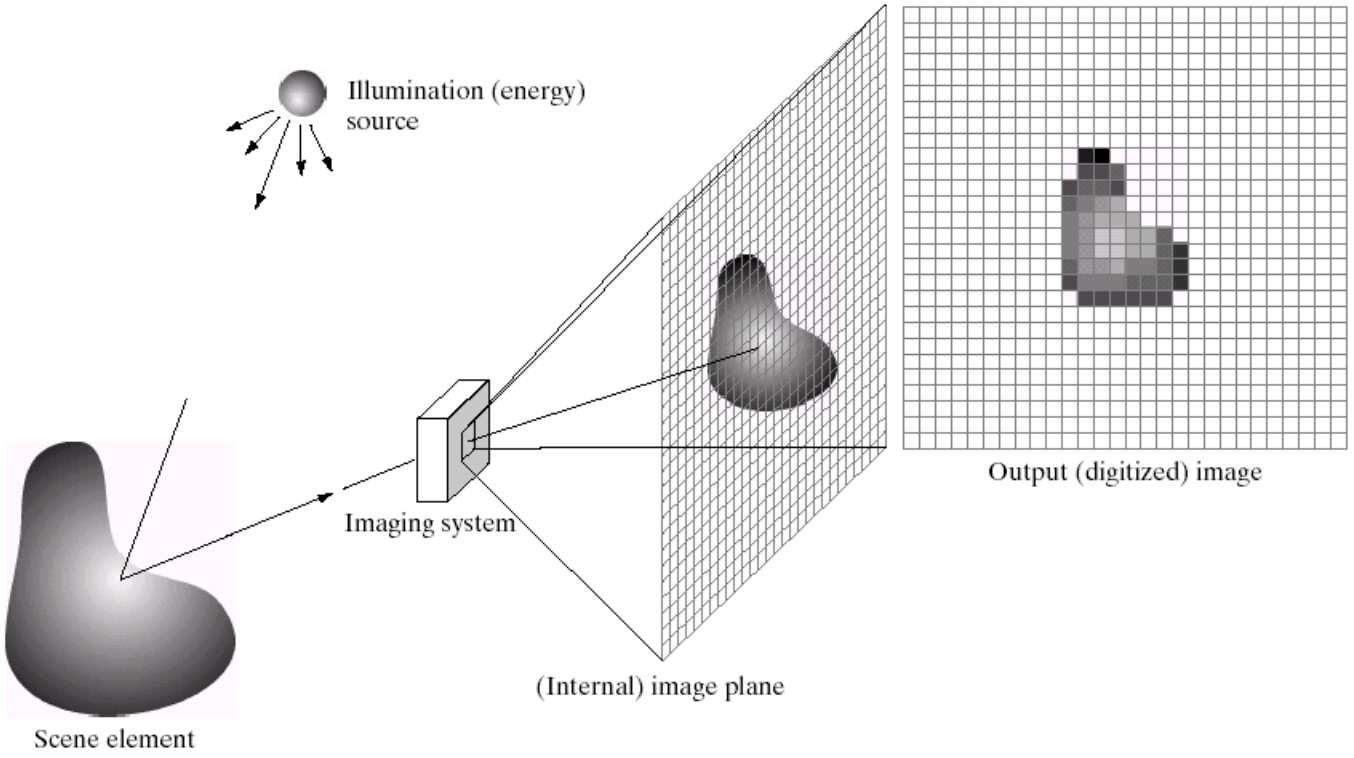
IMAGE PROCESSING
01CE0507

Unit – 1
Introduction to Digital Image Processing

Prof. Urvi Y. Bhatt
Department of Computer Engineering

What is 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



What is Digital Image? (Cont.)

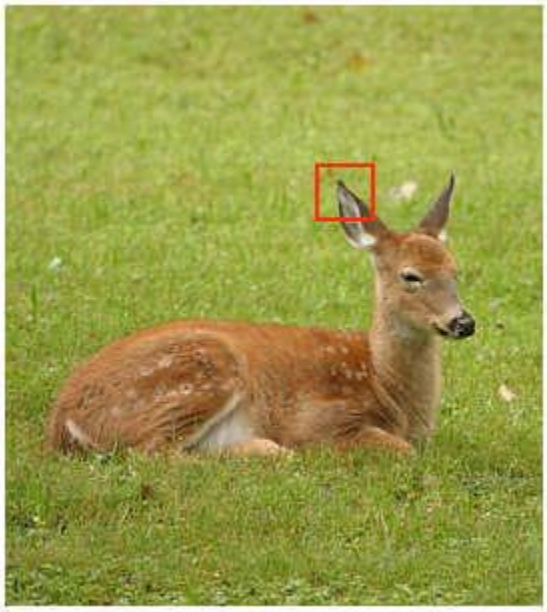
Common image formats include:

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)

For most of this course we will focus on grey-scale images

What is Digital Image? (Cont.)

- Pixels: Elements of the digital image , each has intensity.
- Intensity of pixel: the amplitude of gray level (in gray scale images)

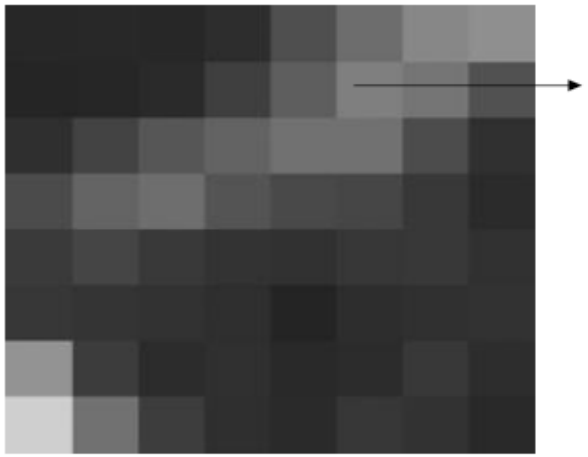


What is Digital Image? (Cont.)

- An image can be defined as function of 2 variables , $f(x,y)$, where ***x*** and ***y*** are spatial coordinates, and the amplitude of **f** at any pair of coordinates (x , y) is called the **intensity** of the image at that point

What is Digital Image? (Cont.)

- The image consists of finite number of pixels (f(x,y))
- Every pixel Is an intersection between a row and a column.
- Every pixel has intensity



Ex:

f(2,6)= 123

Refers to a pixel existing on the intersection between row 2 with column 6, and its intensity is 123.

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

What is Digital Image? (Cont.)

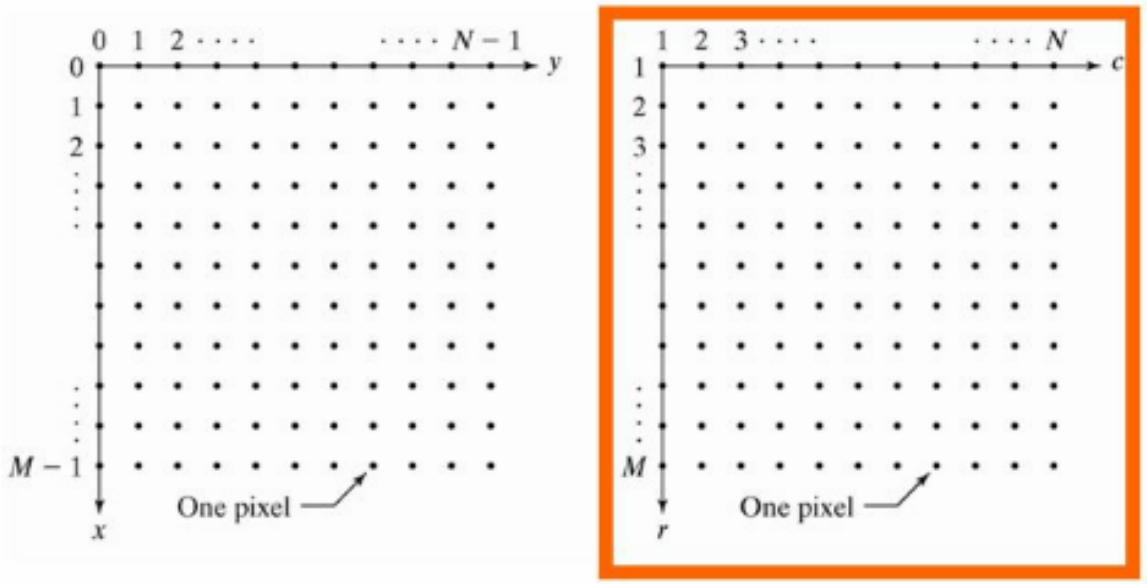
Digital image processing focuses on two major tasks

- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission and representation for autonomous machine perception

What is Digital Image? (Cont.)

- Digital image representation :
  2D function f(x,y) -> finite discrete quantities
- Coordinate Conventions

  img(r,c)
  r – rows (height)
  c – cols (width)
- The first pixel:
  img(1,1)



Pixel

- Pixel is the smallest element of an image. Each pixel correspond to any one value.
- The value of a pixel at any point correspond to the intensity of the light photons striking at that point.
- Each pixel store a value proportional to the light intensity at that particular location.

Calculation of total number of pixels

- We have define an image as a two dimensional signal or matrix.
- Then in that case the number of Pixel would be equal to the number of rows multiply with number of columns.
- This can be mathematically represented as below:

Total No. of pixels = No. of rows * No. of columns

Calculation of total number of pixels (Cont.)

0	0	0
0	0	0
0	0	0

- Total No. of pixels = No. of rows * No. of columns = 3 X 3 = 9.
- It means that an image would be formed with 9 pixels,

What Is Image Processing?

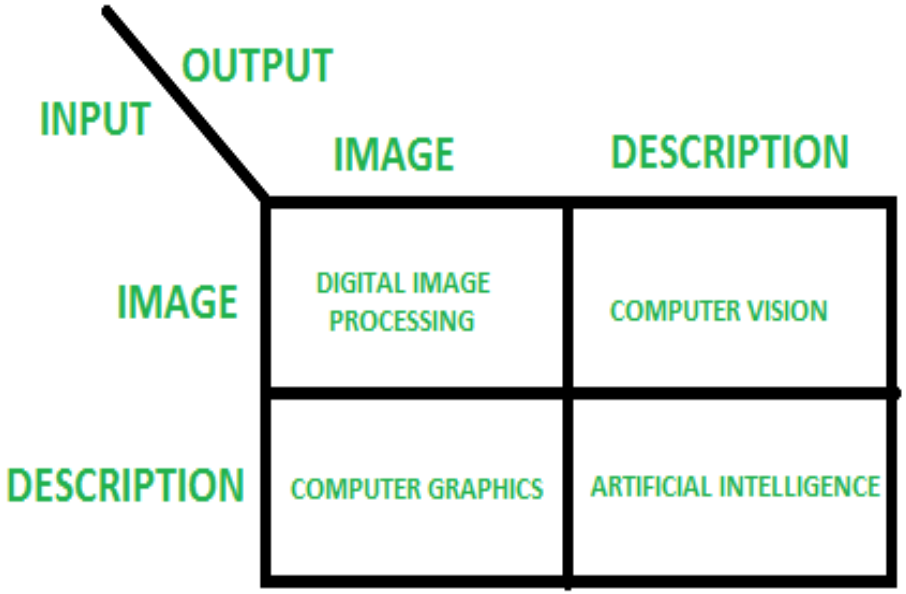
- Image processing is the process of transforming an image into a digital form and performing certain operations to get some useful information from it.
- We can also say that it is a use of computer algorithms, in order to get enhanced image either to extract some useful information.
- The image processing system usually treats all images as 2D signals when applying certain predetermined signal processing methods.

What Is Image Processing? (Cont.)

- Image processing mainly include the following steps:
  1. Importing the image via image acquisition tools;
  2. Analysing and manipulating the image;
  3. Output in which result can be altered image or a report which is based on analysing that image.

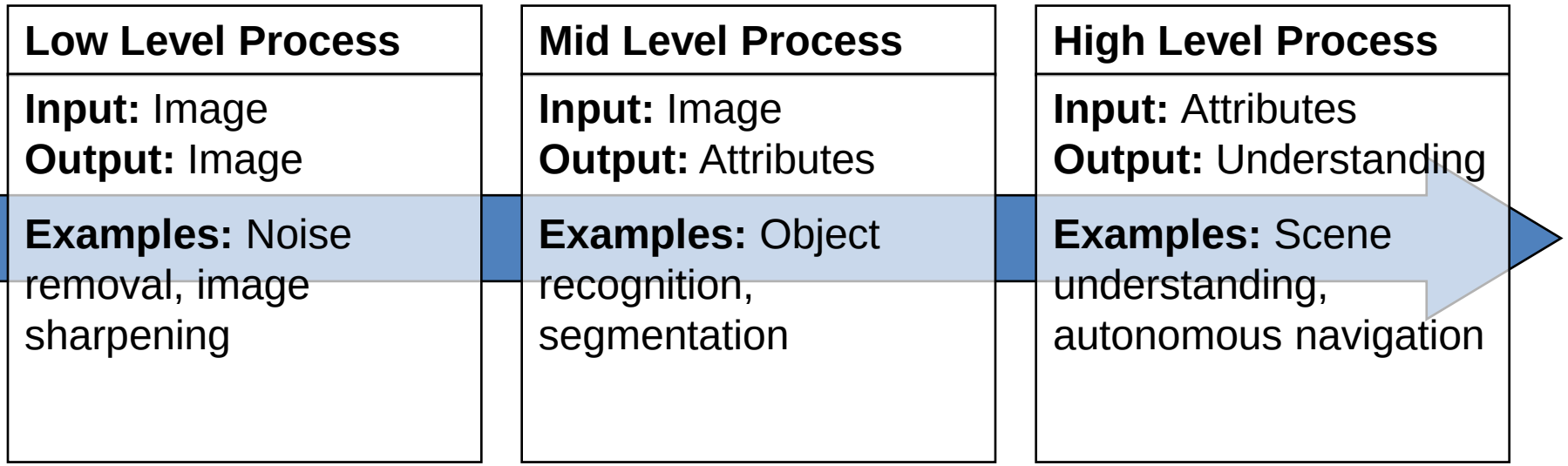
Overlapping Fields With Image Processing

- **According to block 1**,if input is an image and we get out image as a output, then it is termed as Digital Image Processing.
- **According to block 2**,if input is an image and we get some kind of information or description as a output, then it is termed as Computer Vision.
- **According to block 3**,if input is some description or code and we get image as an output, then it is termed as Computer Graphics.
- **According to block 4**,if input is description or some keywords or some code and we get description or some keywords as a output, then it is termed as Artificial Intelligence



Levels of Digital Image Processing

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



Levels of Digital Image Processing (Cont.)

Marwadi University

- **low level processes:**
  - **Input** and **output** are images
  - **Tasks:** Primitive operations, such as, image processing to reduce noise, contrast enhancement and image sharpening

Levels of Digital Image Processing (Cont.)

Marwadi University

- **Mid-Level Processes:**
  - **Inputs**, generally, are images.
  - **Outputs** are attributes extracted from those images (edges, contours, identity of individual objects)
  - **Tasks:**
    - Segmentation (partitioning an image into regions or objects)
    - Description of those objects to reduce them to a form suitable for computer processing
    - Classifications (recognition) of objects

Levels of Digital Image Processing (Cont.)

Marwadi University

- **High-Level Processes**
  - **Input:** Attributes
  - **Output:** Understanding
  - **Tasks:** recognizing objects
    - Image analysis and computer vision(Analysis of the image content)
    - **Examples:** Scene understanding

Application Fields of image Processing

- Image Enhancement
- The Hubble Telescope
- Artistic Effects
- Medicine
- Geographic Information Systems
- Industrial Inspection
- Printed Circuit Board (PCB) inspection
- Law Enforcement
- Human Computer interfaces

Application Fields of image Processing (Cont.)

- Automobile driver assistance
  - Lane departure warning
  - Adaptive cruise control
  - Obstacle warning
- Digital Photography
  - Image Enhancement
  - Compression
  - Color manipulation
  - Image editing
  - Digital cameras
- Sports analysis
  - sports refereeing and commentary
  - 3D visualization and tracking sports actions

Application Fields of image Processing (Cont.)

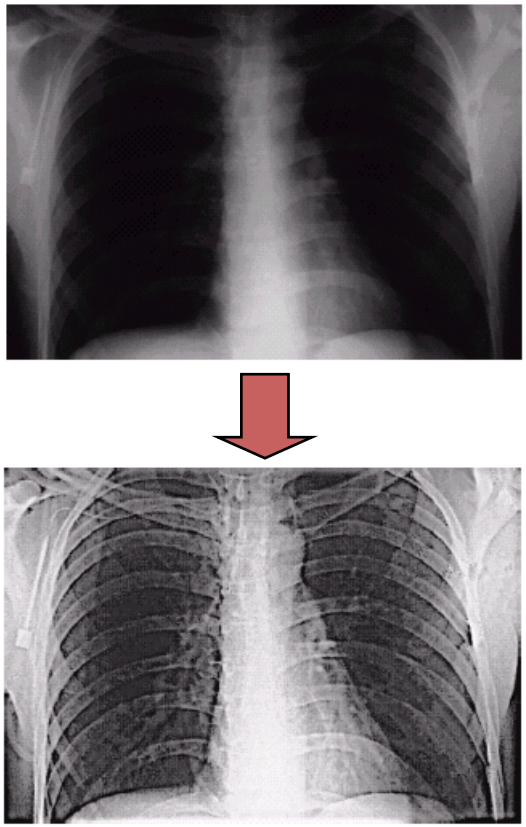
- Film and Video
  - Editing
  - Special effects
- Image Database
  - Content based image retrieval
  - visual search of products
  - Face recognition
- Industrial Automation and Inspection
  - vision-guided robotics
  - Inspection systems
- Medical and Biomedical
  - Surgical assistance
  - Sensor fusion
  - Vision based diagnosis
- Astronomy
  - Astronomical Image Enhancement
  - Chemical/Spectral Analysis

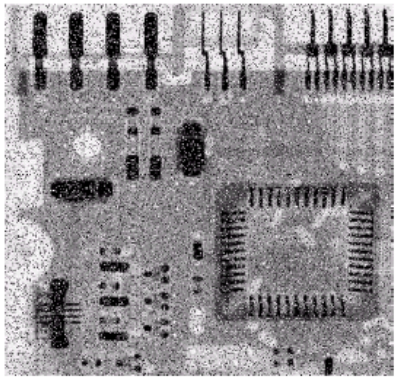
Application Fields of image Processing (Cont.)

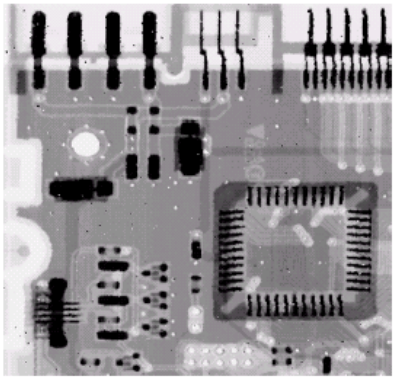
- Arial Photography
  - Image Enhancement
  - Missile Guidance
  - Geological Mapping
- Robotics
  - Autonomous Vehicles
- Security and Safety
  - Biometry verification (face, iris)
  - Surveillance (fences, swimming pools)
- Military
  - Tracking and localizing
  - Detection
  - Missile guidance
- Traffic and Road Monitoring
  - Traffic monitoring
  - Adaptive traffic lights

Examples: Image Enhancement

One of the most common uses of DIP techniques: improve quality, remove noise etc





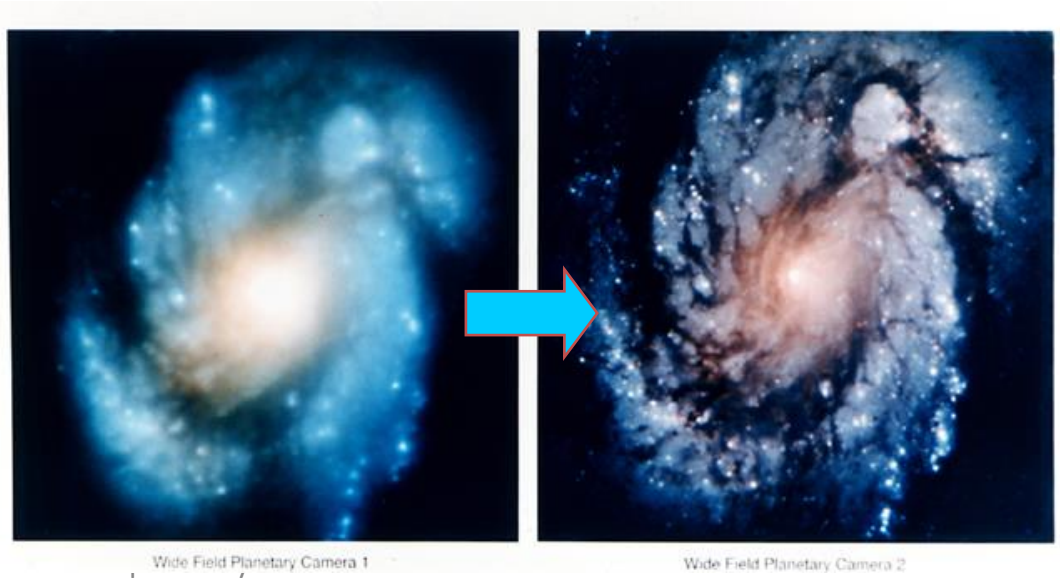


Examples: The Hubble Telescope

Launched in 1990 the Hubble telescope can take images of very distant objects

However, an incorrect mirror made many of Hubble's images useless

Image processing techniques were used to fix this



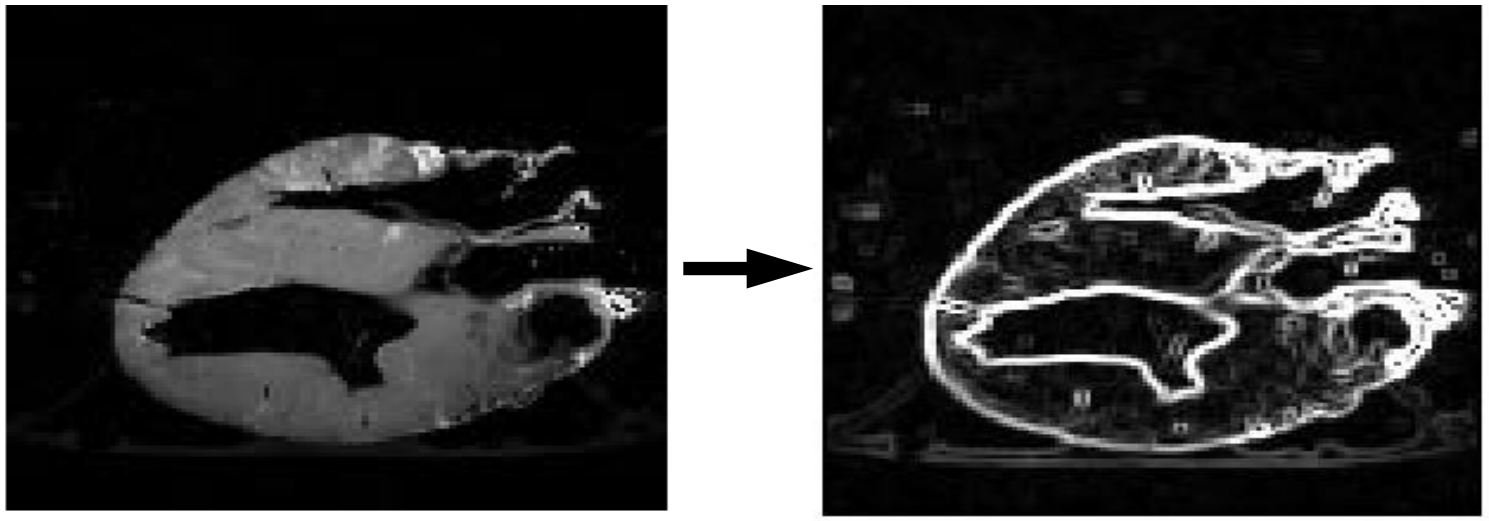
Examples: Artistic Effects

Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

Examples: Medicine

Take slice from MRI scan of canine heart, and find boundaries between types of tissue

- Image with gray levels representing tissue density
- Use a suitable filter to highlight edges



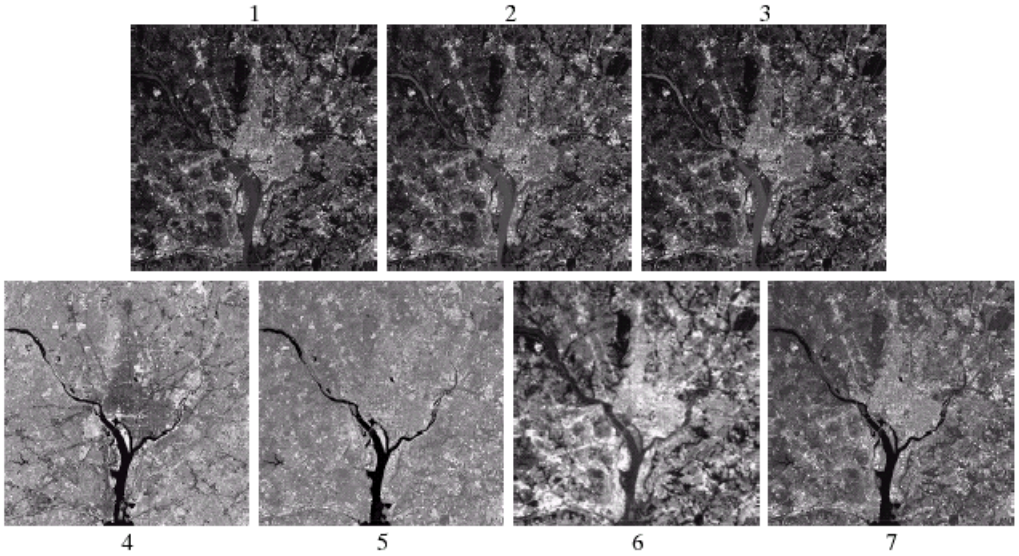
Original MRI Image of a Dog Heart

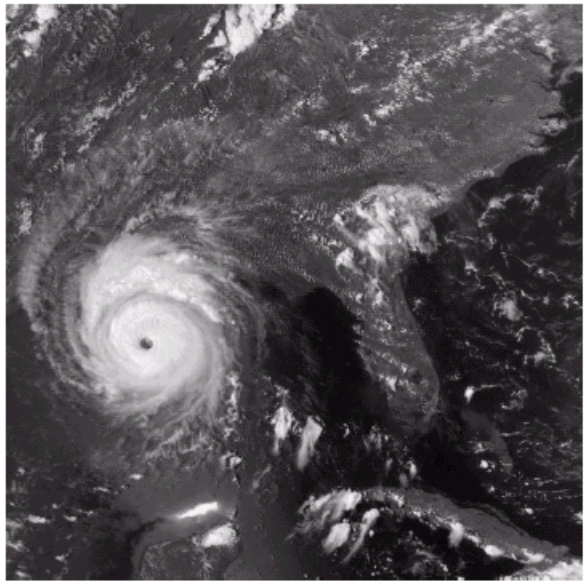
Edge Detection Image

Examples: GIS

Geographic Information Systems

- Digital image processing techniques are used extensively to manipulate satellite imagery
- Terrain classification
- Meteorology

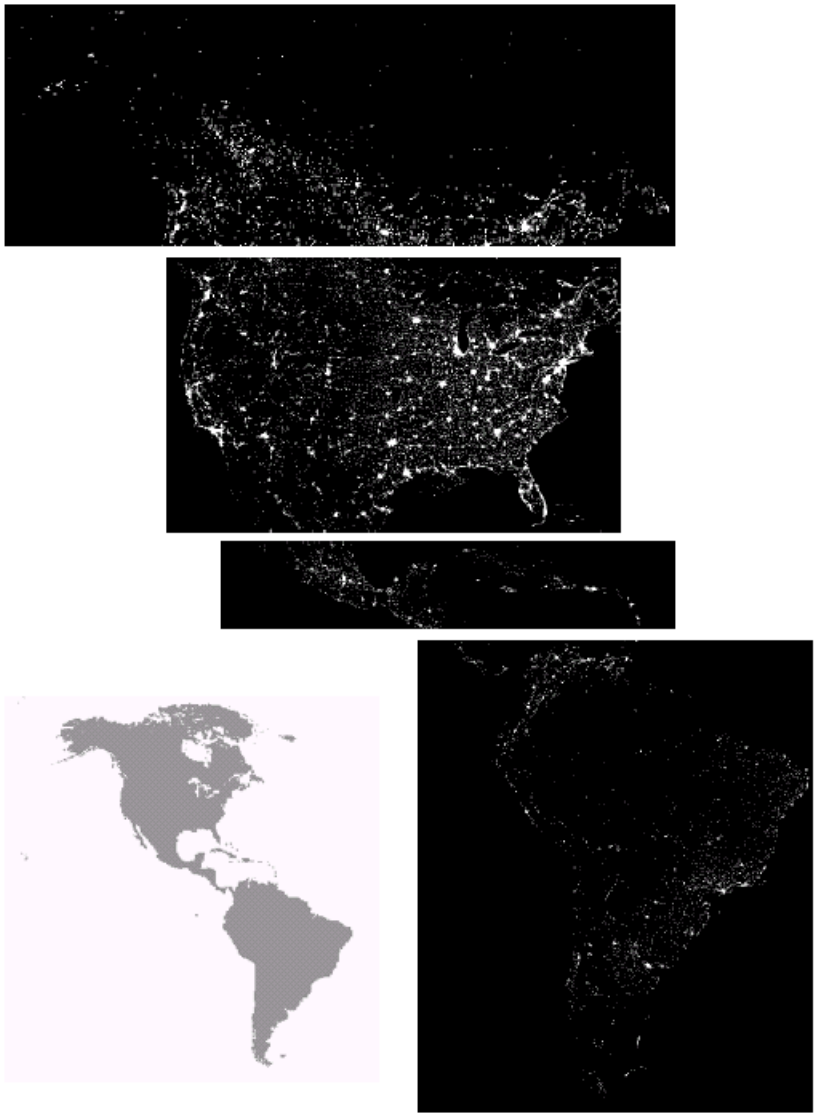




Examples: GIS (Cont…)

Night-Time Lights of the World data set

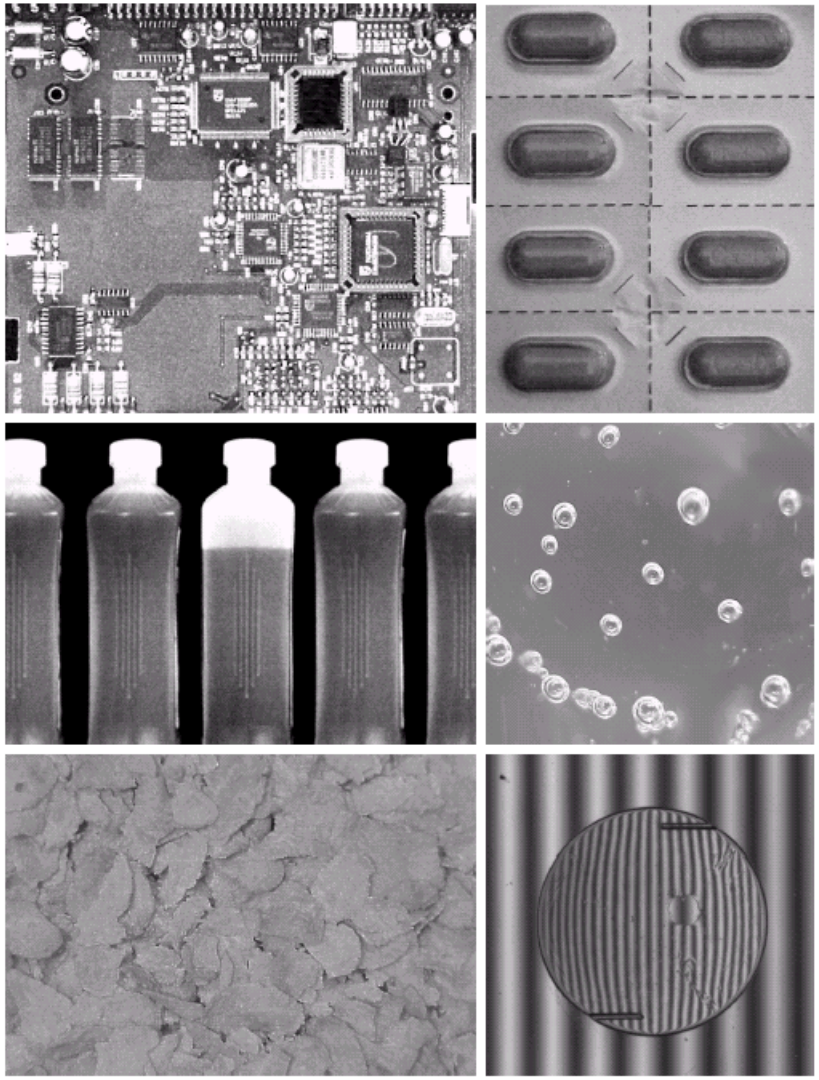
- Global inventory of human settlement
- Not hard to imagine the kind of analysis that might be done using this data



Examples: Industrial Inspection

Marwadi University

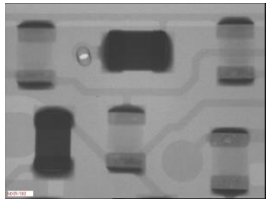
- Human operators are expensive, slow and unreliable
- Make machines do the job instead
- Industrial vision systems are used in all kinds of industries
- Can we trust them?

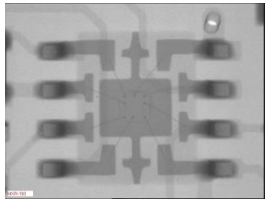


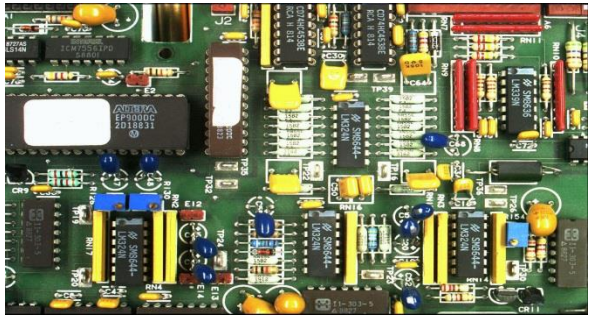
Examples: PCB Inspection

Printed Circuit Board (PCB) inspection

- Machine inspection is used to determine that all components are present and that all solder joints are acceptable
- Both conventional imaging and x-ray imaging are used



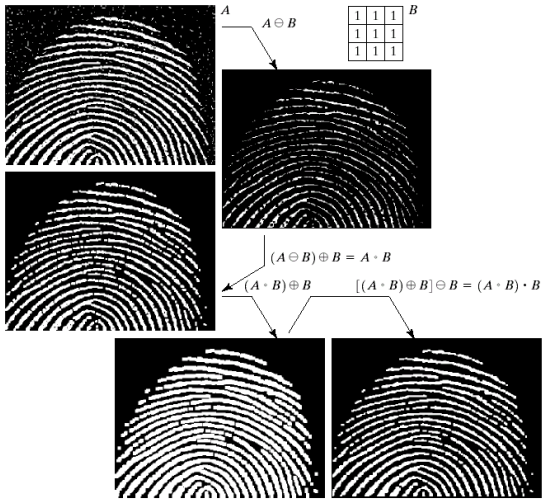




Examples: Law Enforcement

Image processing techniques are used extensively by law enforcers

- Number plate recognition for speed cameras/automated toll systems
- Fingerprint recognition
- Enhancement of CCTV images

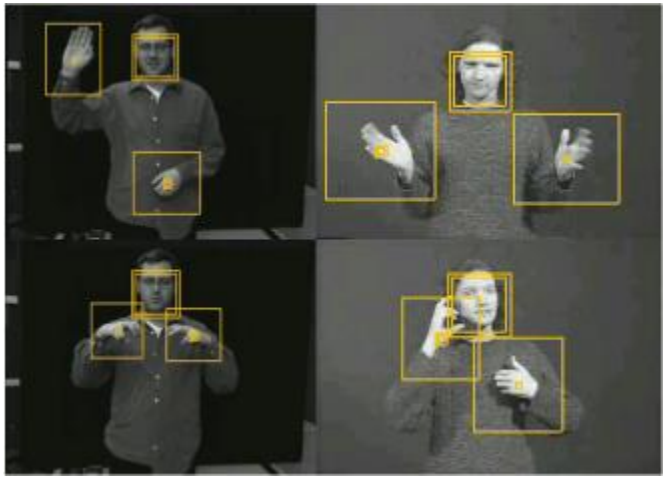


Examples: HCI

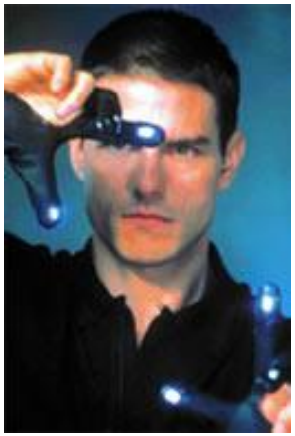
Marwadi University

Try to make human computer interfaces more natural

- Face recognition
- Gesture recognition

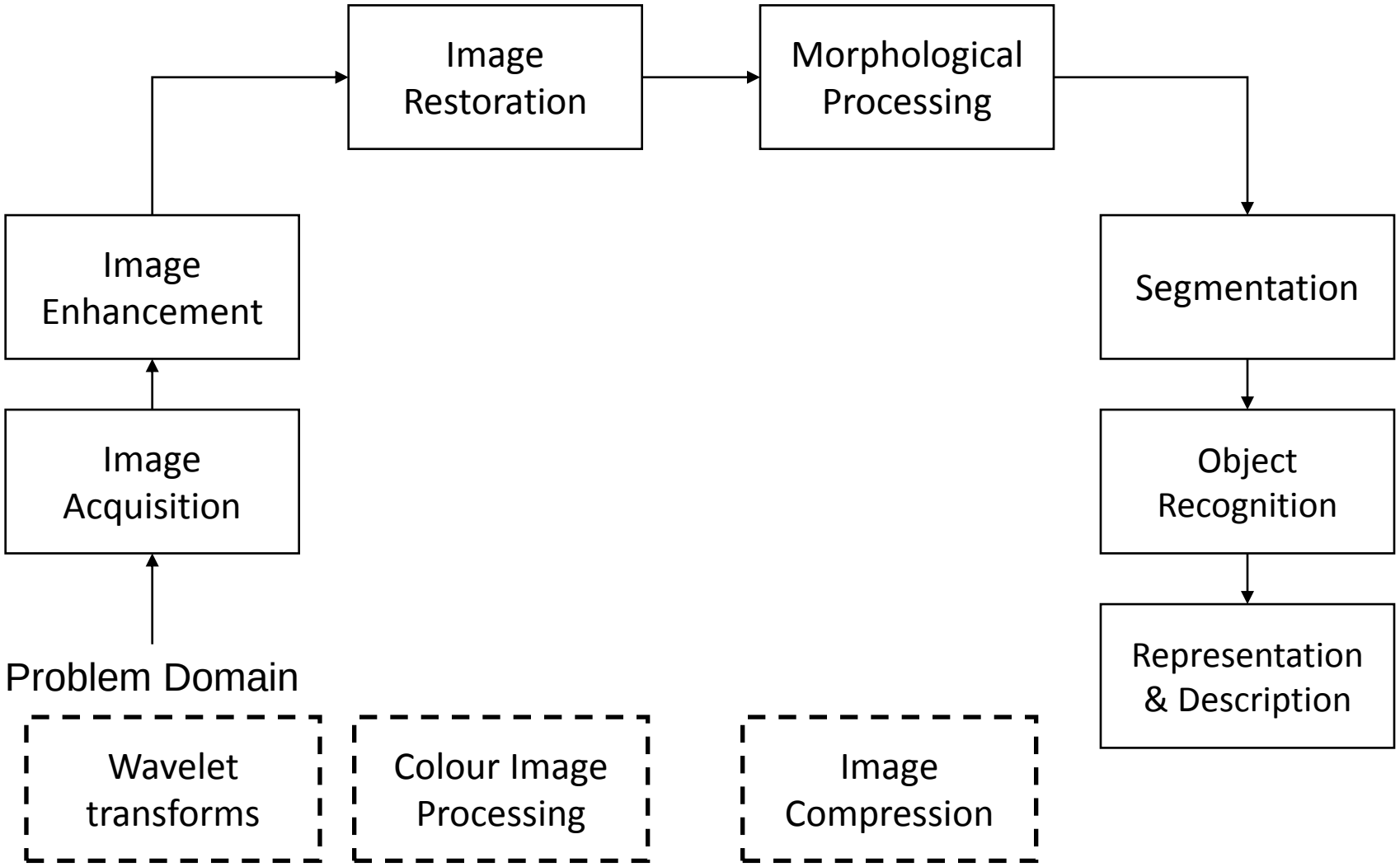


Does anyone remember the user interface from “Minority Report”?

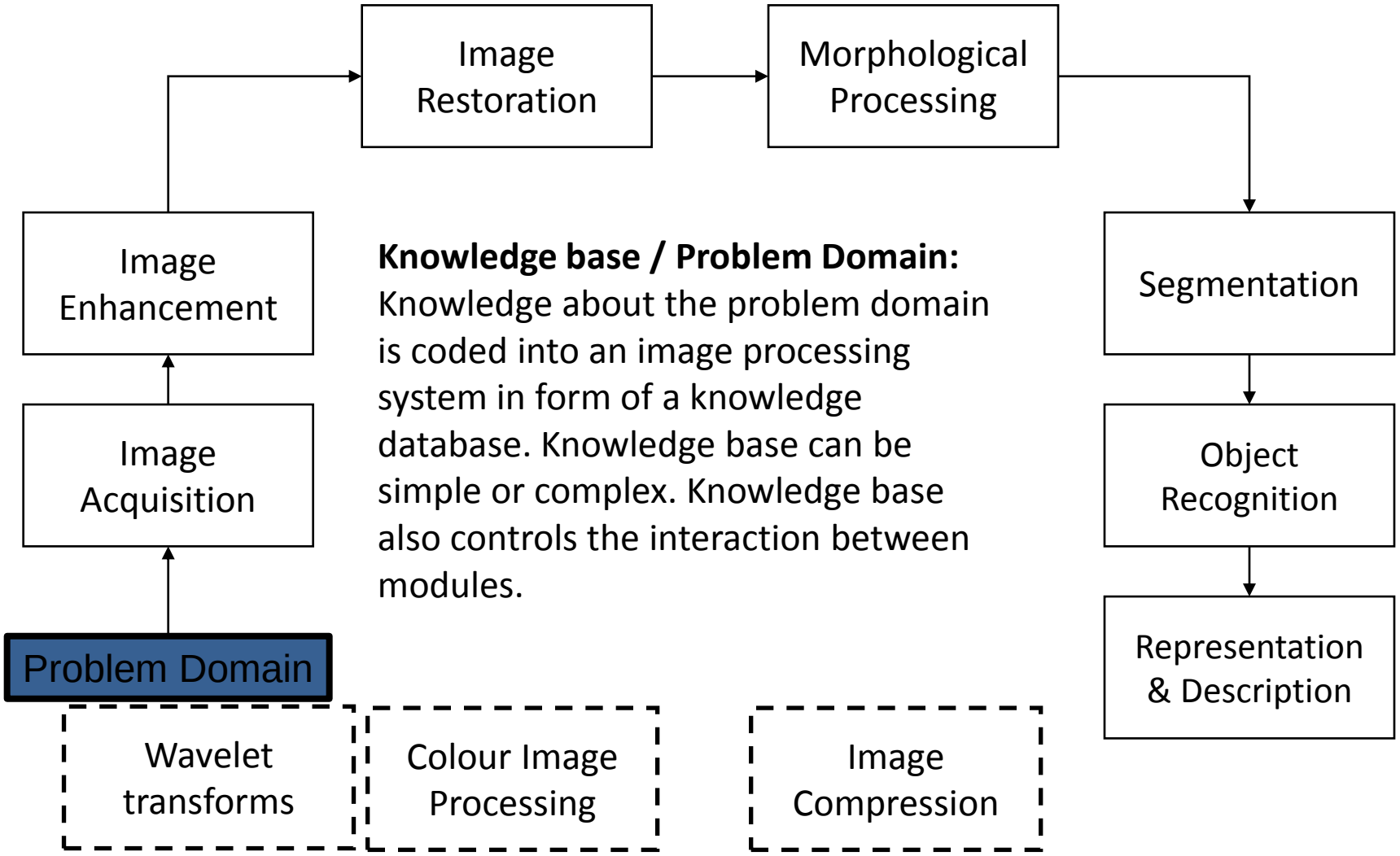


These tasks can be extremely difficult

Key Stages in Digital Image Processing



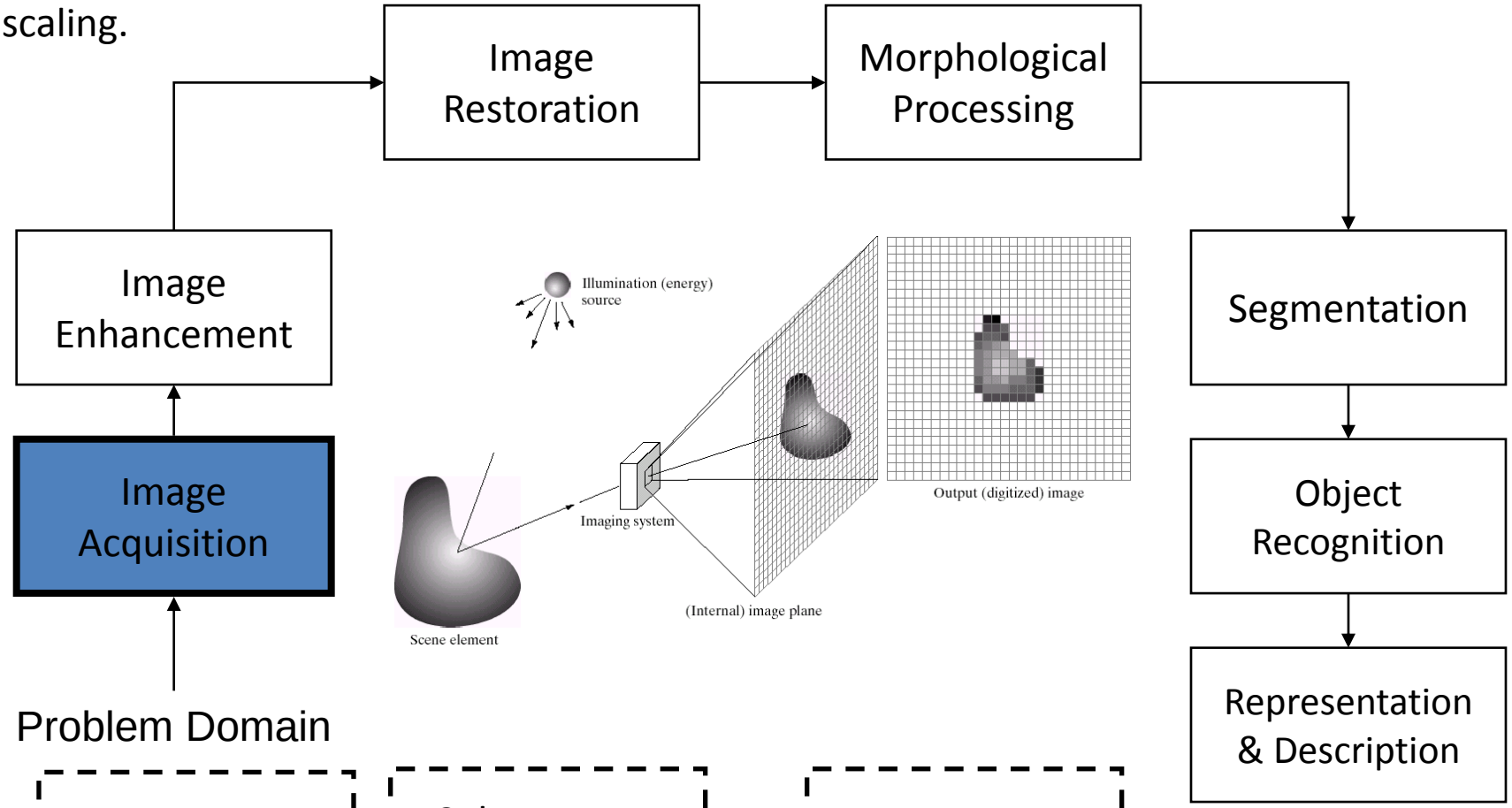
Key Stages in Digital Image Processing



Knowledge base / Problem Domain: Knowledge about the problem domain is coded into an image processing system in form of a knowledge database. Knowledge base can be simple or complex. Knowledge base also controls the interaction between modules.

Key Stages in Digital Image Processing: Image Enhancement

Image acquisition is very first stage. Generally this stage involves preprocessing, such as scaling.



Key Stages in Digital Image Processing: Image Enhancement

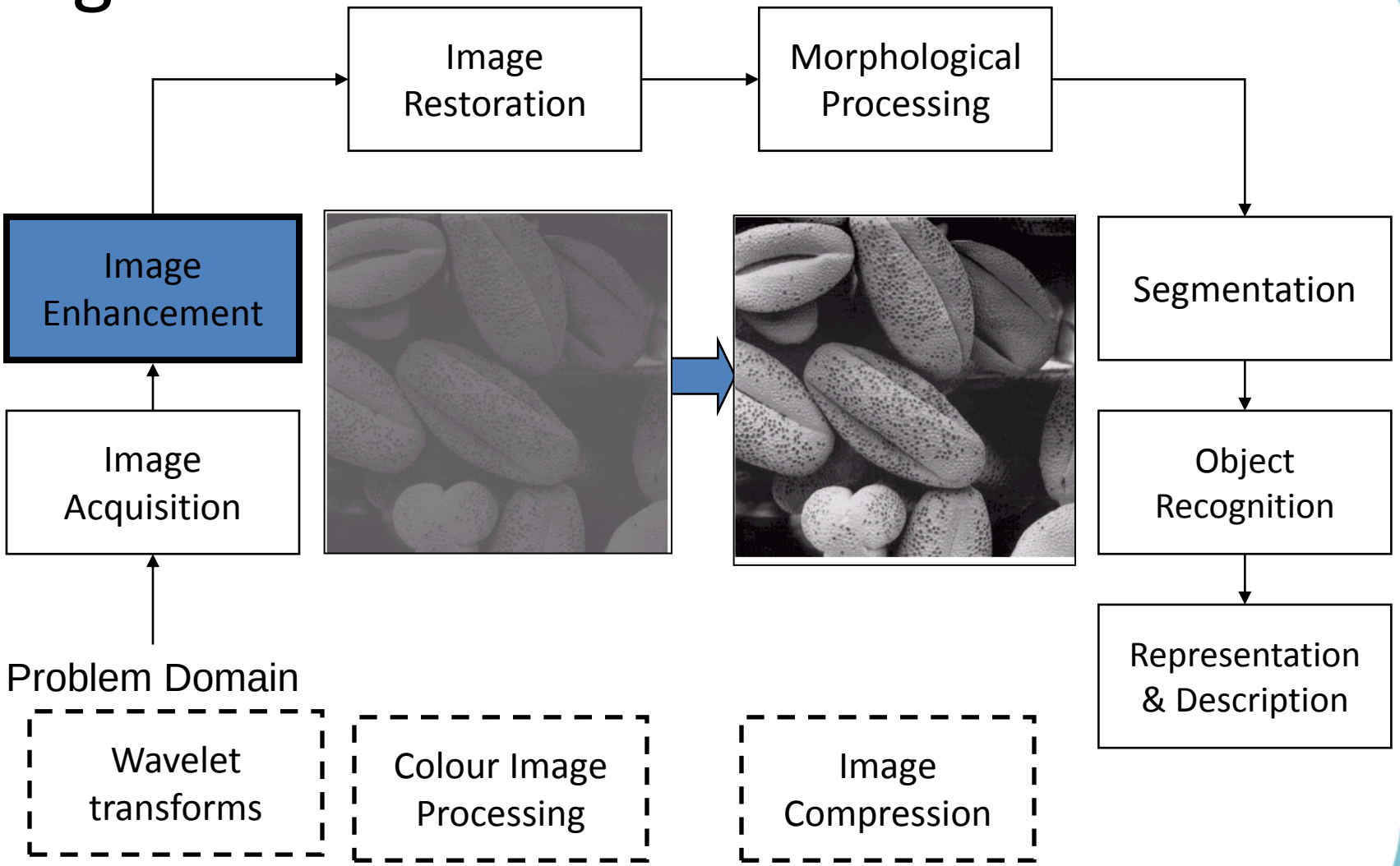


Image enhancement is the process of manipulating an image so that the result is more suitable than the original for a specific application. This techniques are problem oriented (Subjective)

Key Stages in Digital Image Processing: Image Restoration

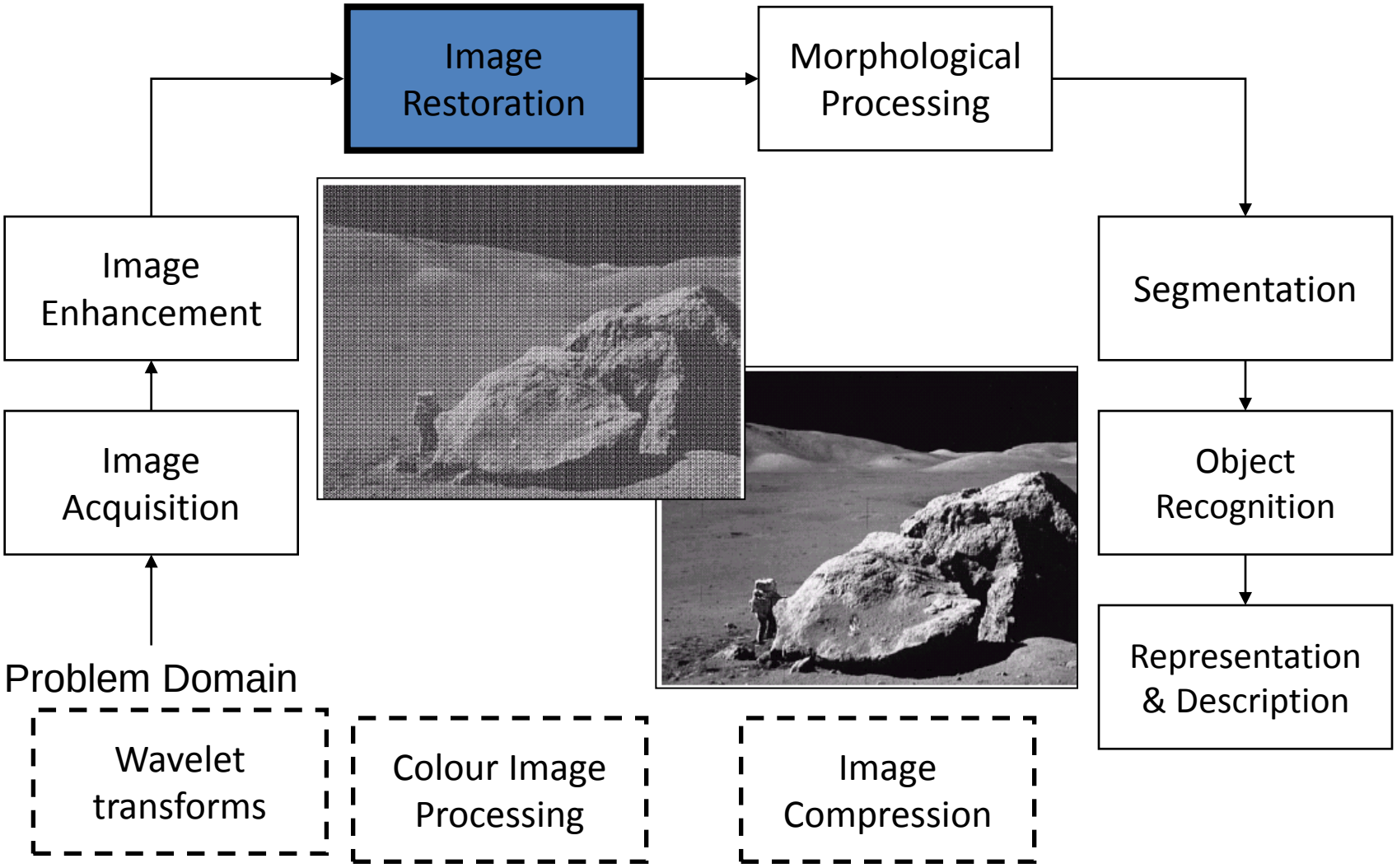
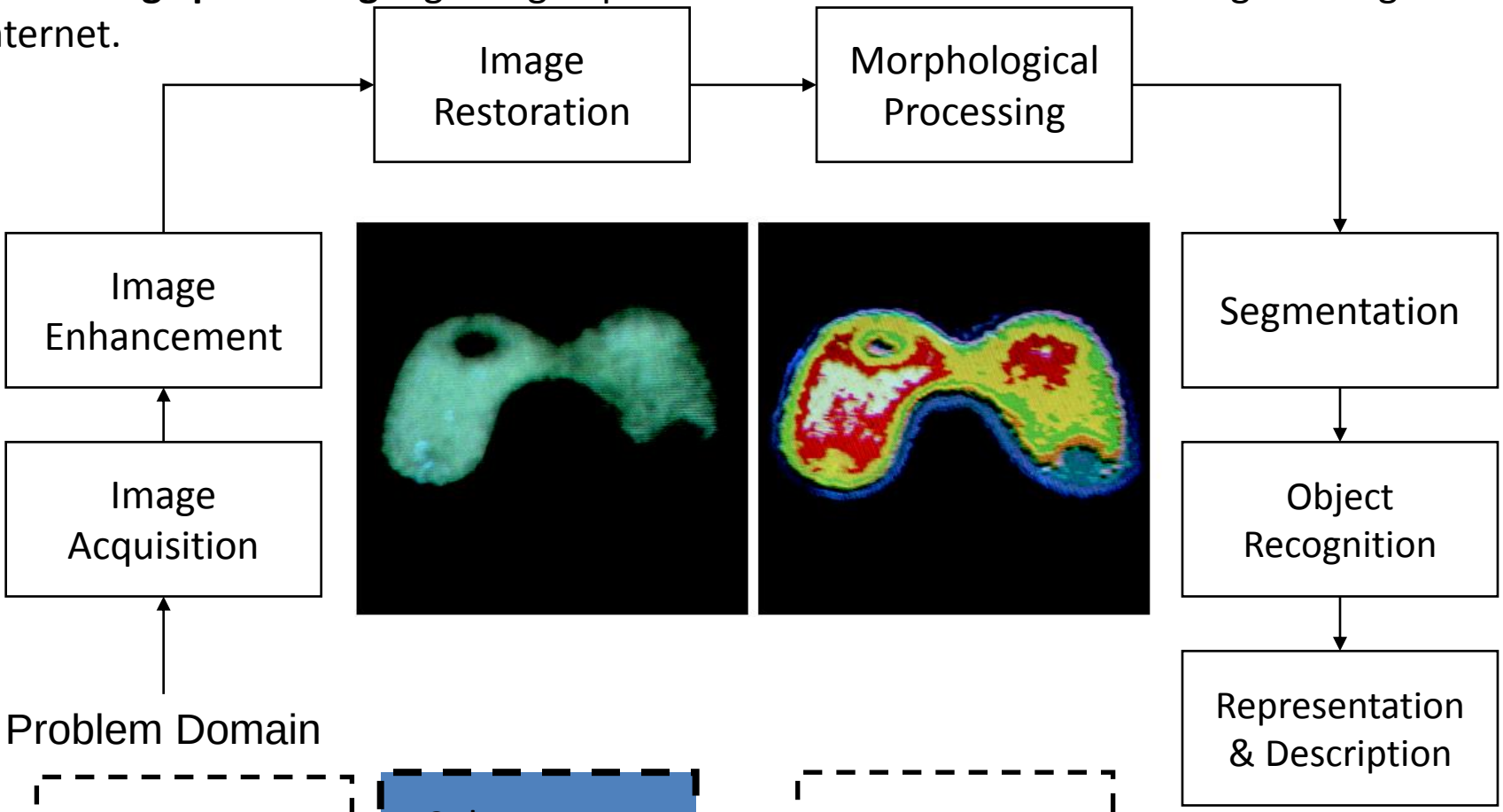


Image Restoration is an area that deals with improving the appearance of an image.

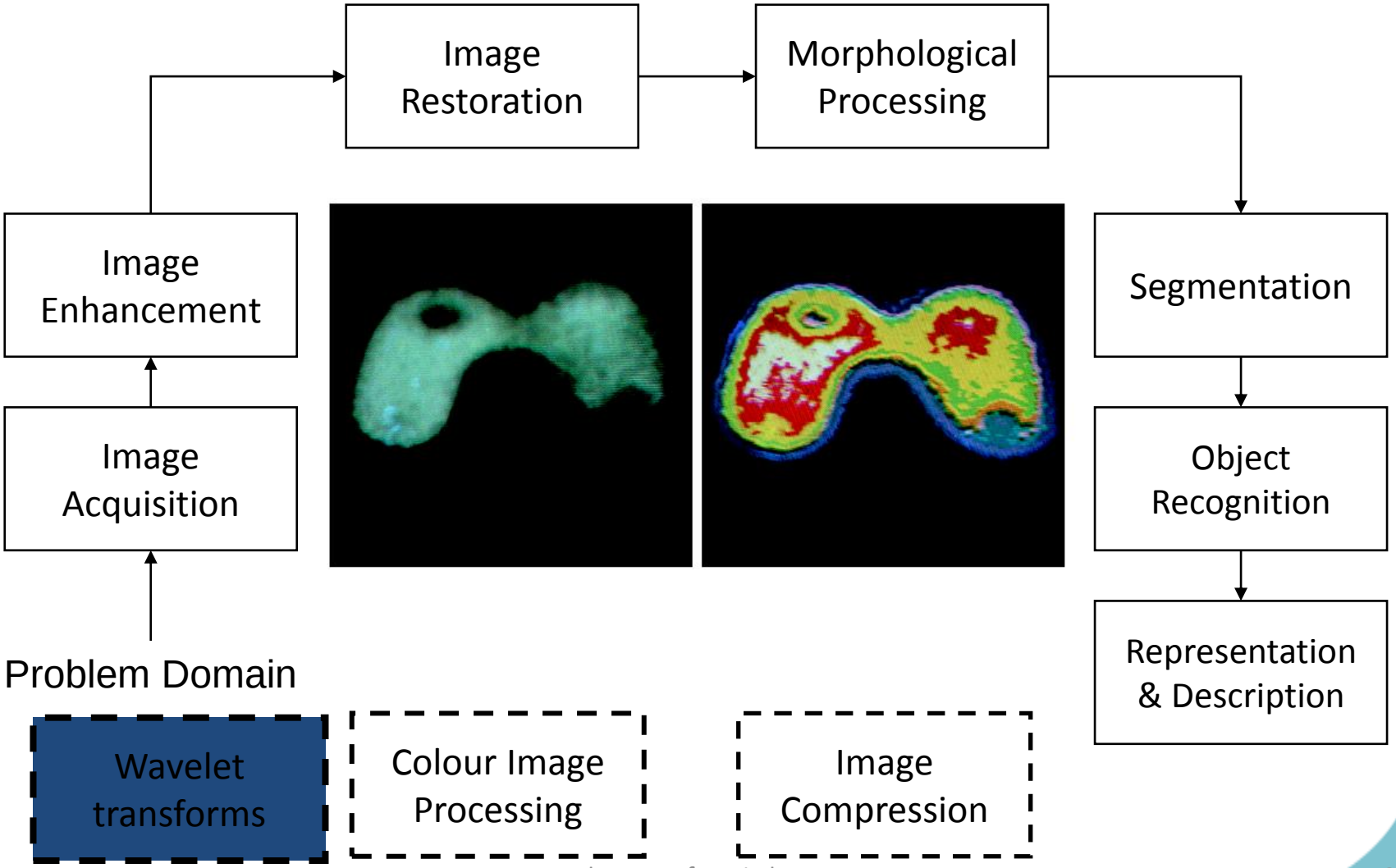
Key Stages in Digital Image Processing: Colour Image Processing

Color Image processing is gaining importance due to increase in use of digital images over internet.



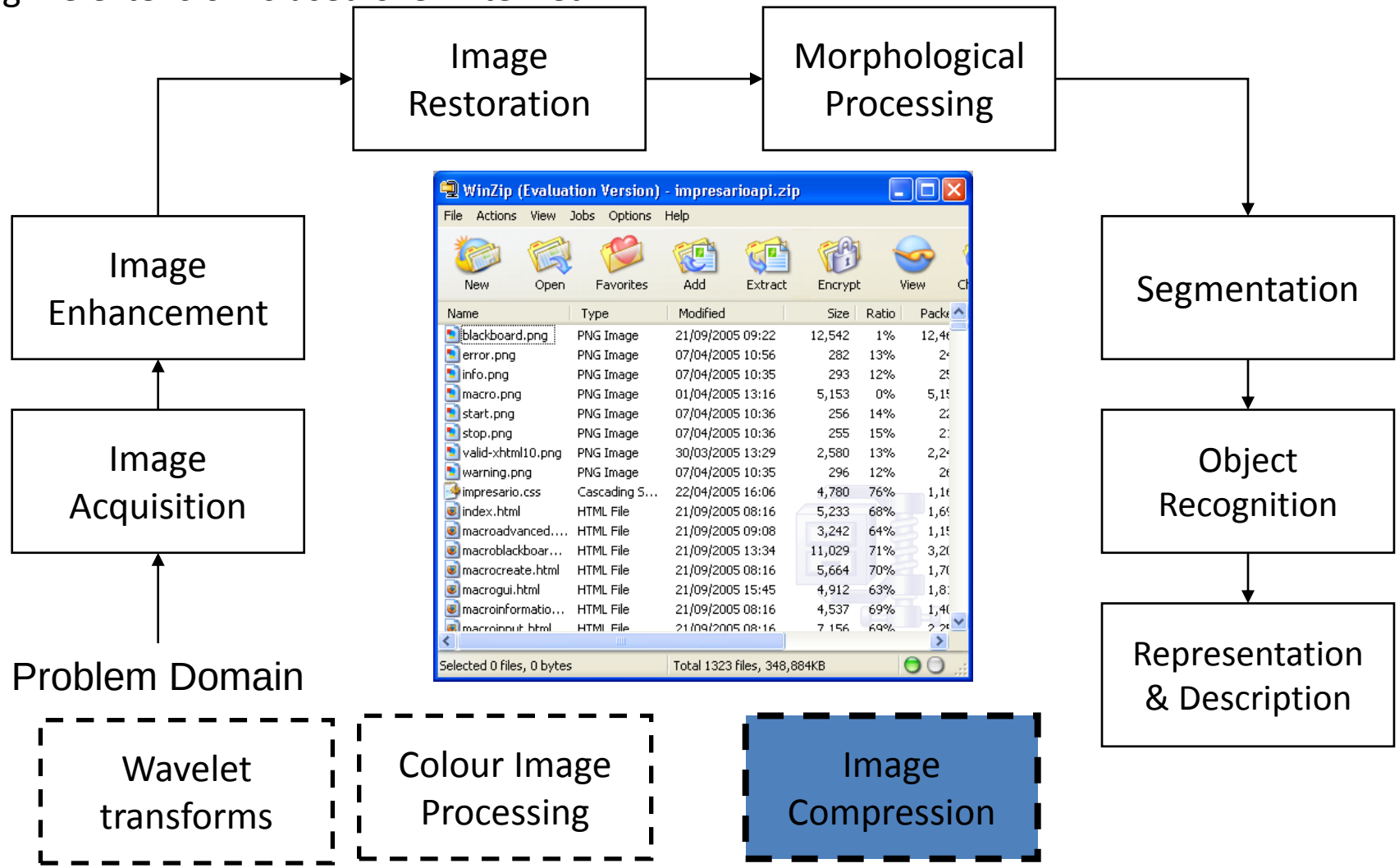
Key Stages in Digital Image Processing: Wavelet transforms

Wavelets are the foundation for representing images in various degrees of solution, in which images are subdivided into smaller regions.



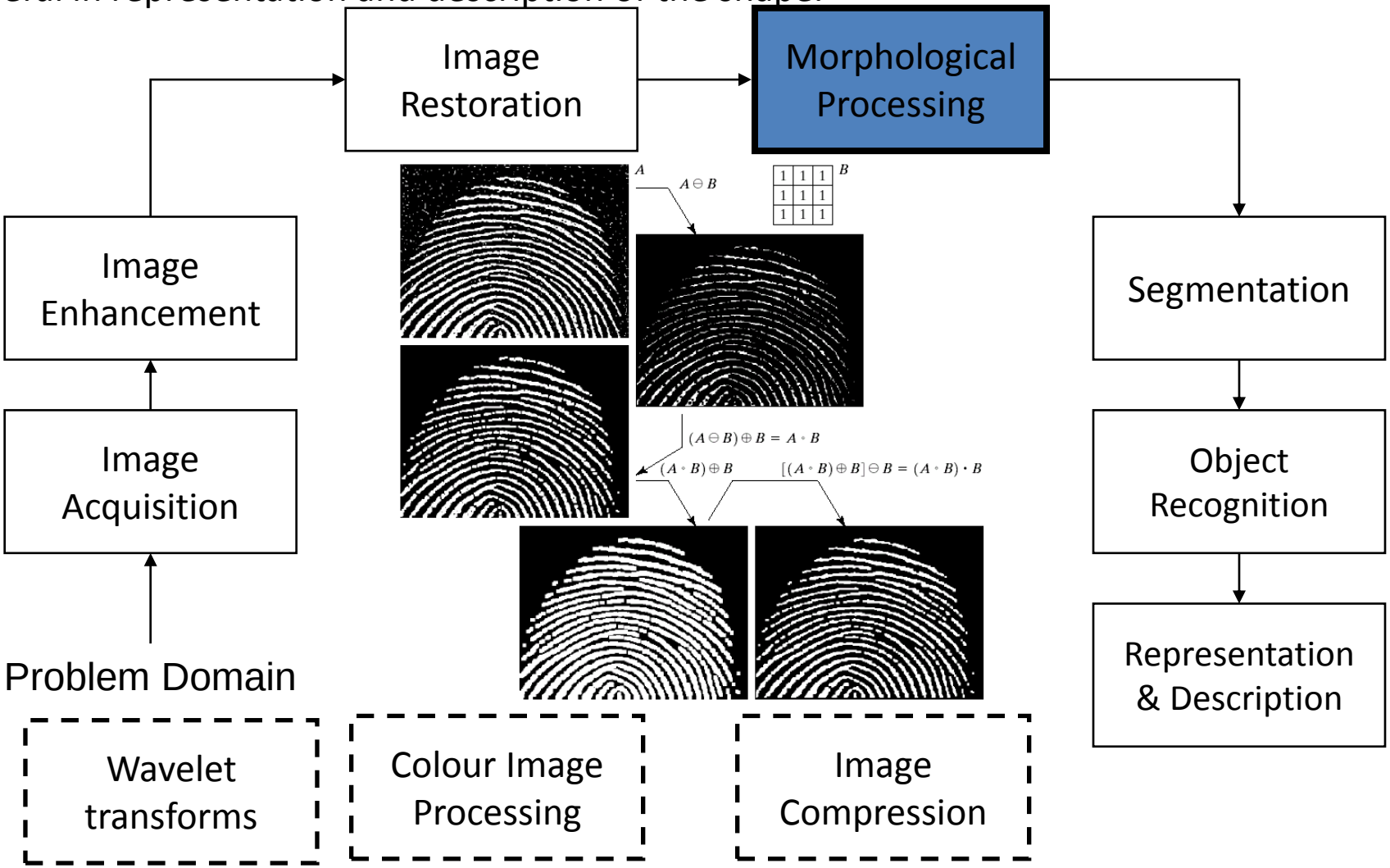
Key Stages in Digital Image Processing: Image Compression

Compression deals with the techniques for reducing the storage required to save an image. Jpg file extension is used over internet.



Key Stages in Digital Image Processing: Morphological Processing

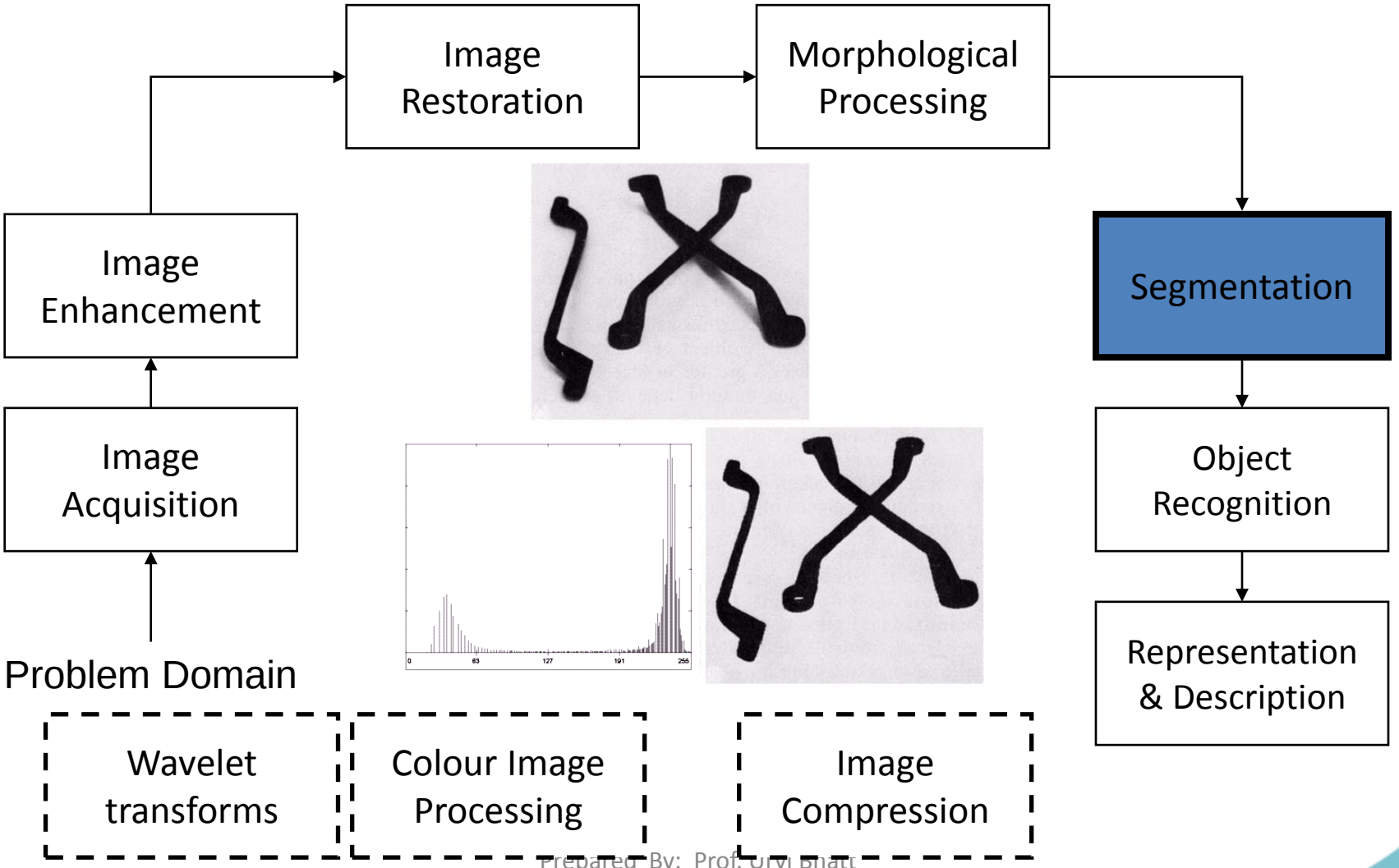
Morphological processing deals with the tools for extracting image components that are useful in representation and description of the shape.



Key Stages in Digital Image Processing: Segmentation

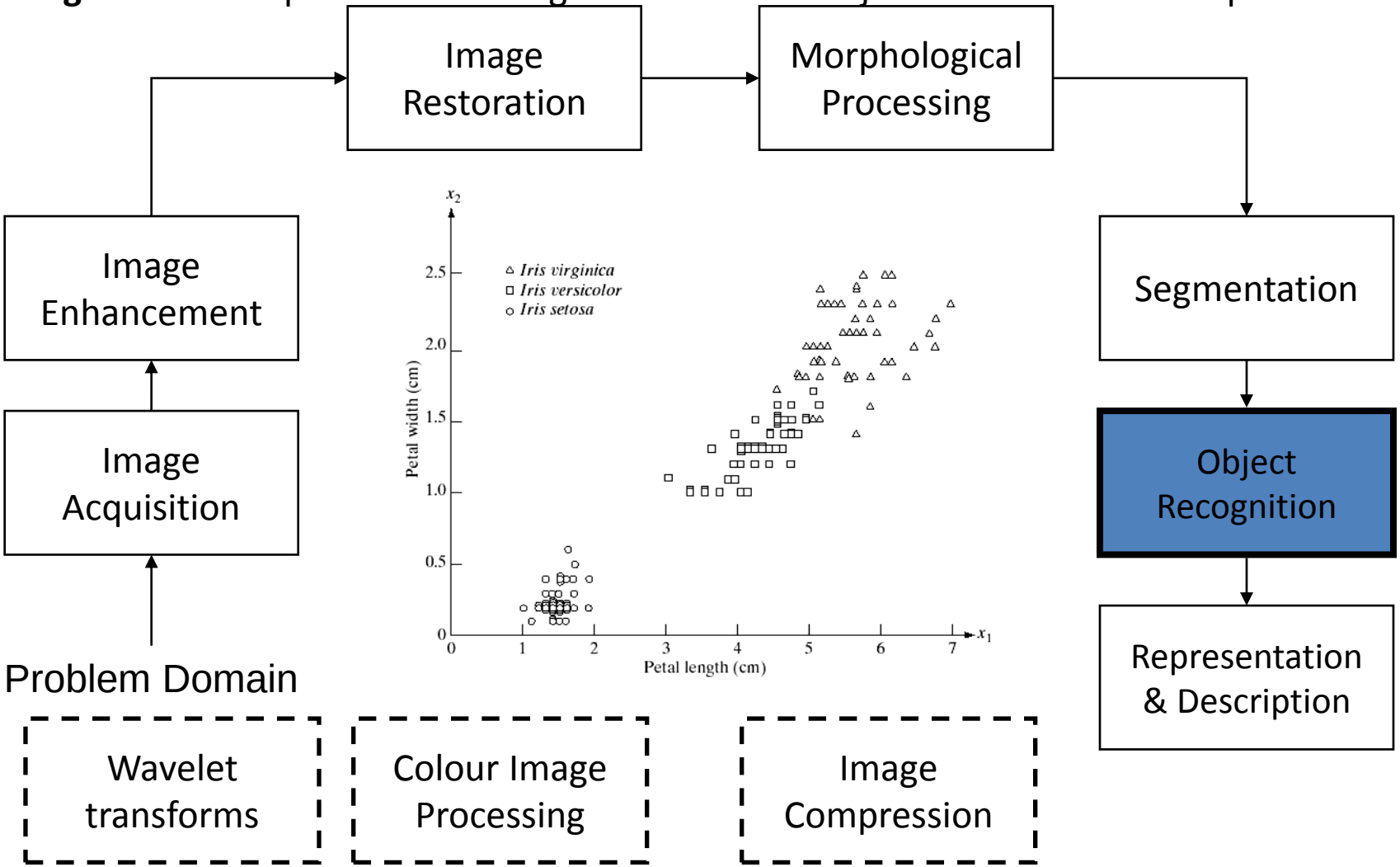
Segmentation partition an image into its constituent parts or objects.

In general, the more accurate the segmentation, the more likely recognition is to succeed.



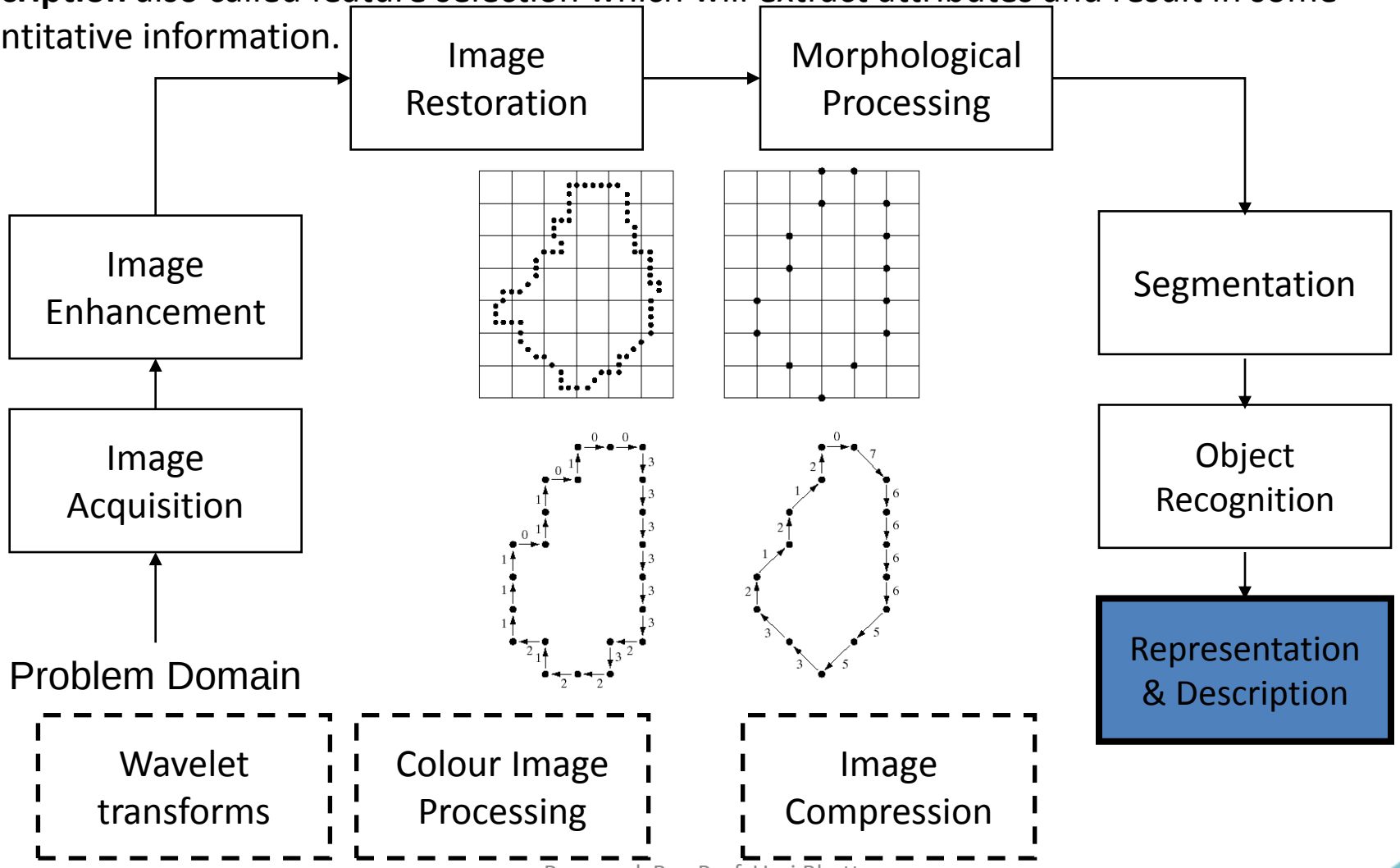
Key Stages in Digital Image Processing: Object Recognition

Recognition is the process that assigns a label to an object based on its descriptor.



Key Stages in Digital Image Processing: Representation & Description

Representation and description almost always follows output of a segmentation stage.
Description also called feature selection which will extract attributes and result in some quantitative information.

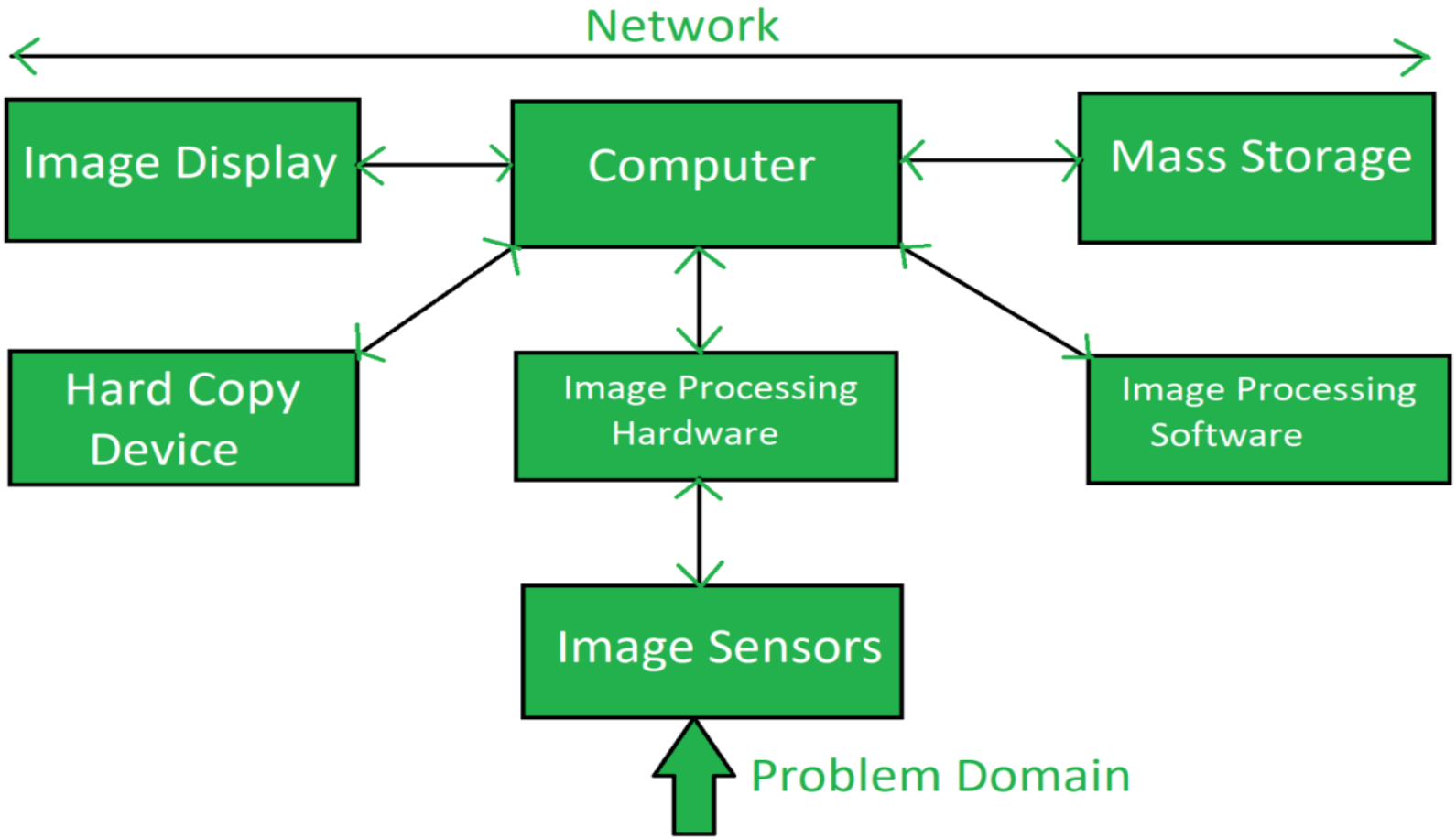


Components of Image Processing System

- Image Processing System is the combination of the different elements involved in the digital image processing.
- Digital image processing is the processing of an image by means of a digital computer. Digital image processing uses different computer algorithms to perform image processing on the digital images.

Components of Image Processing System (Cont.)

- It consists of following components:-



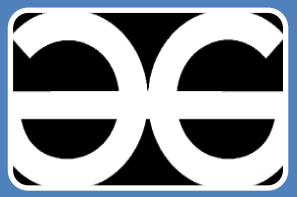
Components of Image Processing System (Cont.)

- Image Sensors:
  - Image sensors senses the intensity, amplitude, co-ordinates and other features of the images and passes the result to the image processing hardware. It includes the problem domain.
- Image Processing Hardware:
  - Image processing hardware is the dedicated hardware that is used to process the instructions obtained from the image sensors. It passes the result to general purpose computer.
- Computer:
  - Computer used in the image processing system is the general purpose computer that is used by us in our daily life.
- Image Processing Software:
  - Image processing software is the software that includes all the mechanisms and algorithms that are used in image processing system.

Components of Image Processing System (Cont.)

- Mass Storage:
  - Mass storage stores the pixels of the images during the processing.
- Hard Copy Device:
  - Once the image is processed then it is stored in the hard copy device. It can be a pen drive or any external ROM device.
- Image Display:
  - It includes the monitor or display screen that displays the processed images.
- Network:
  - Network is the connection of all the above elements of the image processing system.

Types of Image Representation



BINARY IMAGE / BLACK AND WHITE IMAGE

- The binary image as its name suggests, contain only two pixel elements
- i.e 0 & 1,where 0 refers to black and 1 refers to white.
- This image is also known as Monochrome.
- The image which consist of only black and white color is called BLACK AND WHITE IMAGE.

Gray IMAGE / 8 bit COLOR FORMAT

- It is the most famous image format.
- It has 256 different shades of colors in it and commonly known as Grayscale Image.
- In this format, 0 stands for Black, and 255 stands for white, and 127 stands for gray.

Color Image

- 16 bit COLOR FORMAT
  - It is a color image format. , It has 65,536 different colors in it. It is also known as High Color Format. In this format the distribution of color is not as same as Grayscale image.
- 24 bit COLOR FORMAT
  - It is a color image format. It has 2^24 different colors in it.It is also known as RGB Color Format.
  - In this format the distribution of color is not as same as Grayscale image.

Multispectral IMAGE

- The Image contain the information outside the Normal Human perceptual range
- This may include infrared, ultra violate, X-Rays, Radar Data or acoustic data

Types of Image Representation (Cont.)

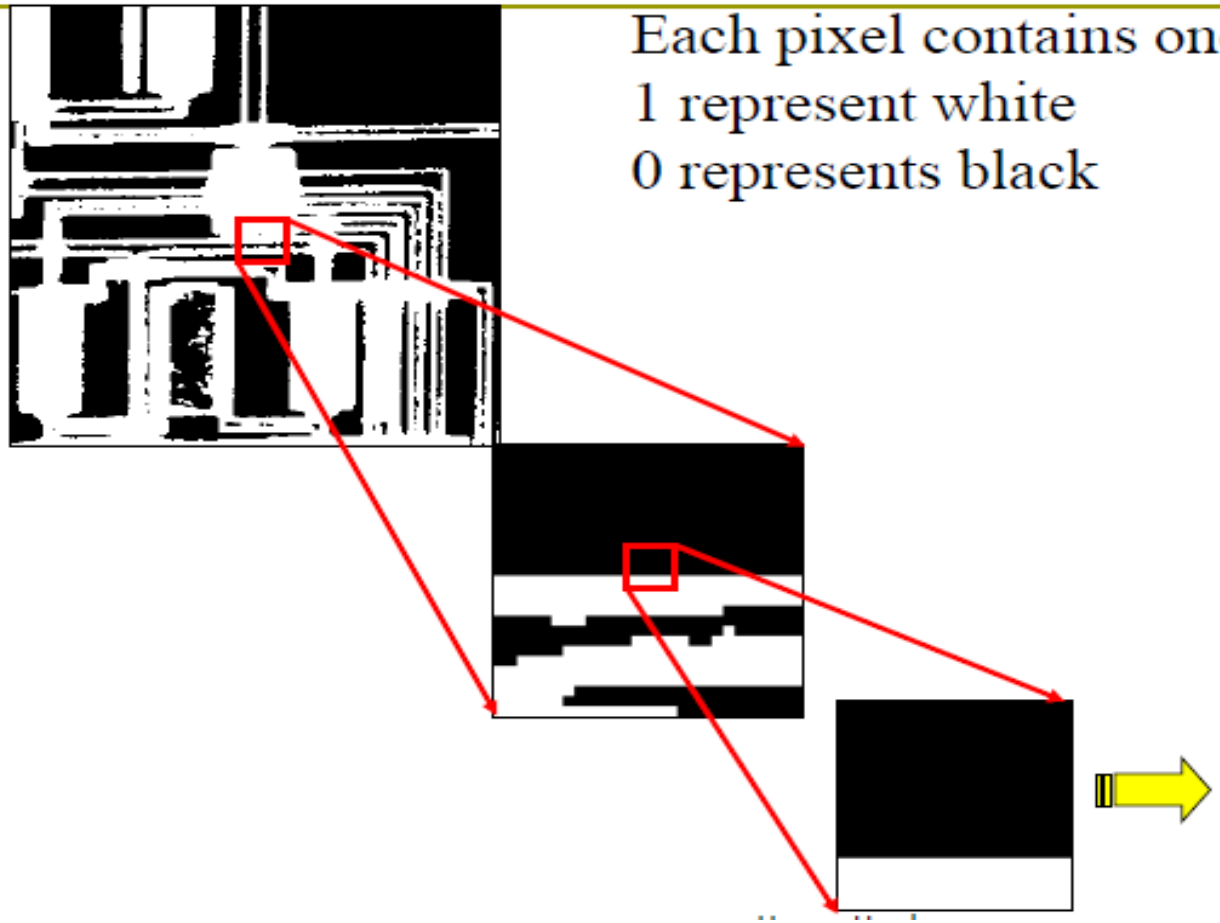
Image Types : Binary Image

Binary image or black and white image

Each pixel contains one bit :

1 represent white

0 represents black



Binary data

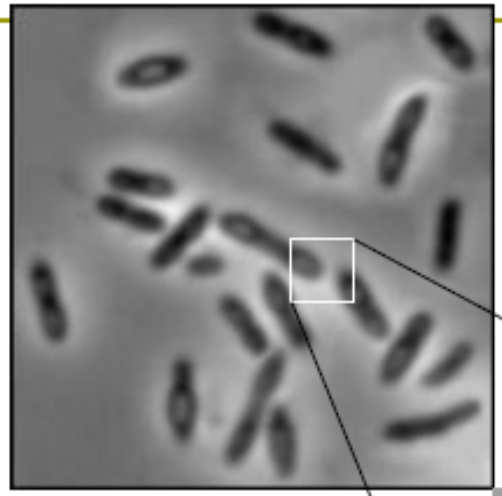
$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Types of Image Representation (Cont.)

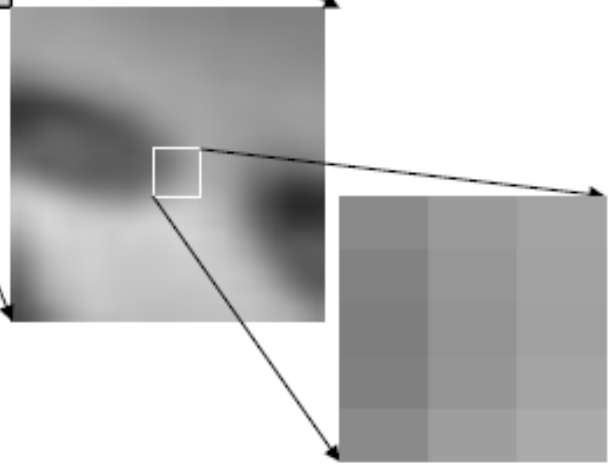
Grayscale Images

- A grayscale (or graylevel) image is simply one in which the only colors are shades of gray (0 – 255)

Types of Image Representation (Cont.)



Intensity (monochrome or gray scale) image each pixel corresponds to light intensity normally represented in gray scale (gray level).



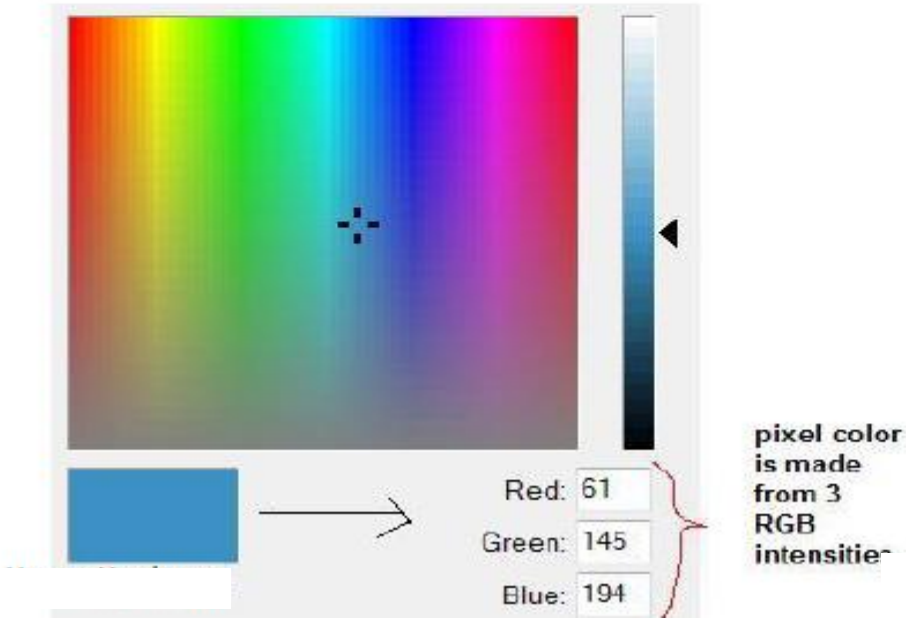
Gray scale values

$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 6 & 26 & 37 \\ 15 & 25 & 13 & 22 \\ 32 & 15 & 87 & 39 \end{bmatrix}$$

Types of Image Representation (Cont.)

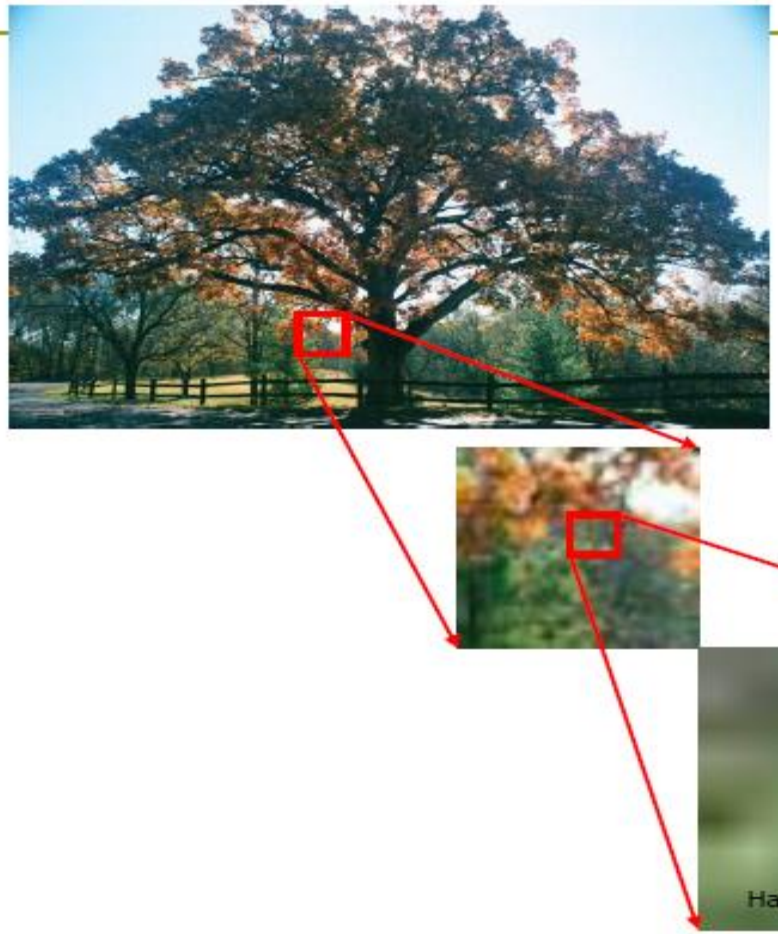
Color Images

- Color image: A color image contains pixels each of which holds three intensity values corresponding to the red, green, and blue or(RGB)



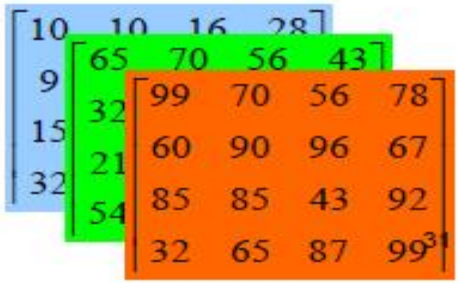
Types of Image Representation (Cont.)

Digital Image Types : RGB Image



Color image or RGB image: each pixel contains a vector representing red, green and blue components.

RGB components



Types of Image Representation (Cont.)

8 Bit Color Format

- Known as Gray scale Image
- Use to store Image Information
- Range: 0 to 255
- Red Bit – 3, Green Bit – 3 Blue Bit - 2
- Used By: Unix OS
- Extension: PGM (Portable Gray Map)

16 Bit Color Format

- Known as High color Format
- Red Bit – 5, Green Bit – 6 Blue Bit - 5
- Range: 0 to 65535
- Used By: Microsoft

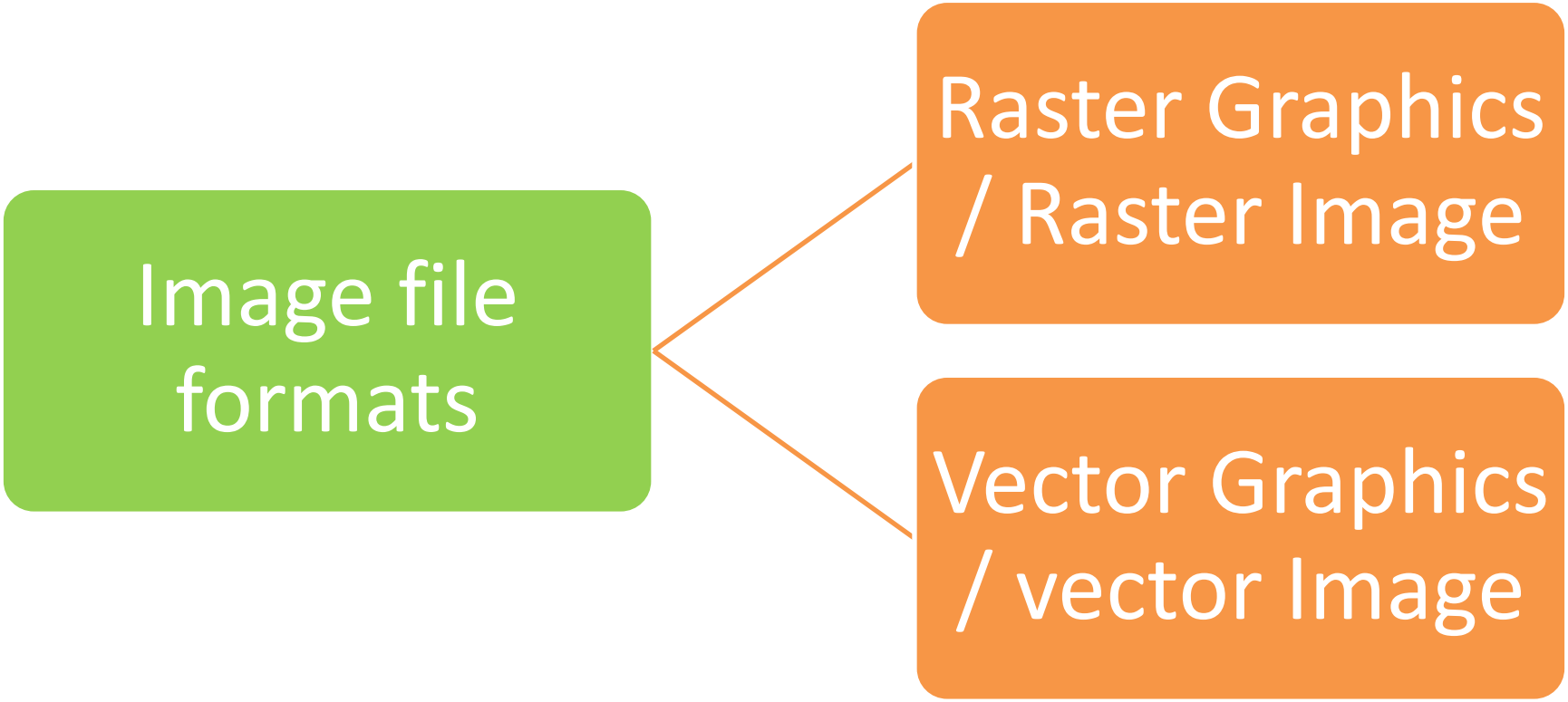
24 Bit Color Format

- True Color Format
- Most common used Format
- Red Bit – 8, Green Bit – 8 Blue Bit - 8
- Extension: PPM (Portable PixMap) – for Linux , BMP (BitMap) – for Windows

Pixel & Bitmap

- Pixel
  - In Computer graphics a pixel, dots, or picture element is a physical point in a picture.
  - A pixel is simply the smallest addressable element of a picture represented on a screen.
- Bitmap
  - In computer graphics, a bitmap is a mapping from some domain (for example, a range of integers) to bits, that is, values which are zero or one.
  - It is also called a bit array or bitmap index.
  - The more general term pixmap refers to a map of pixels, where each one may store more than two colors, thus using more than one bit per pixel. Often bitmap is used for this as well.

Image file formats



Raster Graphics VS Vector Graphics

Raster	Vector
Raster images are also known as Bitmap images and are made up of small dots known as pixels.	Vector images are made up of lines, fills, and curves.
In Raster, pixels of the same colour or different colour are placed close to each other so that the human eye perceives them as pictures but not as dots.	Vector images are collections of elements such as lines, rectangles, circles, and square. Each vector element has its own coordinates and can be resized.
Raster image knows the colour of each pixel.	The vector consists of instructions on where to place its components.
Raster has only two colours, black or white. With an increase in complexity, it can contain more colours.	Vectors use mathematical formulas in describing colours, shapes, and placement.
Raster images have a wide range of colour gradations and less scalable than Vector images.	Vector images are much more scalable than Raster images.

Raster Graphics VS Vector Graphics

Marwadi University

Raster	Vector
File formats extension for raster: XBM, TIFF, PCX, and bitmap fonts .tif .tiff: Tagged Image File Format .jpg .jpeg: Joint Photographic Experts Group .psd: Photoshop Document .gif: Graphics Interchange Format .bmp: Bitmap image file .png: Portable Network Graphics XBM: X Bitmap Graphic file PCX: PiCture eXchange	File format extension for Vector:, PICT, WMF, PostScript, TrueType .eps: Encapsulated PostScript .ai: Adobe Illustrator Artwork .cdr: CorelDraw .svg: Scalable Vector Graphics .pdf: Portable Document Format
The conversion of raster to vector is time-consuming and based on complexity.	A vector image can be easily converted to a bitmap image.
Some of the raster programs include photo editing, Photoshop, GIMP, paint shop.	Vector programs include Illustrator, Inkscape, CorelDraw.
A kind of Raster file can be easily converted to another and high processing speed	Vectors are difficult to modify or display if not opened in programs that understand vector and having low processing Speed

Raster Graphics VS Vector Graphics

Raster	Vector
When the user paints a raster image, it looks similar to dipping brush in paint and painting images.	When the user paints a vector image, only the outline of the shape is painted. Similar to creating an image with different tiles of different shapes and sizes.
On enlarging a raster image without a change in pixel count, the image looks blurry. Enlarging file with increasing in pixel count, which may produce better results comparatively.	On enlarging a vector image, mathematical formulas remain the same, scalable to any size.
Raster programs are best suitable for photo editing, the creation of a continuous toned image with soft colour.	Vectors are best suitable for drawings, creating logos, illustrations, and technical drawings
A huge dimension and fair detailed image produce a large size of the image.	Vectors are resolution dependent, can be printed at any size or resolution.
Difficult to print raster images using limited spot colours.	In vector, the numbers of colours can be increased or decreased for printing.

Question

Digital Image is Raster Graphics or Vector Graphics ?

Digital Image

- A digital image is a numeric representation (normally binary) of a two-dimensional image. Depending on whether the image resolution is fixed.

- The term "digital image" usually refers to raster images or bitmapped images

System

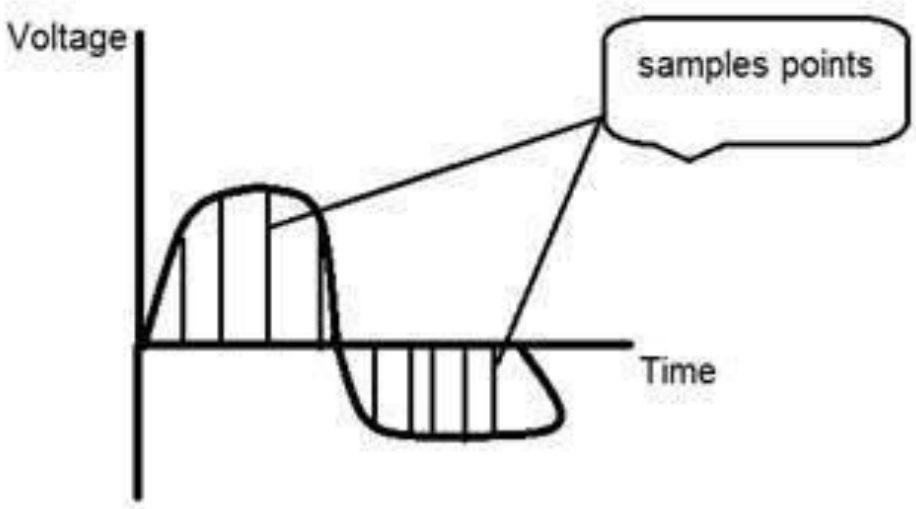
- A system is a defined by the type of input and output it deals with.
- The input is known as excitation and the output is known as response.

Conversion of Analog to Digital signals

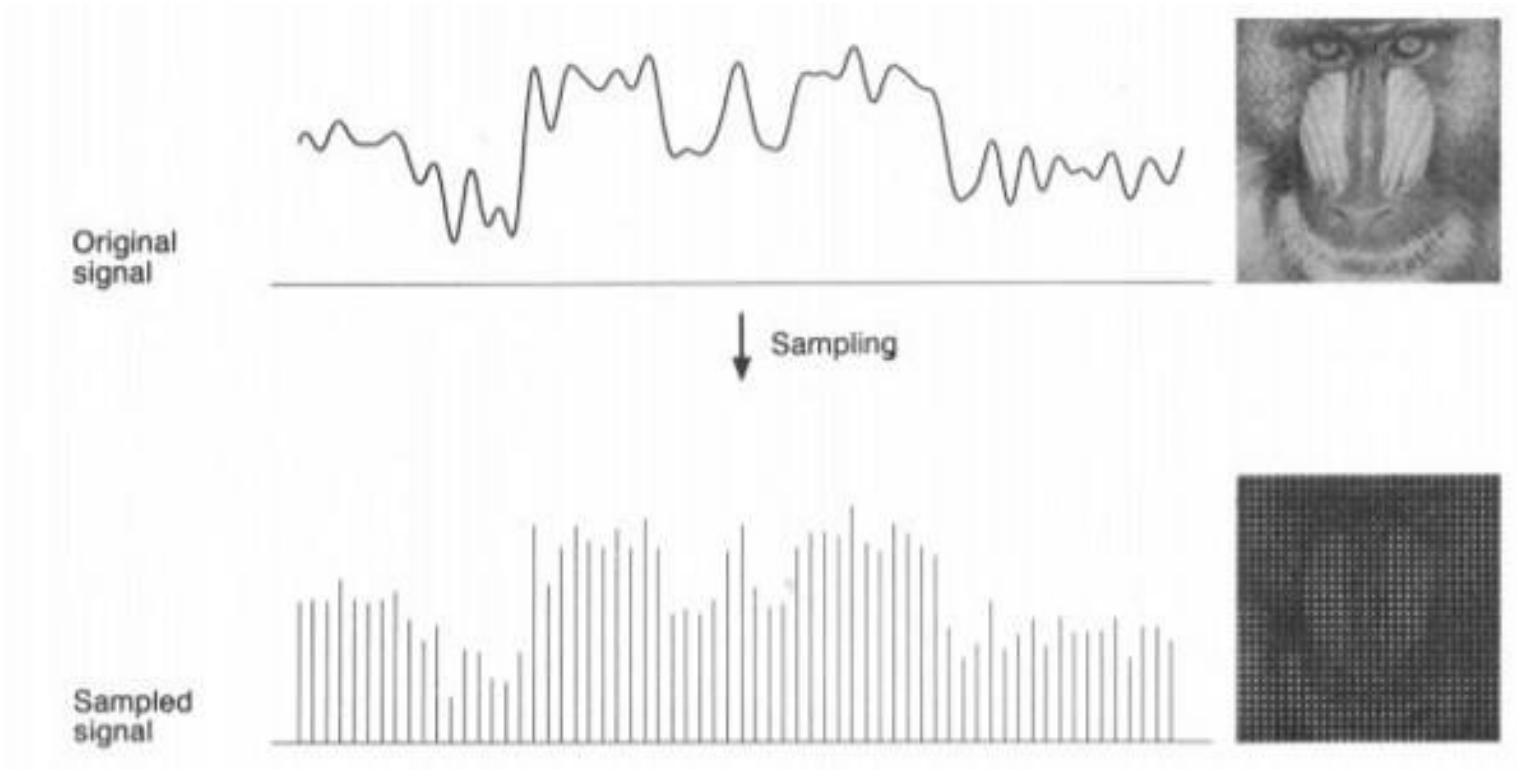
- There two main concepts that are involved in the conversion.
  - Sampling
  - Quantization

Sampling

- Sampling as its name suggests can be defined as take samples.
- Take samples of a digital signal over x axis.
- Sampling is done on the x variable.

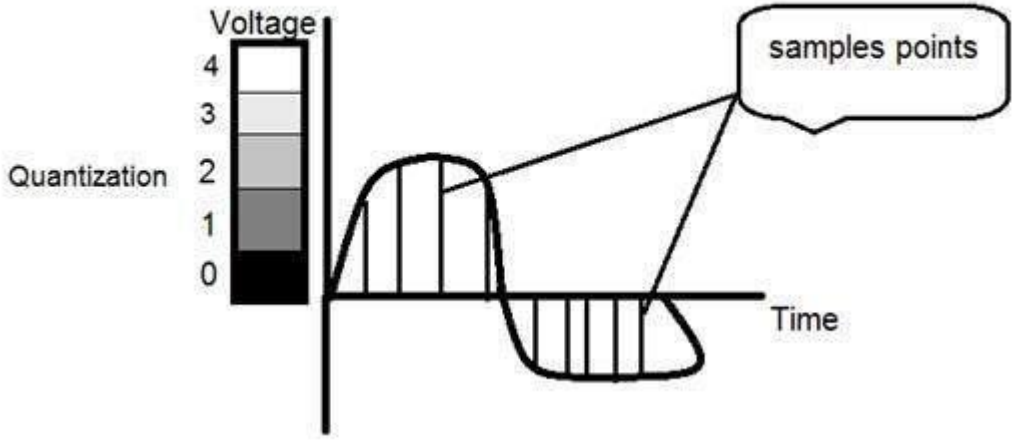


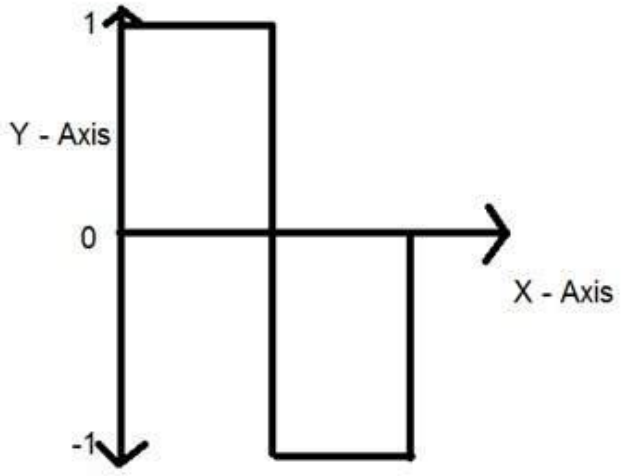
Sampling (Cont.)



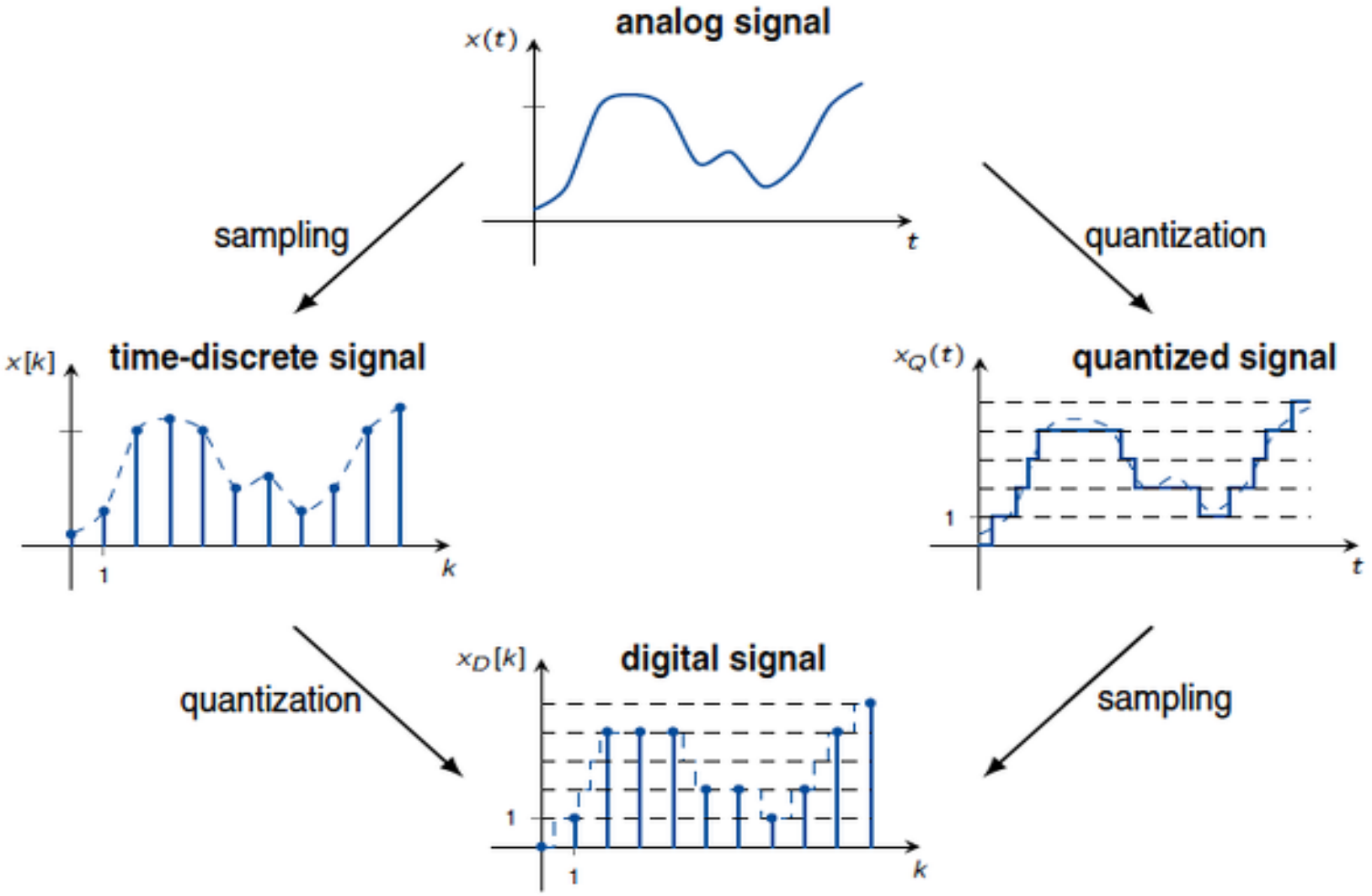
Quantization

- Quantization as its name suggest can be defined as dividing into quanta (partitions).
- It is opposite to sampling.
- Sampling is done on the x variable.





Sampling VS Quantization



Concept of Bits Per Pixel

- BBP – Bits per Pixel
- It is used to denote the no of bits per Pixel

$$\text{No. of Colors or Shades} = 2^{BPP}$$

Concept of Bits Per Pixel (Cont.)

Marwadi University

Suppose a pixel has 1 bit, how many no of color that Image have?

Answer:

- 2 intensity levels only, black and white.

  No. of Colors or Shades = $2^{BPP} = 2^1 = 2$

- Bit (0,1)
  - 0:black
  - 1: white

Concept of Bits Per Pixel (Cont.)

Marwadi University

Suppose a pixel has 2 bit, how many gray levels can it represent?

Answer:

- 4 gray intensity levels
- No. of Colors or Shades = $2^{BPP} = 2^2 = 4$
- 2 Bit So Combinations - (00, 01, 10 ,11).

Concept of Bits Per Pixel (Cont.)

Marwadi University

Suppose if we want to represent 256 No of Colors, how many bits do we need?

Answer:

- No. of Colors or Shades = $2^{BPP} = 2^8 = 256$
- 8 bits are required

Image Size / Number of storage of bits

Image Size = No. of Rows * No. of Cols. * BPP bits

1 Byte = 8 bit

Example: Rows : 3000, Col.: 1687, Shades: 256, Find the Size of Image

- No. of Colors or Shades = $2^{BPP} = 2^8 = 256$
- BPP = 8

Image Size = No. of Rows * No. of Cols. * BPP

= 3000 * 1687 * 8

= 40488000 bits

= 40488000 / 8 Byte = 5061000 Byte

= 5061000 / 1024 KB = 4942 KB

= 4942 / 1024 MB = 4 MB

Image Size / Number of storage of bits (Cont.)

Image Size = No. of Rows * No. of Cols. * BPP

Example: Rows : 1024, Col.: 1024 , BPP = 8, Find the Size of Image

Image Size = No. of Rows * No. of Cols. * BPP

= 1024 * 1024 * 8

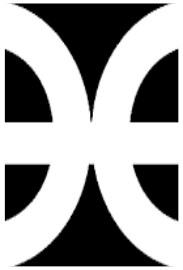
= 8388608 bits

= 8388608 / 8 Byte = 1048576 Byte

= 1048576 / 1024 KB = 1024 KB

= 1024 / 1024 MB = 1 MB

Color Code Conversion



Binary Color Format

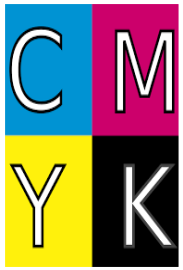
- Black – RGB (0 , 0 , 0)
- While – RGB (255 , 255 , 255)

Gray Color Format

- Gray– RGB (127, 127 , 127)

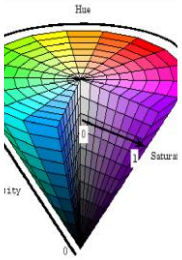
RGB Color Format (Red, Green, Blue)

- Red– RGB (255 , 0 , 0)
- Green– RGB (0, 255 , 0)
- Blue– RGB (0, 0 , 255)



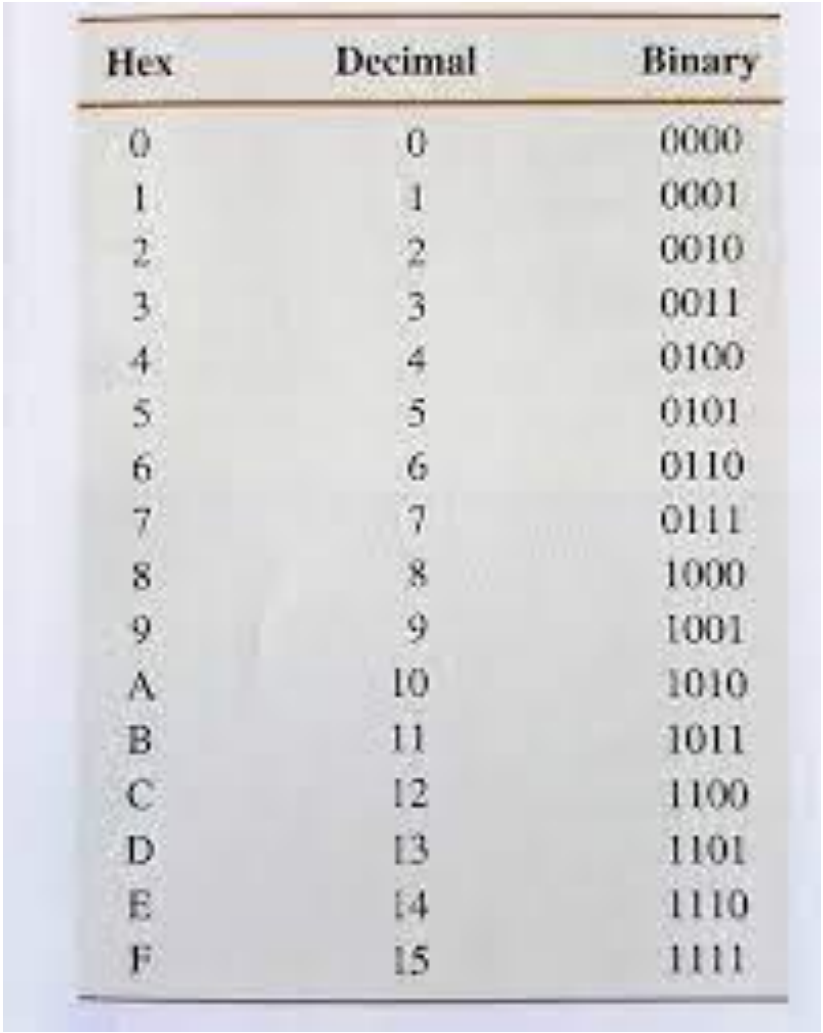
CMYK Color Format (Cyan, Magenta, Yellow, Black)

- Cyan– RGB (0 , 255 , 255)
- Magenta– RGB (255, 0 , 255)
- Yellow– RGB (255, 255 , 0)



HSI Color Format (Hue, Saturation, Intensity)

RGB to Hex Code Conversion



Hex	Decimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
A	10	1010
B	11	1011
C	12	1100
D	13	1101
E	14	1110
F	15	1111

RGB	Hex
(255, 255, 255)	#FFFFFF
(255, 0 , 255)	#FF00FF
(255, 255, 0)	#FFFF00
(0, 255, 255)	#00FFFF
(0, 0 , 0)	#000000
(127 , 127 , 127)	#7F7F7F
(128 , 128 , 128)	#808080
(190 , 121 , 163)	#BE79A3
(201 , 182 , 95)	#C9B65F

Grayscale to RGB Conversion

Marwadi University

- To convert a grayscale image into color or RGB format, we have two methods.
  - Average method
  - Weighted method or luminosity method

Average Method

- It is the simplest method. We have to take an average of all the 3 colors.
- **Formula:** (R + G + B)/3

Explanation

As we can see, there are changes in the image by applying the average method. But the result is unexpected as we want a grayscale image, but it turned to be a black image.

RGB image

Grayscale image

Average Method (Cont.)

- **Problem**
  - This problem occurs because we have taken an average of 3 colors.
  - All the 3 colors have different wavelength and have their contribution to the formation of an image. In the above image, we are taking 33% from each portion that is why the image does not occur in grayscale.
- The solution to this problem is given by the weighted method.

Weighted Method or luminosity Method

- As we have seen the problem in the average method. And for this problem weight method is the solution.
- In all the 3 portions of color, red color has more wavelength, and green color has less wavelength. But green color gives a more soothing effect to the eyes as compared to red color.
- By decreasing the value of red color and increasing the value of green color and the value for blue color will be between these two colors.
- The equation for a new grayscale image will be:

$$X = (0.3 * R) + (0.59 * G) + (0.11 * B)$$

Weighted Method or luminosity Method (Cont.)

- According to the above equation, red is used 30%, green is used 59%, and blue is used 11%. The contribution of green is highest.
- By Applying the equation in an image, we will get:

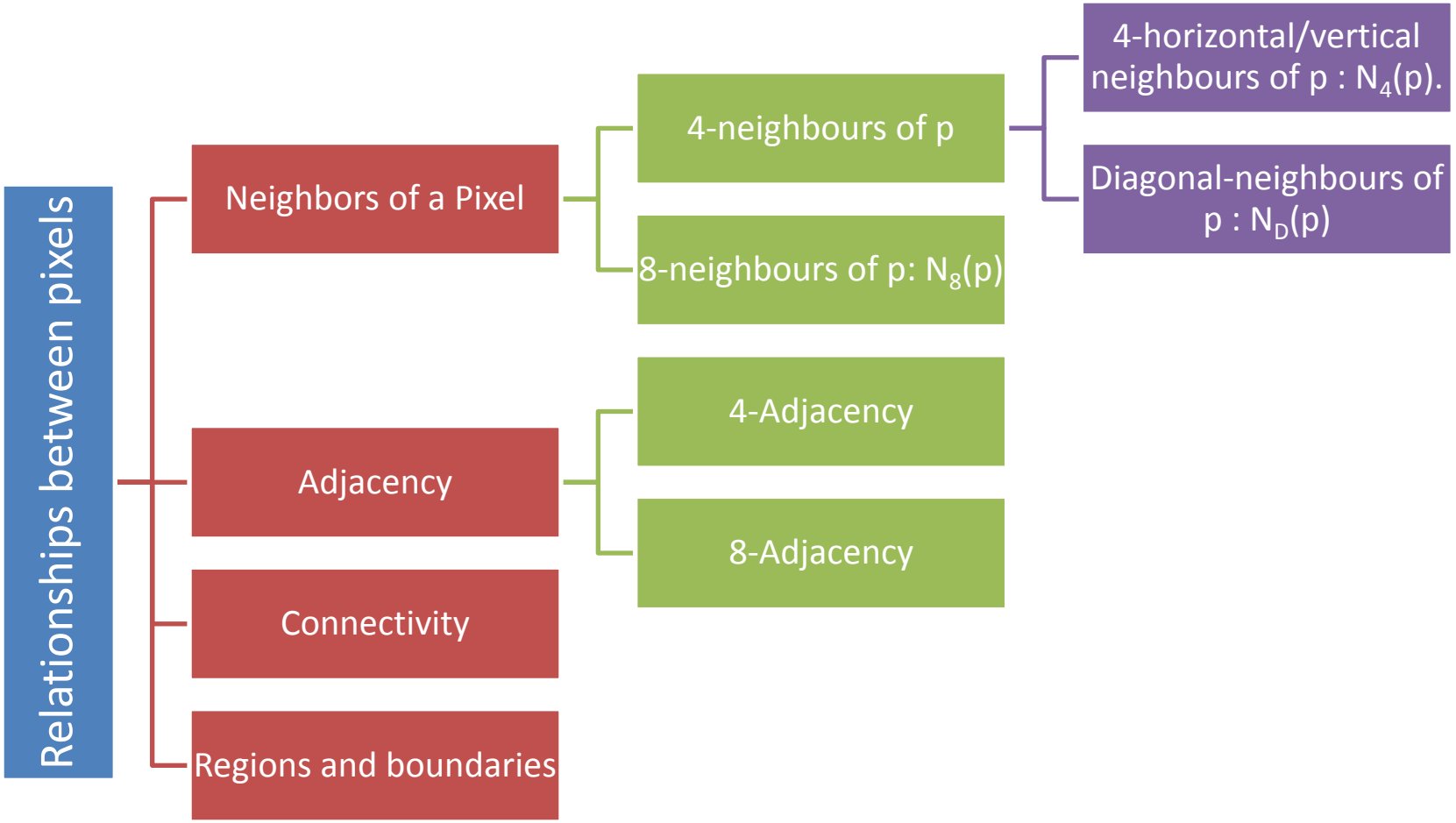
Explanation

As we can see using the weighted method the image is properly converted into grayscale. Image is brighter as compared with the image which was generated using the average method.

Original Image

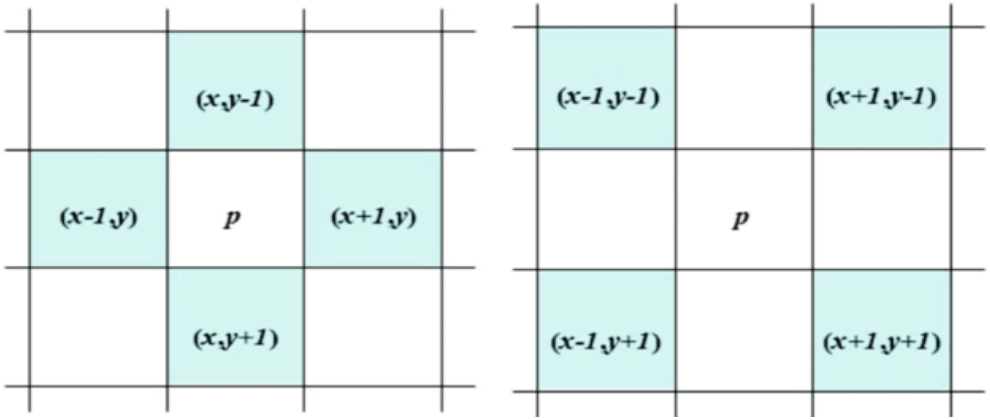
Grayscale Image

Some basic Relationships between Pixels



Neighbors of a Pixel

- **4-neighbours of p**
  - **4-horizontal/vertical neighbours of p : $N_4(p)$**
    - A pixel p at (x,y) has 4-horizontal/vertical neighbours at (x+1,y), (x-1,y), (x,y+1) and (x,y-1).
  - **Diagonal-neighbours of p : $N_D(p)$**
    - A pixel p at (x,y) has 4 diagonal neighbours at (x+1,y+1), (x+1,y-1), (x-1,y+1) and (x-1,y-1).



Neighbors of a Pixel

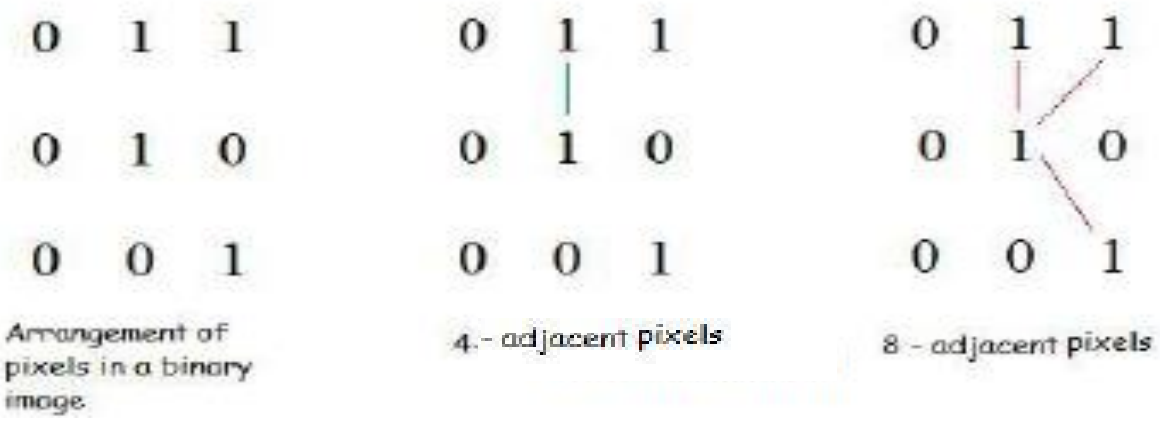
- **8-neighbours of p**
  - The 4-neighbours and the diagonal neighbours of p are called **8-neighbours of p : $N_8(p)$.**
  - A pixel p at (x,y) has 4-horizontal/vertical neighbours at (x+1,y), (x-1,y), (x,y+1), (x,y-1) + 4 diagonal neighbours at (x+1,y+1), (x+1,y-1), (x-1,y+1) , (x-1,y-1).

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

8-neighbourhood

Adjacency

- *V*: set of gray level values (L), (V is a subset of L.)
  - 4- adjacency: 2 pixels *p* and *q* with values from *V* are 4- adjacent if *q* is in the set $N_4(p)$
  - 8- adjacency: 2 pixels *p* and *q* with values from *V* are 8- adjacent if *q* is in the set $N_8(p)$



Connectivity

- Two pixels p and q are said to be connected in S if there exists a path between them consisting entirely of pixels in S.

Regions and boundaries

- **Region**
  - Let R be a subset of pixels in an image, we call R a region of the image if R is a connected set.
- **Boundary**
  - The boundary (also called border or contour) of a region R is the set of pixels in the region that have one or more neighbors that are not in R.

Distance Measures

- If we have 3 pixels: p,q,z respectively
  - p with (x,y)
  - q with (s,t)
  - z with (v,w)

Then:

1. $D(p,q) \geq 0$, $D(p,q) = 0$ iff $p = q$
2. $D(p,q) = D(q,p)$
3. $D(p,z) \leq D(p,q) + D(q,z)$

Distance Measures (Cont.)

Euclidean Distance: $D_e(p,q) = \sqrt{(x-s)^2+(y-t)^2}$

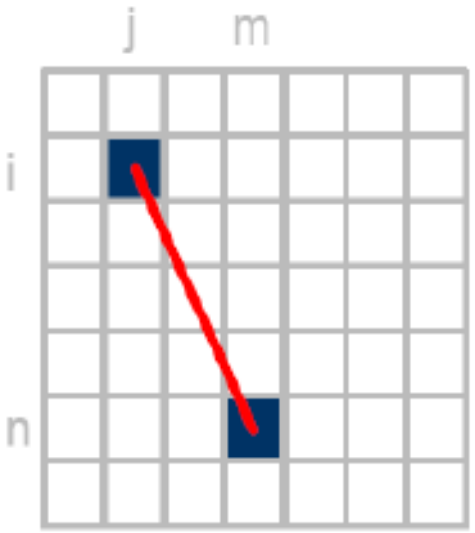
City-Block Distance : $D_4(p,q) = |x-s| + |y-t|$

Chessboard Distance) $D_8(p,q) = \max(|x-s|, |y-t|)$

D_m Distance

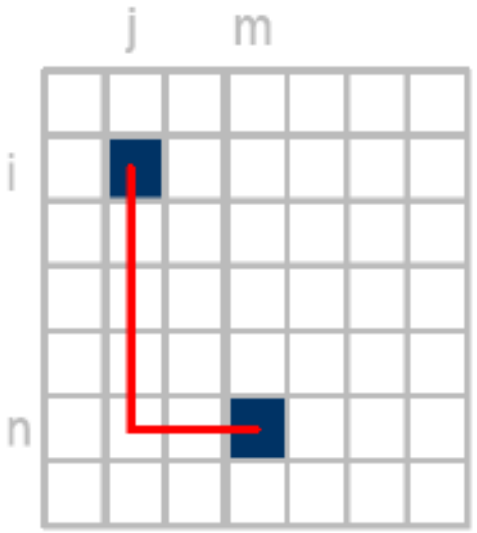
- It is Defined as a shortest m=path between pointes.
- In this case, the distance between two pixels will depend on the values of the pixels along the path, as well as the values of their neighbors.

Distance Measures (Cont.)



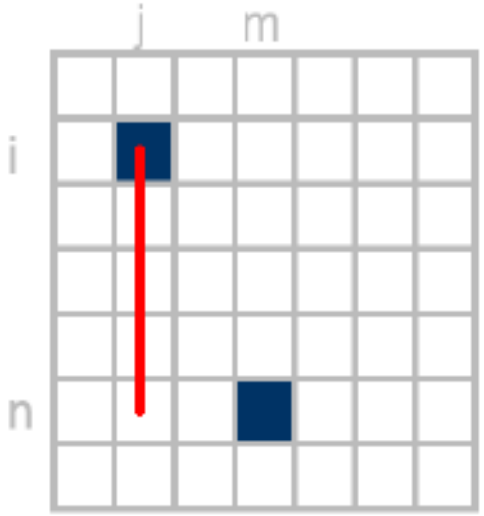
Euclidean Distance

$$= \sqrt{(i-n)^2 + (j-m)^2}$$



City Block Distance

$$= |i-n| + |j-m|$$

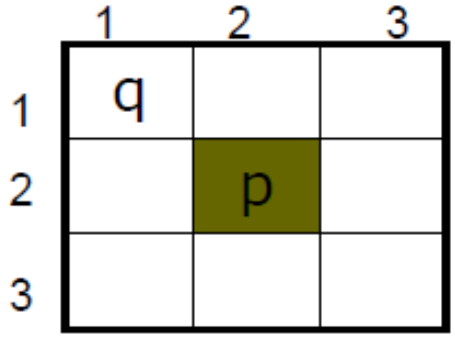


Chessboard Distance

$$= \max[\, |i-n|, |j-m| \,]$$

Distance Measures (Cont.)

Example: Compute Euclidian distance , City Block distance and chessboard distance between the two pixels using the three distances



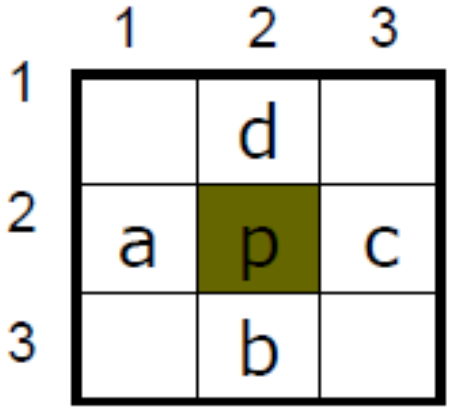
Answer:

- q:(1,1)
- P: (2,2)
- Euclidian distance : ((1-2)2+(1-2)2)1/2 = sqrt(2).
- D4(City Block distance): |1-2| +|1-2| =2
- D8(chessboard distance) : max(|1-2|,|1-2|)= 1

Distance Measures (Cont.)

Example :

Use the city block distance to prove 4-neighbors ?



Pixel A : | 2-2| + |1-2| = 1

Pixel B: | 3-2|+|2-2|= 1

Pixel C: |2-2|+|2-3| =1

Pixel D: |1-2| + |2-2| = 1

Now as a homework try the chessboard distance to proof the 8- neighbors!!!!

Distance Measures (Cont.)

Q-1 An image segment is shown below Let V be the set of gray level values used to define connectivity in the image compute D_4, D_8 and D_m distance between pixels P and Q for

V = {2, 3}

V = {2, 6}

(0,0) (P)	2	3	2	6	1
	6	2	3	6	2
	5	3	2	3	5
	2	4	3	5	2
	4	5	2	3	6 (Q) (4,4)

Distance Measures (Cont.)

Marwadi University

distance

(o-ordinates of $p(x, y) = (0, 0)$

$q(s, t) = (4, 4)$

$D_4(P, Q) = |x - s| + |y - t|$

$= |0 - 4| + |0 - 4|$

$= |-4| + |-4|$

$= 4 + 4$

$= 8$ units.

$D_8(P, Q) = \max(|x - s|, |y - t|)$

$= \max(|0 - 4|, |0 - 4|)$

$= \max(4, 4)$

$= 4$ units.

Distance Measures (Cont.)

① $V = \{2, 3\}$

D_m.

$p = 2$,
$q = 6$ → but in $V = \{2, 3\}$ 6 is not included.
for making connections only 2, 3 can include.

~~Ato~~ → There is no path between p and q, as q (6) is not included in the set V.

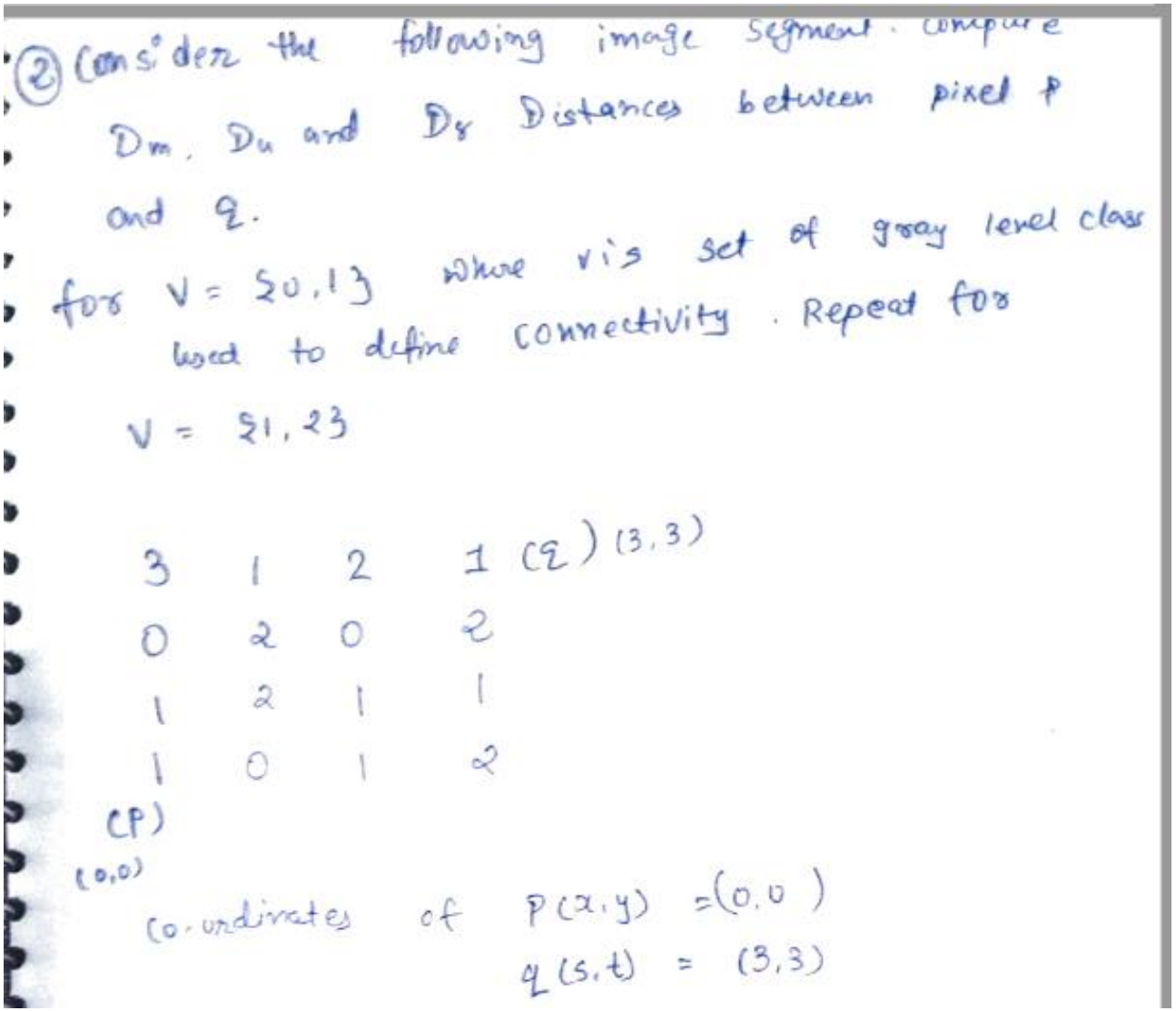
② $V = \{2, 6\}$

Traverse 2 and 6 to reach.
There is no path between p and q.

(1)

2	3	2	6	1
6	2	3	6	2
5	3	2	3	5
2	4	3	5	2
4	5	2	3	6 (2)

Distance Measures (Cont.)



(2) Consider the following image segment. Compute Dm, Du and Dd Distances between pixel p and q.

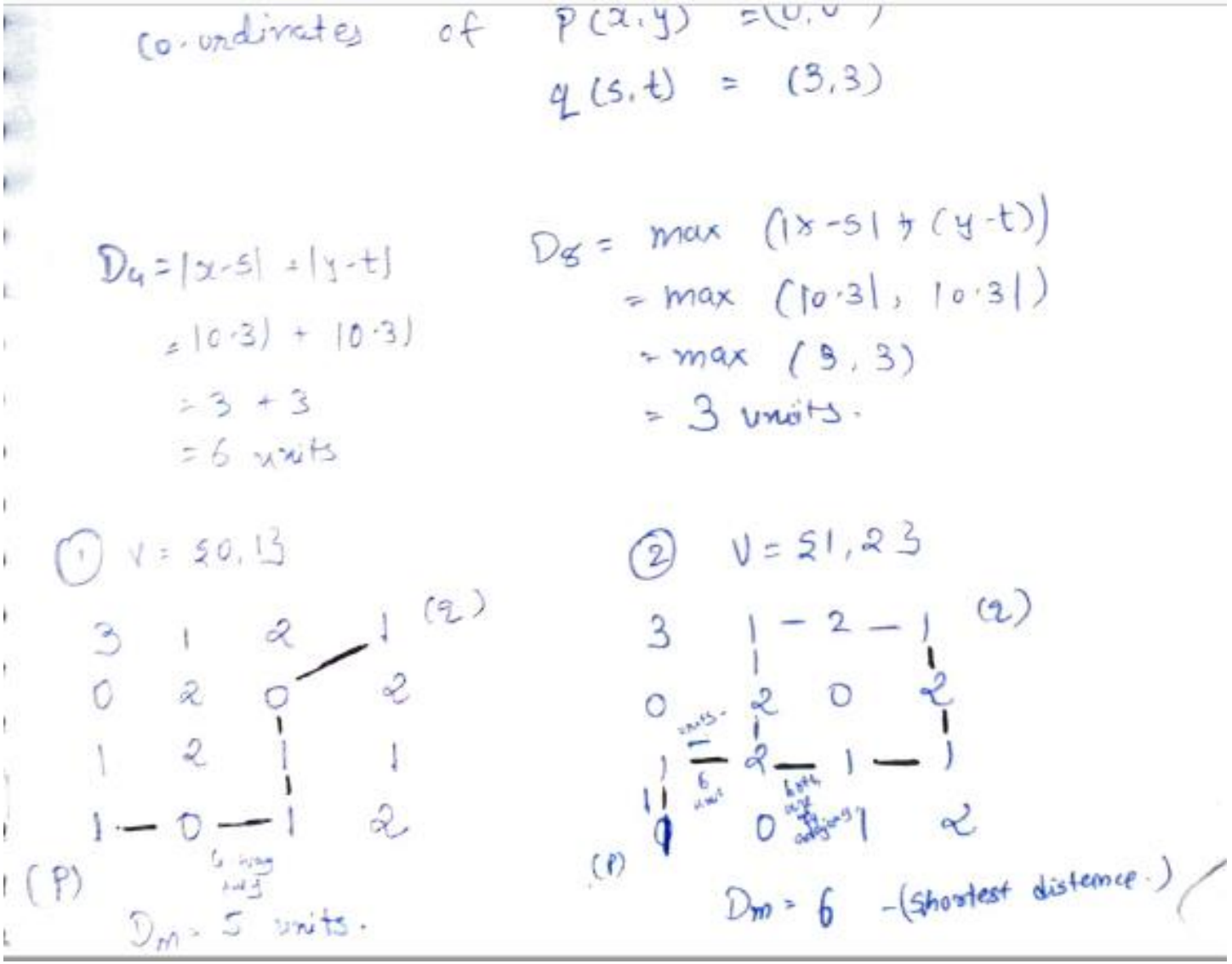
for V = {0,1} where V is set of gray level class used to define connectivity. Repeat for V = {1,2}

3	1	2	1 (q) (3,3)
0	2	0	2
1	2	1	1
1	0	1	2

(p)
(0,0)

Co-ordinates of P(x,y) = (0,0)
q(s,t) = (3,3)

Distance Measures (Cont.)



Distance Measures (Cont.)

(3) Compute the distance between two pixels using the three distances:

$q = (1, 1)$

$p = (2, 2)$

Euclidian Distance $= \left[(1-2)^2 + (1-2)^2\right]^{1/2}$

$= \text{sqrt}(2)$

D_4 (City Block distance) $= |1-2| + |1-2| = 2$

D_8 (chess board distance) $= \max(|1-2|, |1-2|) = 1.$


Thank
you