CST 304
Computer Graphics & Image Processing
Module - 4
Fundamentals of Digital Image Processing

SYLLABUS

- Introduction to Image Processing and applications.
- Image as 2D data. Image representation in Gray scale, Binary and Colour images.
- Fundamental steps in Image Processing. Components of image processing system. Coordinate conventions. Sampling and quantization. Spatial and Gray Level Resolution.
- Basic relationship between pixels– Neighbourhood, Adjacency, Connectivity.
- Fundamentals of spatial domain- Convolution operation.

IMAGE PROCESSING – Fundamentals

- Image processing involves processing or altering an existing image in a desired manner.
- **Digital Image Processing - Two major tasks :**
  - Improvement of pictorial information for human interpretation
  - Processing of image data for storage, transmission and representation for autonomous machine perception
- **Need of image processing:-**
  - Since the digital image is “invisible” it must be prepared for viewing on one or more output device (laser printer, monitor, etc)
  - The digital image can be optimized for the application by enhancing or altering the appearance of structures within it (based on: body part, diagnostic task, viewing preferences, etc)
  - It might be possible to analyze the image in the computer and provide cues to the radiologists to help detect important/suspicious structures (e.g.:Computed Aided Diagnosis, CAD)

Image Processing Fields

- Computer Graphics: Creation of images
- Image Processing: Enhancement or other manipulation of the image
- Computer Vision: Analysis of the image content

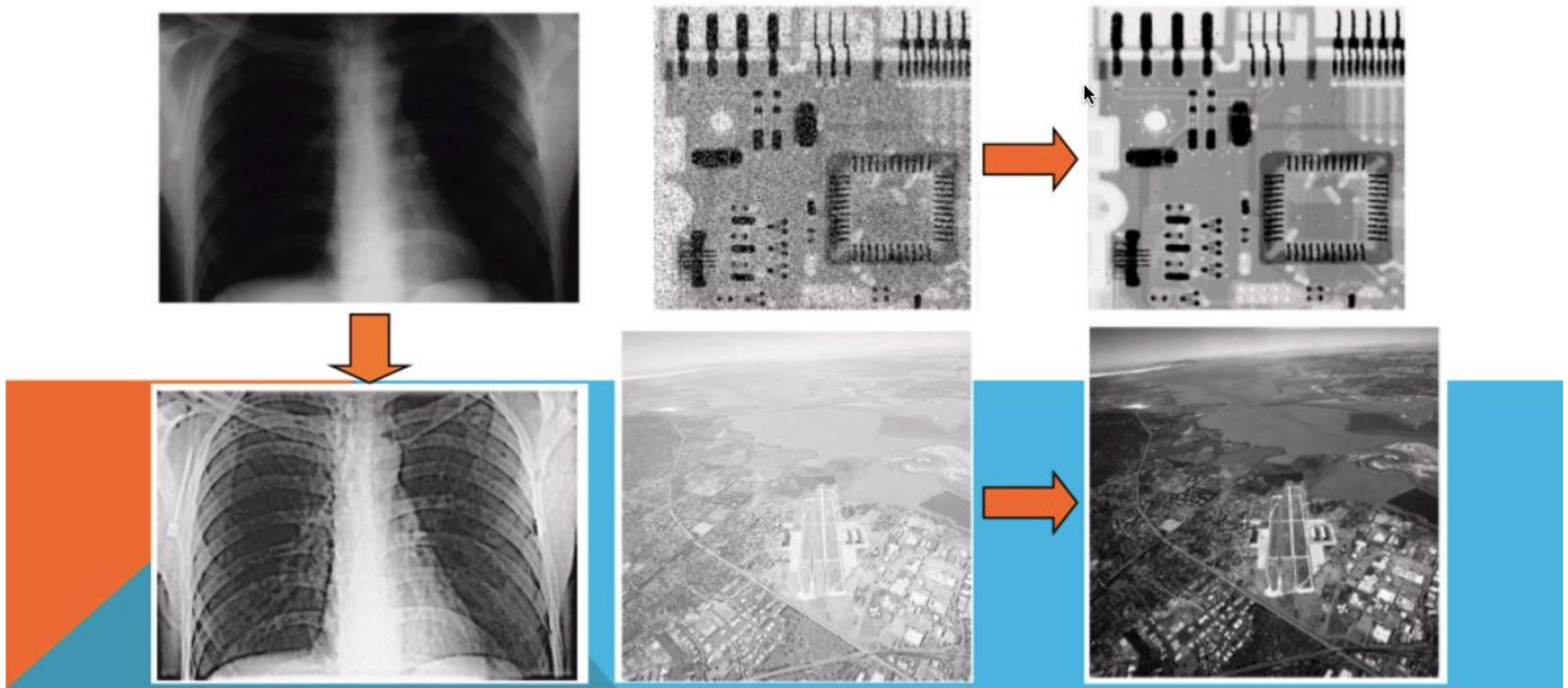
The continuum from image processing to computer vision can be broken up into low, mid and high-level processes.s

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

Applications

Image Enhancement

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



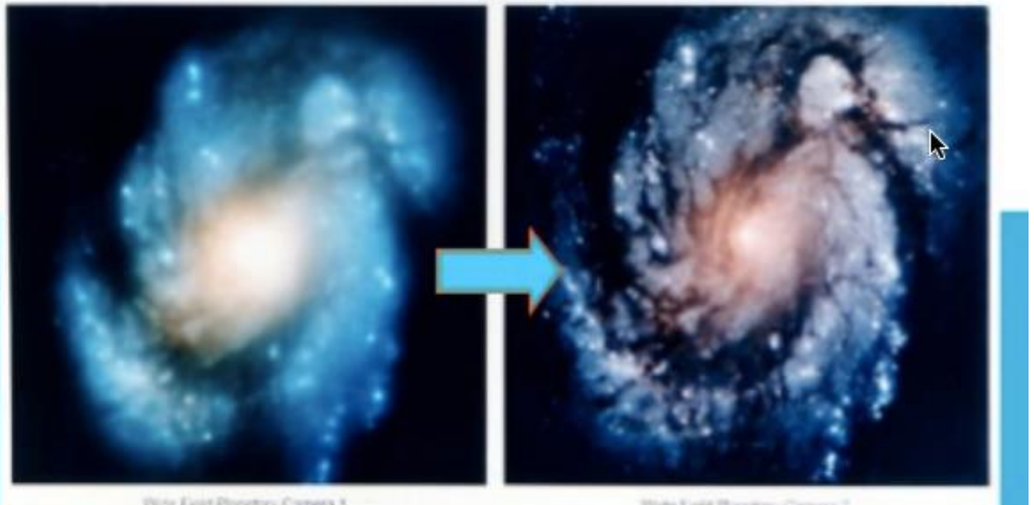
Applications

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



Applications

Artistic Effect

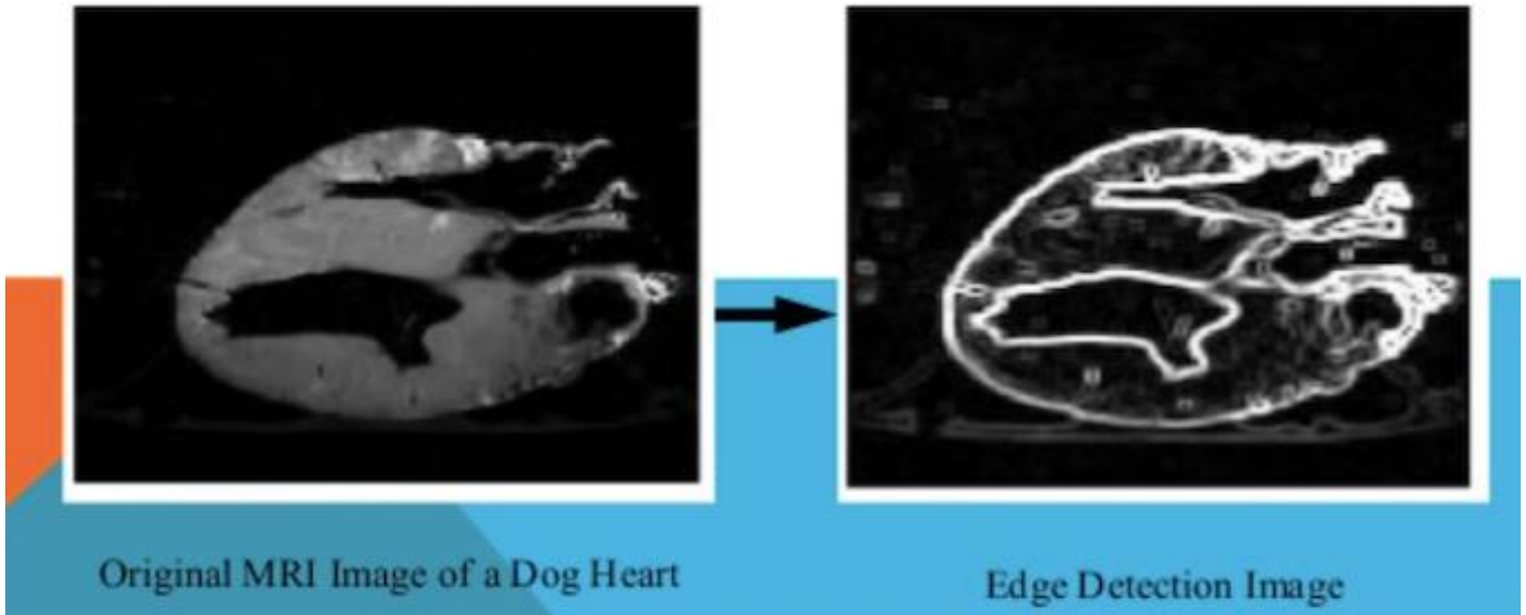
Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

Applications

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

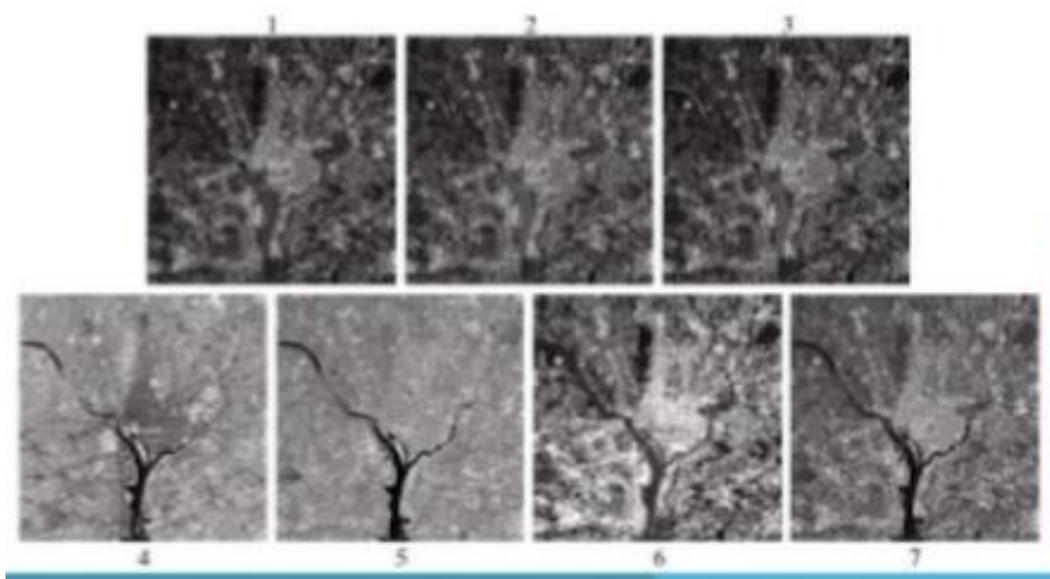


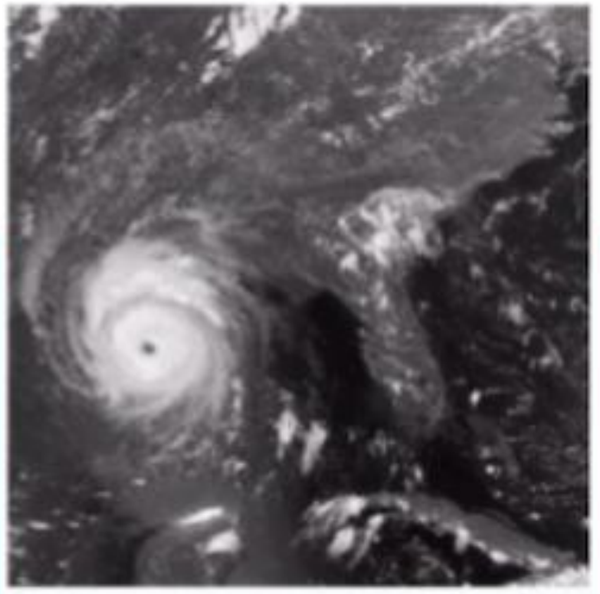
Applications

GIS

Geographic Information Systems

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





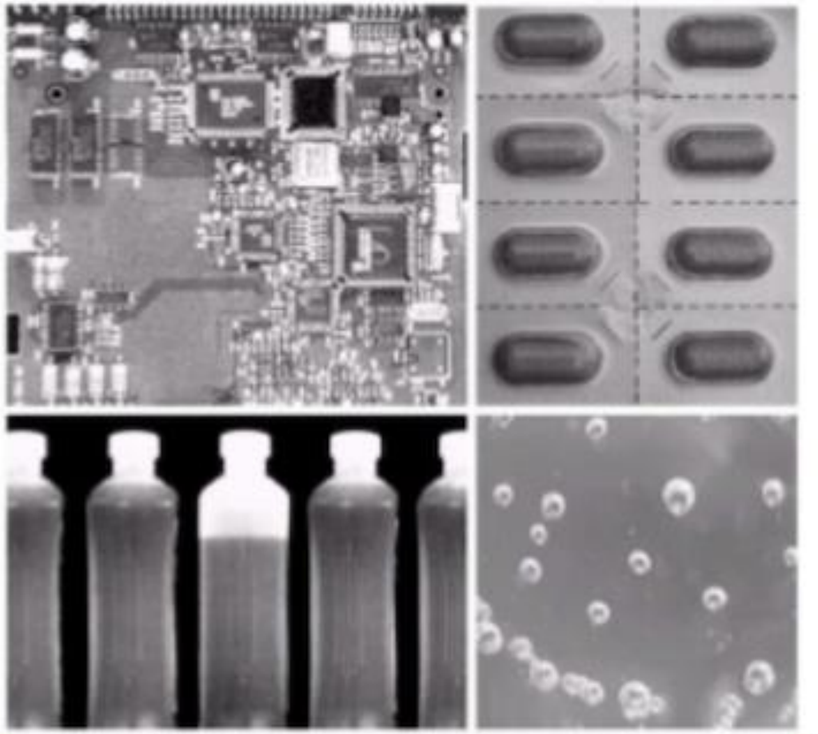
Applications

Industrial Inspection

Human operators are expensive, slow and unreliable

Make machines do the job instead

Industrial vision systems are used in all kinds of industries

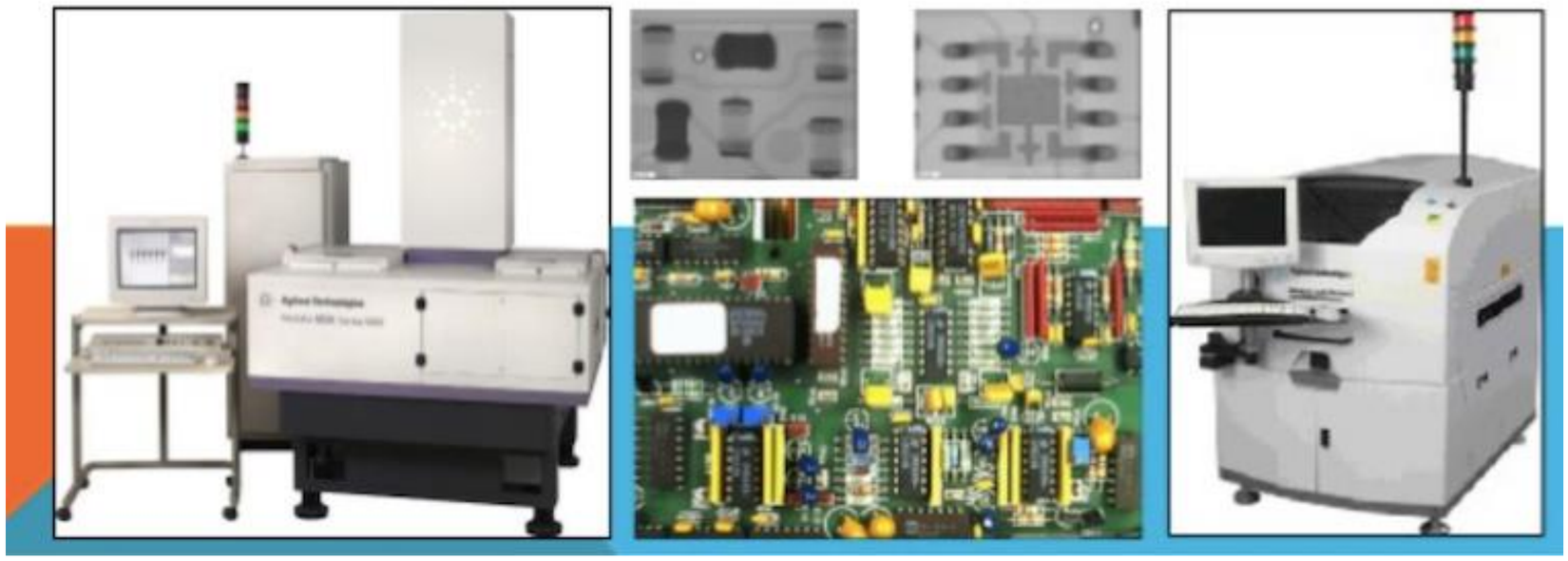


Applications

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

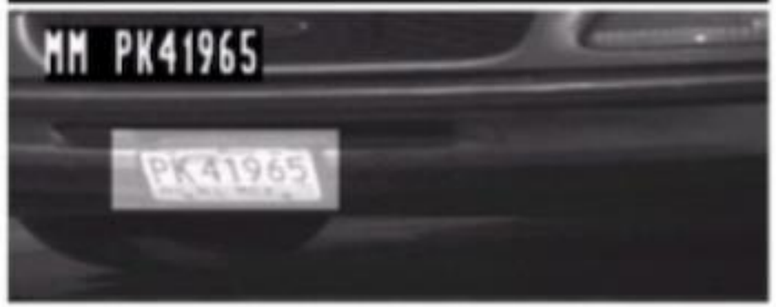


Applications

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

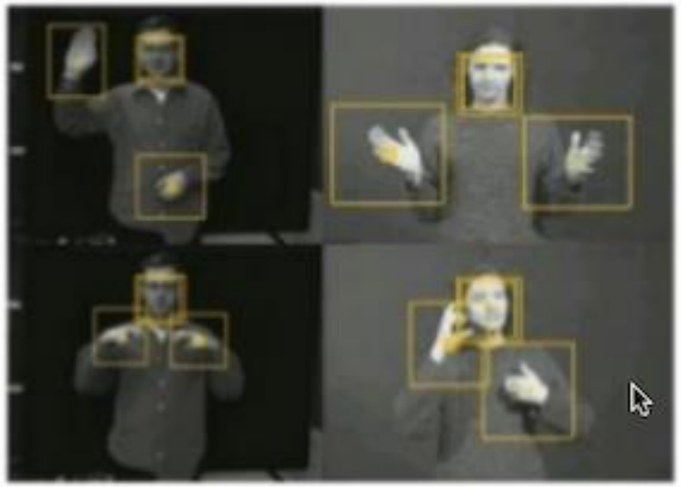


Applications

HCI

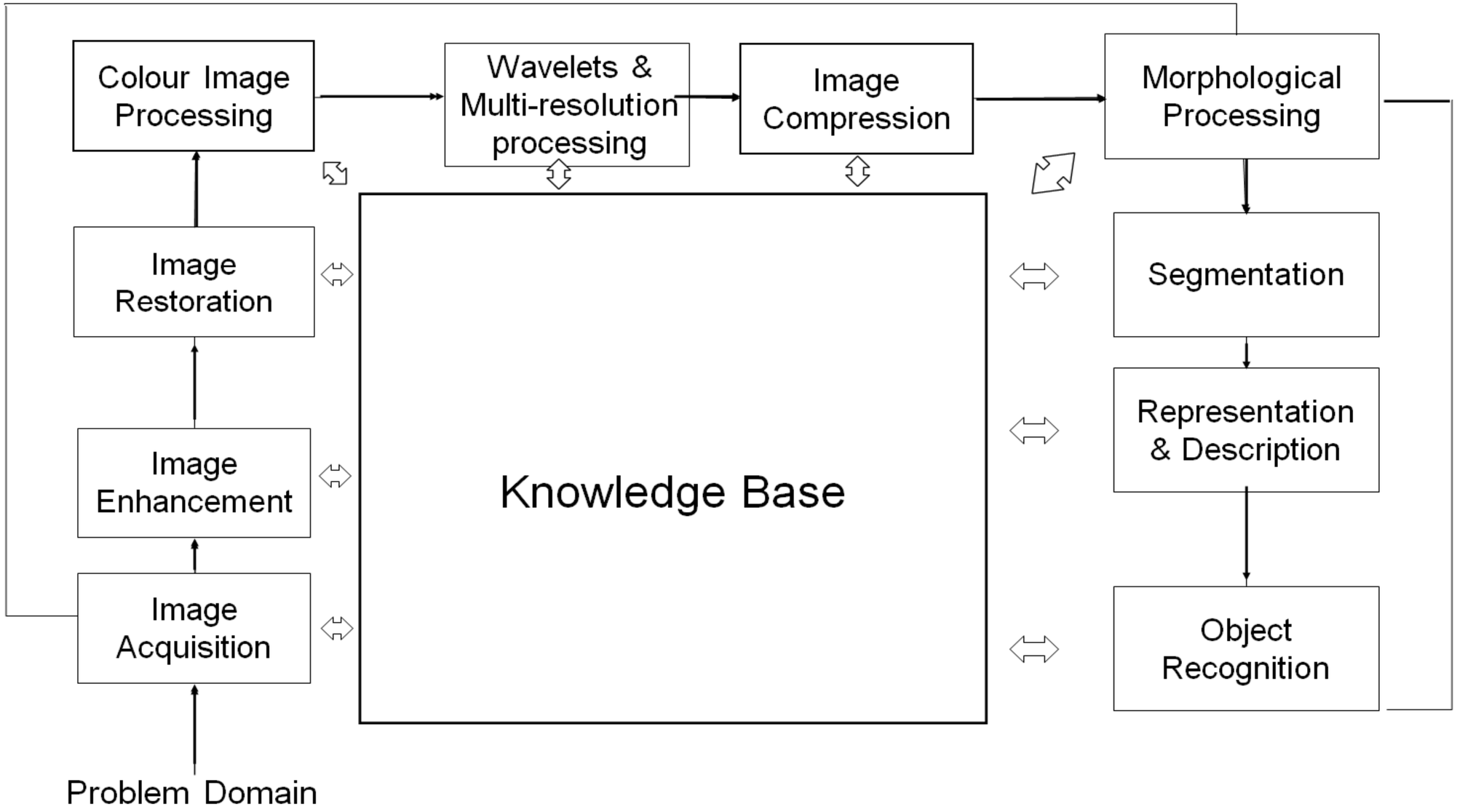
Try to make human computer interfaces more natural

- Face recognition
- Gesture recognition



Fundamental Steps in Digital Image Processing

Outputs of these processes generally are images

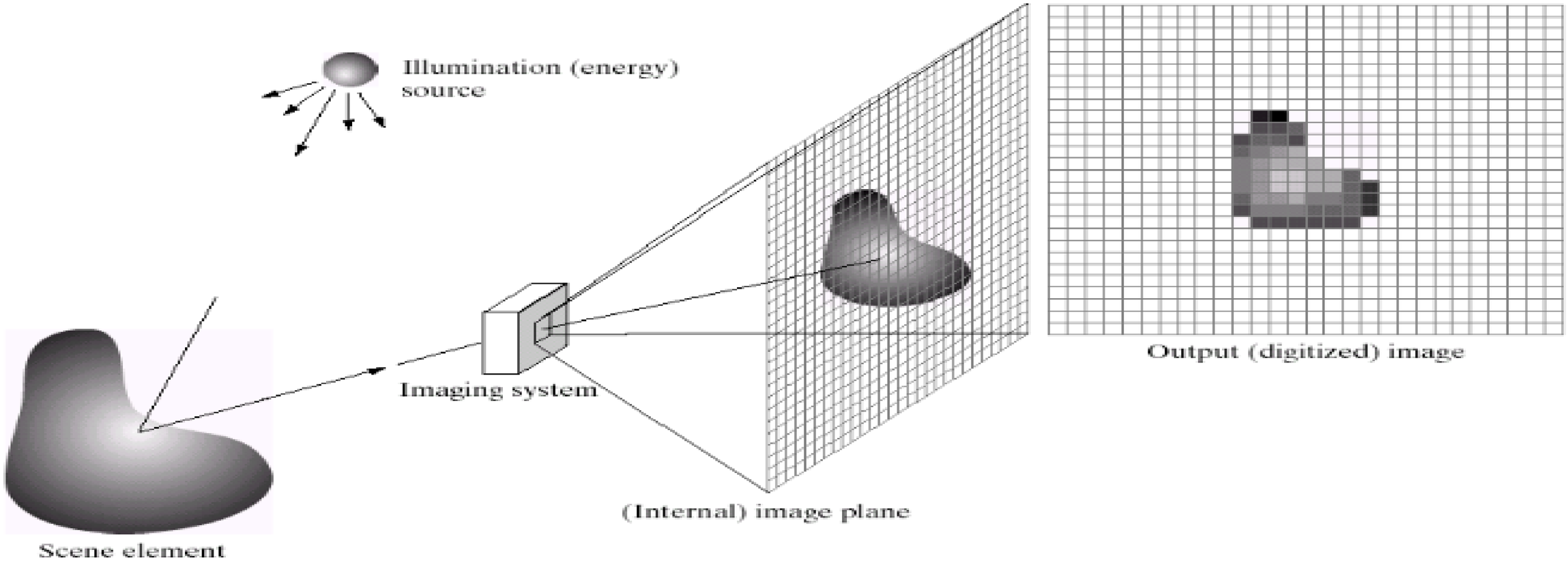


Outputs of these processes generally are image attributes

Fundamental Steps in Digital Image Processing

Step 1 : Image Acquisition

- The image is captured by a sensor (eg. Camera), and digitized if the output of the camera or sensor is not already in digital form, using analogue-to-digital convertor.



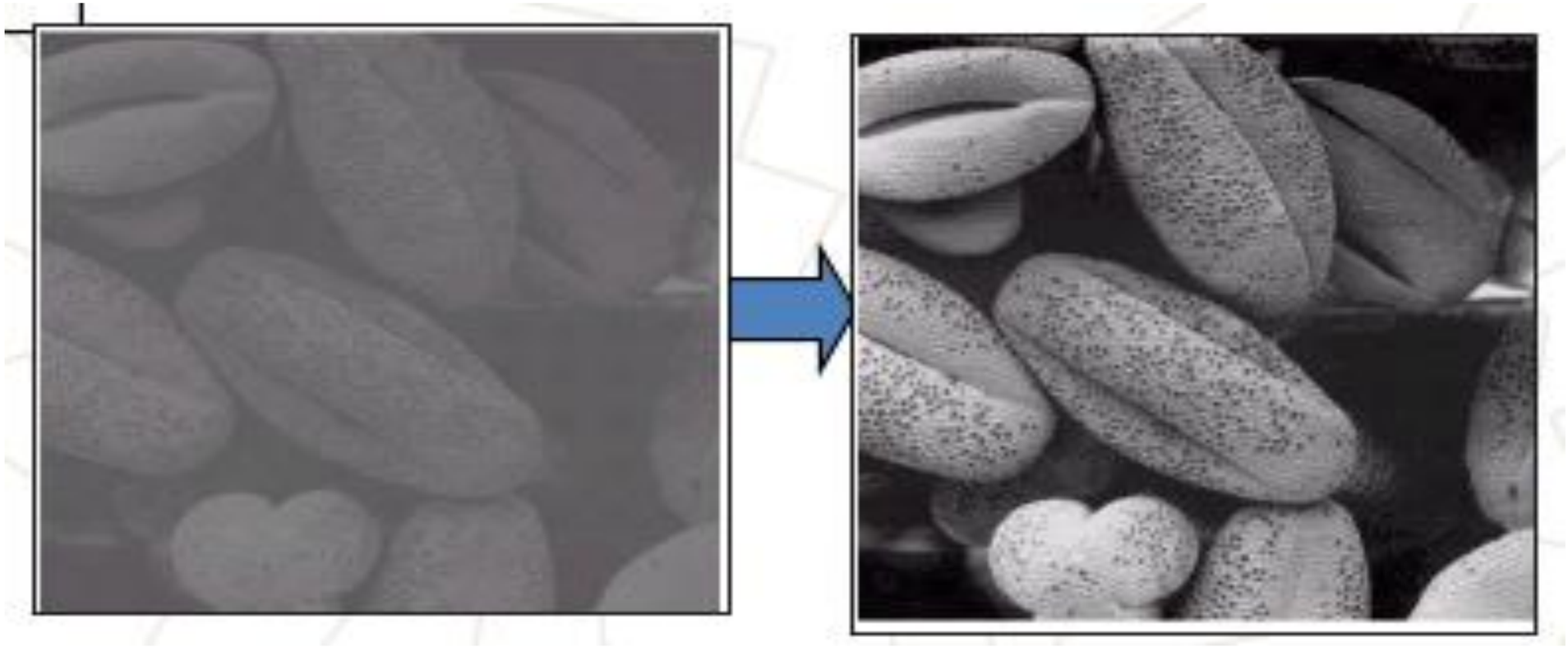
a b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Fundamental Steps in Digital Image Processing

Step 2 : Image Enhancement

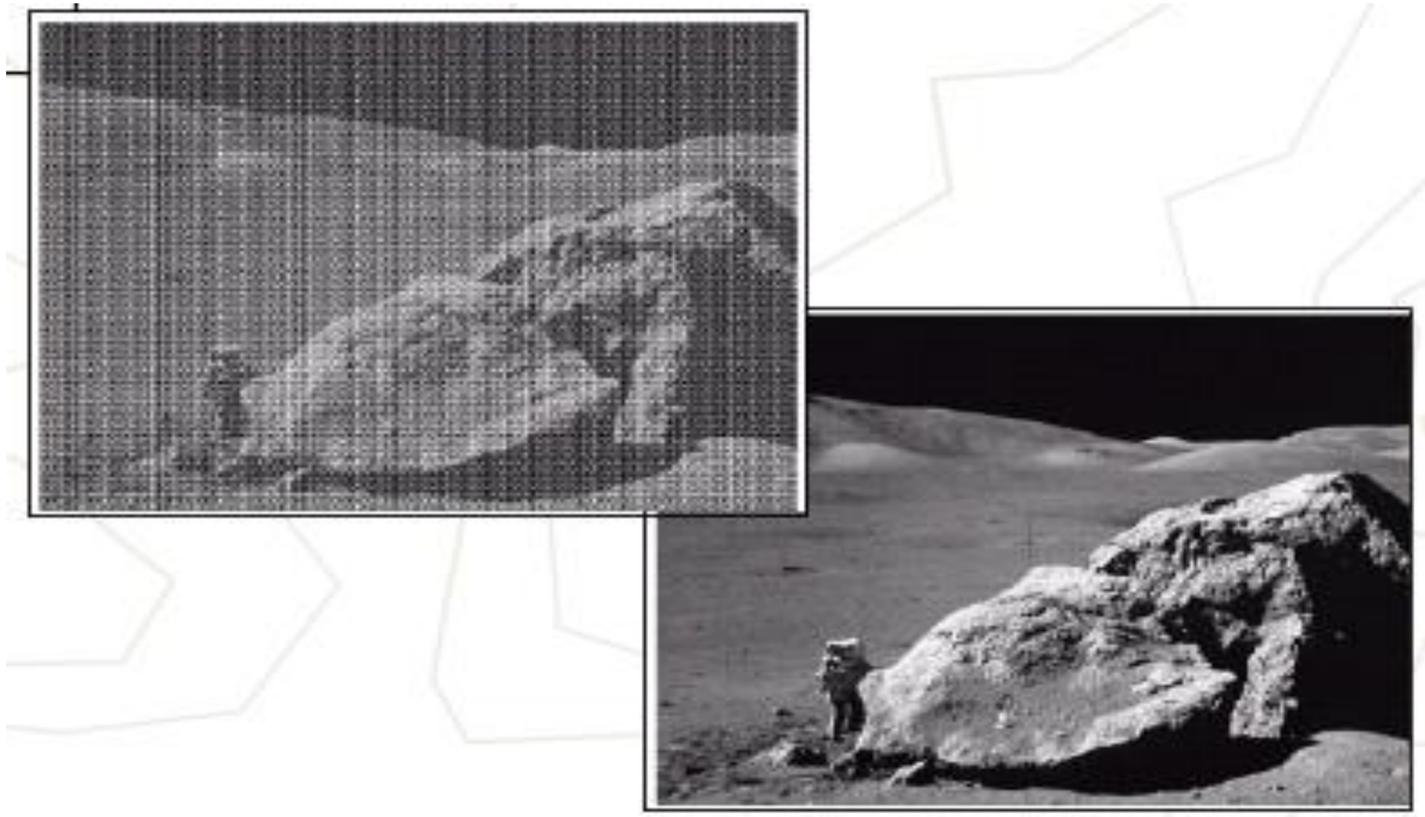
- The process of manipulating an image so that the result is more suitable than the original for specific applications.
- The idea behind enhancement techniques is to bring out details that are hidden, or simply to highlight certain features of interest in an image.



Fundamental Steps in Digital Image Processing

Step 3 : Image Restoration

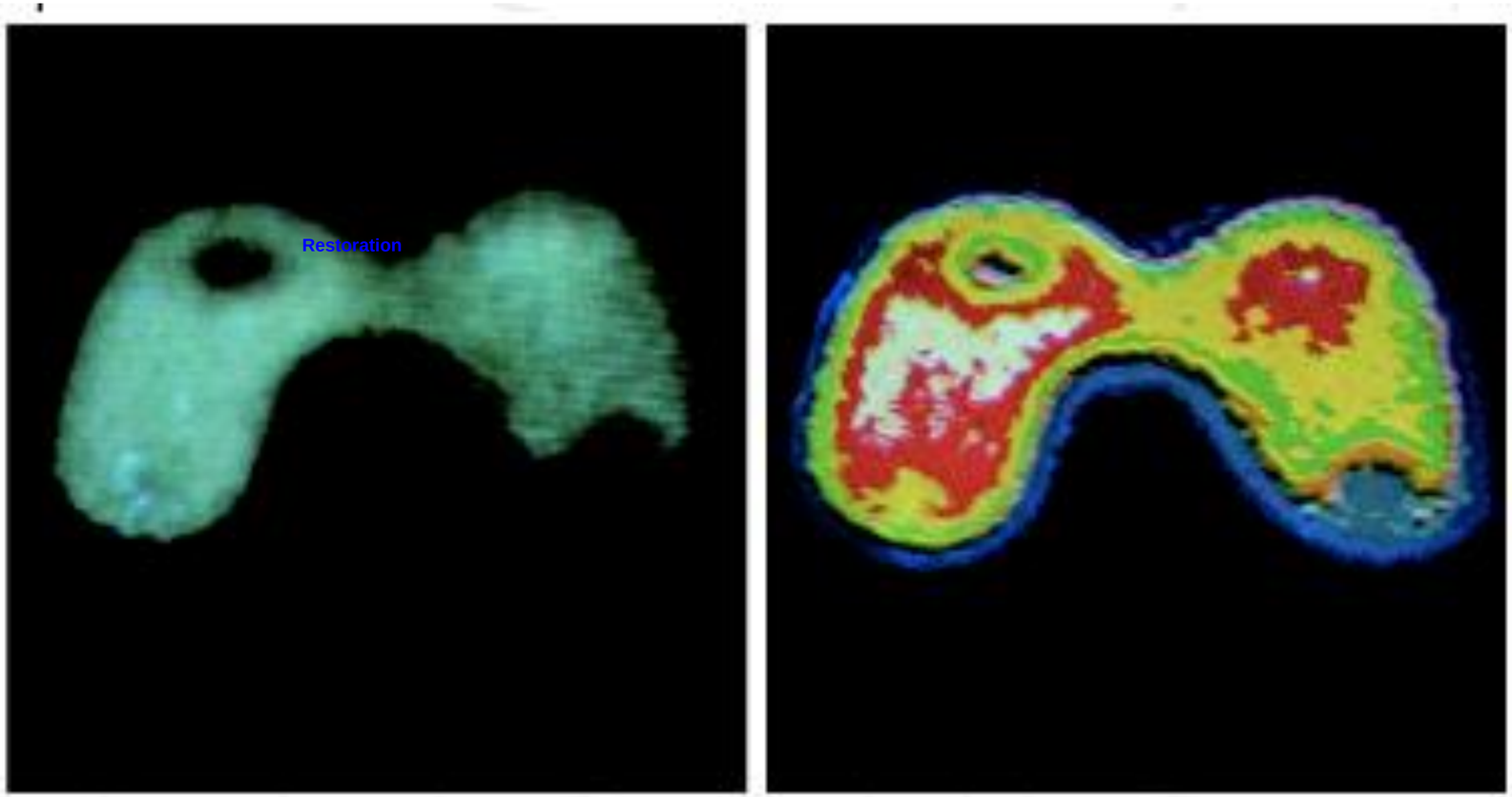
- Restoration - Improving the appearance of an image. Tend to be mathematical or probabilistic models.
- Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a “good” enhancement result.



Fundamental Steps in Digital Image Processing

Step 4 : Colour Image Processing

- Use the colour of the image to extract features of interest in an image



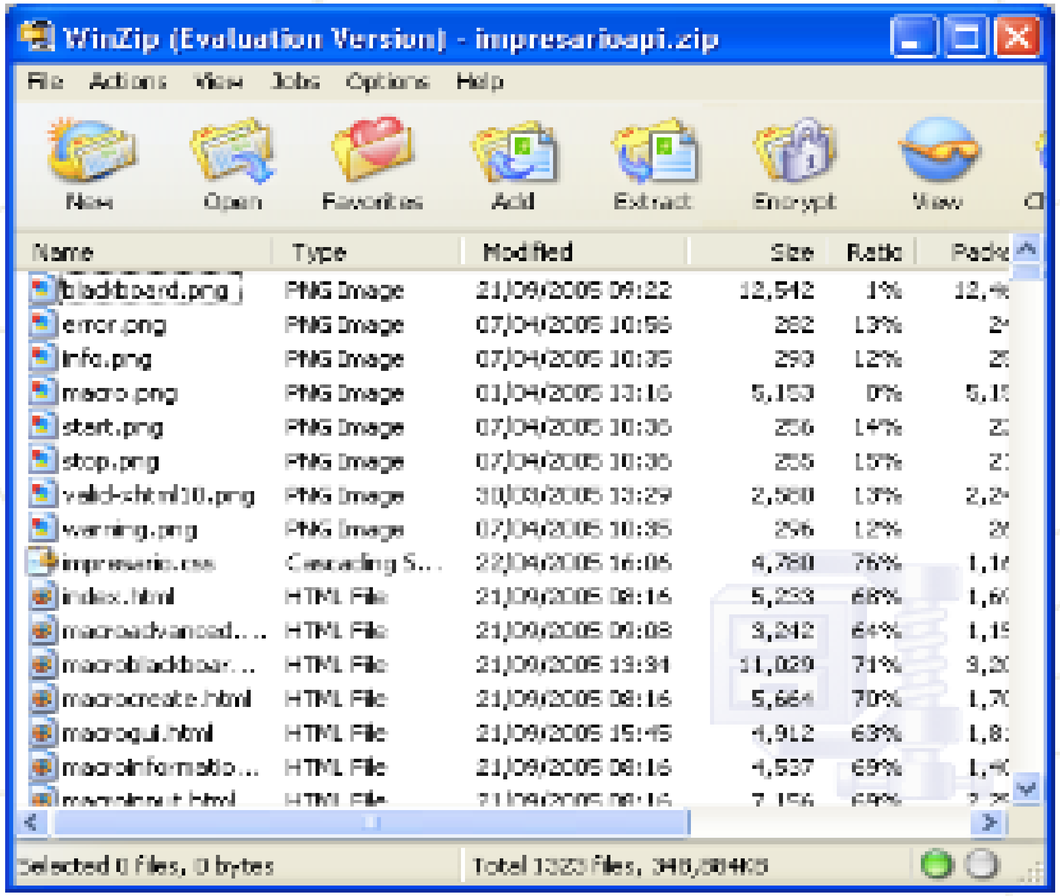
Fundamental Steps in Digital Image Processing

Step 5 : Wavelets

- Are the foundation of representing images in various degrees of resolution.
- It is used for image data compression.

Step 6 : Compression

- Techniques for reducing the storage required to save an image or the bandwidth required to transmit it.



Fundamental Steps in Digital Image Processing

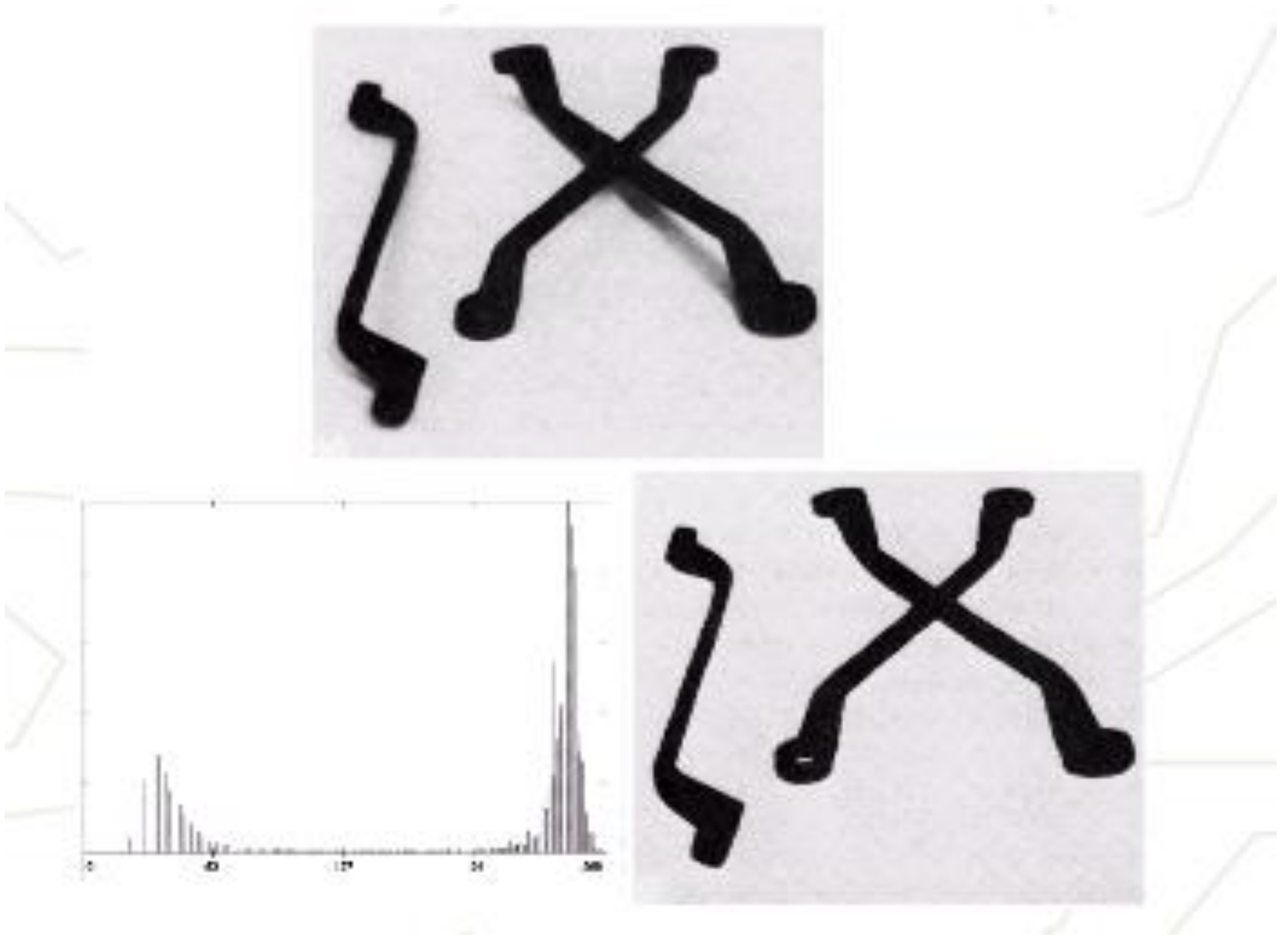
Step 7 : Morphological Processing

- Tools for extracting image components that are useful in the representation and description of shape.
- In this step, there would be a transition from processes that output images, to processes that output image attributes.

Fundamental Steps in Digital Image Processing

Step 8 : Image Segmentation

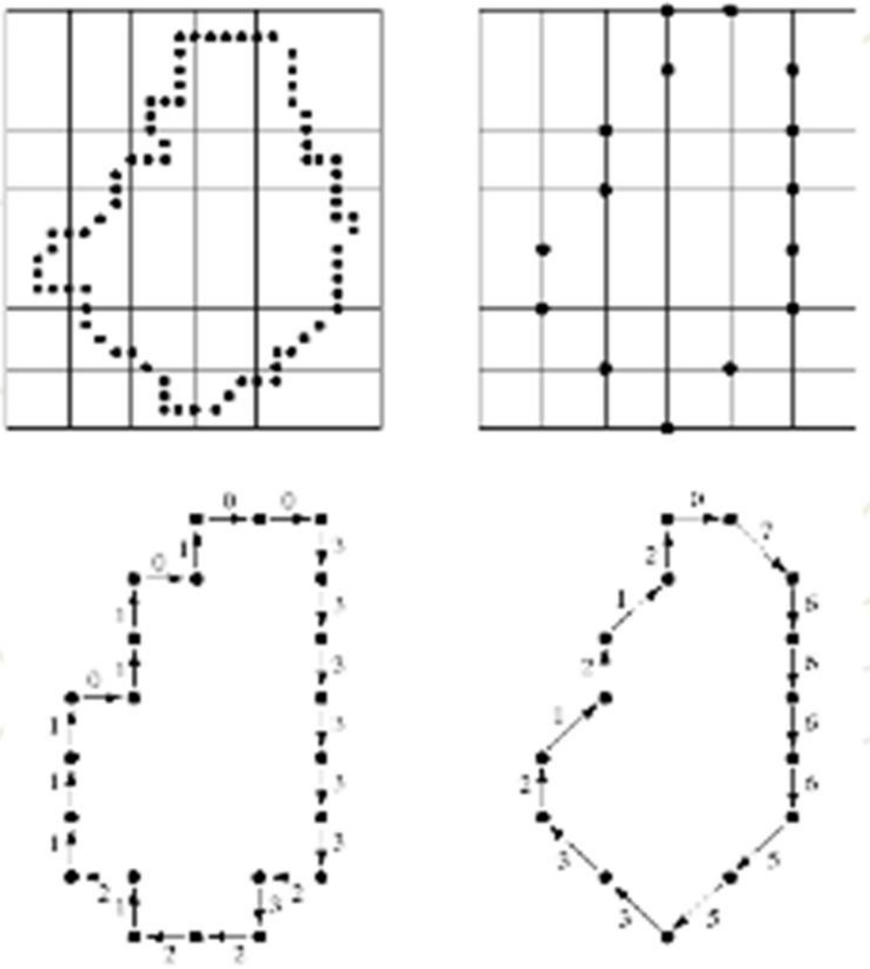
- Segmentation procedures partition an image into its constituent parts or objects.



Fundamental Steps in Digital Image Processing

Step 9 : Representation and Description

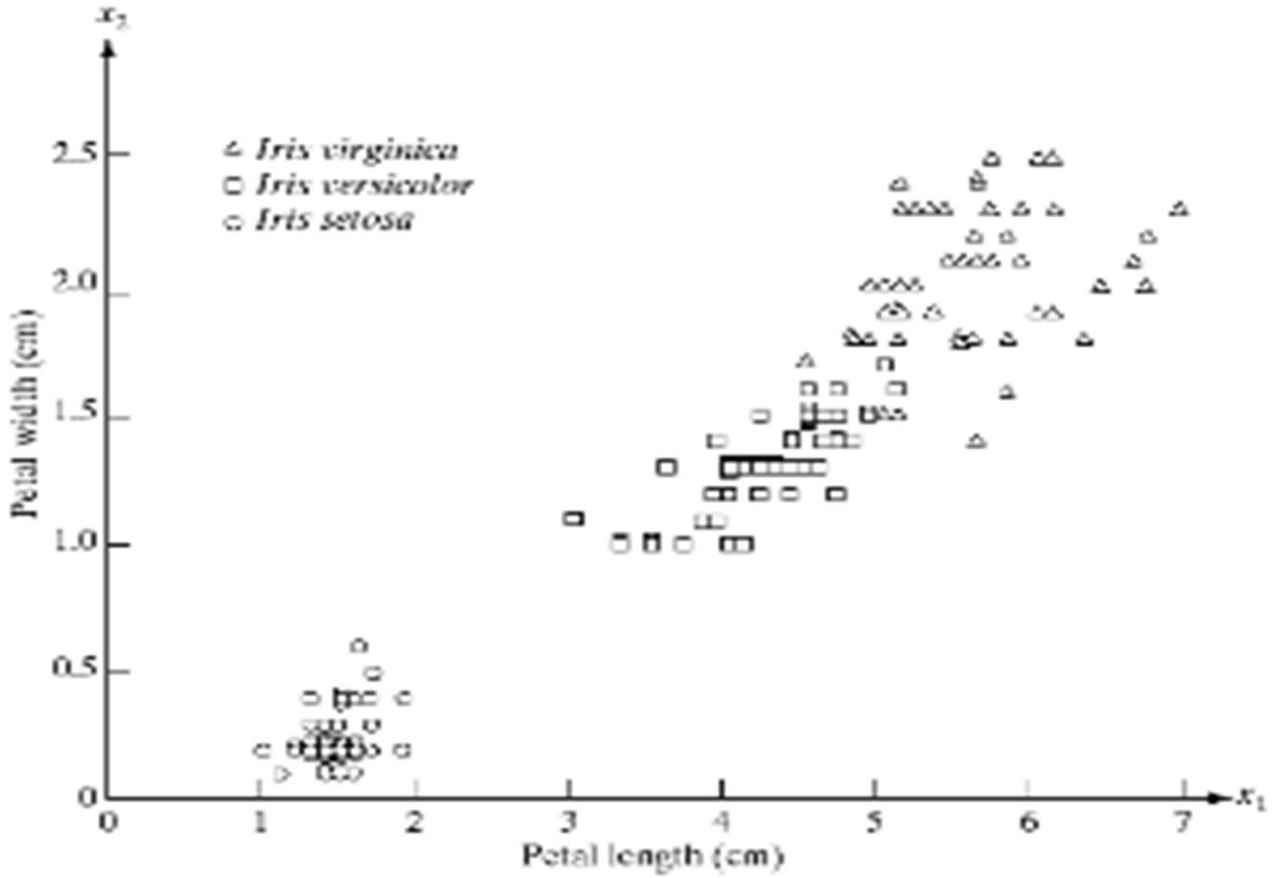
- **Representation:** Make a decision whether the data should be represented as a boundary or as a complete region. It almost always follows the output of a segmentation stage.
  - **Boundary Representation:** Focus on external shape characteristics, such as corners
  - **Region Representation:** Focus on internal properties, such as texture
- Choosing a representation is only part of the solution for transforming raw data into a form suitable for subsequent computer processing (mainly recognition).
- **Description:** also called, feature selection, deals with extracting attributes that result in some information of interest.



Fundamental Steps in Digital Image Processing

Step 10: Object Recognition

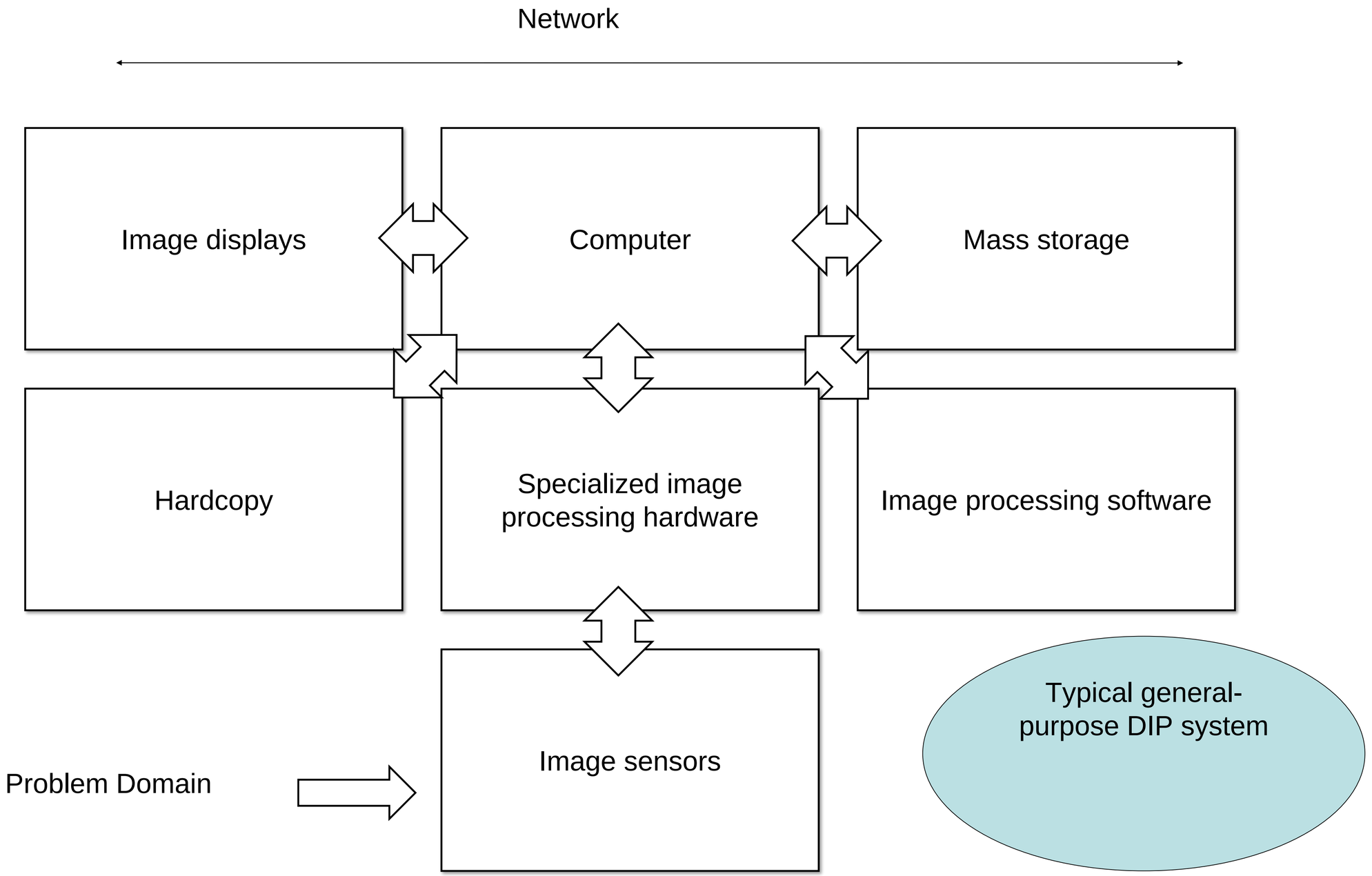
- Recognition: the process that assigns label to an object based on the information provided by its description.



Step 11 : Knowledge Base

- Knowledge about a problem domain is coded into an image processing system in the form of a knowledge database.

Components of an Image Processing System



Components of an Image Processing System

1. Image Sensors - Two elements are required to acquire digital images. The first is the physical device that is sensitive to the energy radiated by the object we wish to image (*Sensor*). The second, called a *digitizer*, is a device for converting the output of the physical sensing device into digital form.

2. Specialized Image Processing Hardware - Usually consists of the digitizer, mentioned before, plus hardware that performs other primitive operations, such as an arithmetic logic unit (ALU), which performs arithmetic and logical operations in parallel on entire images.

This type of hardware sometimes is called a front-end subsystem, and its most distinguishing characteristic is speed. In other words, this unit performs functions that require fast data throughputs that the typical main computer cannot handle.

3. Computer - The computer in an image processing system is a general-purpose computer and can range from a PC to a supercomputer. In dedicated applications, sometimes specially designed computers are used to achieve a required level of performance.

Components of an Image Processing System

4. Image Processing Software - Software for image processing consists of specialized modules that perform specific tasks. A well-designed package also includes the capability for the user to write code that, as a minimum, utilizes the specialized modules.

5. Mass Storage Capability - Mass storage capability is a must in a image processing applications. And image of sized 1024 * 1024 pixels requires one megabyte of storage space if the image is not compressed.

- Digital storage for image processing applications falls into three principal categories:
  - ✓ **Short-term storage for use during processing**
  - ✓ **Online storage for relatively fast recall**
  - ✓ **Archival storage, characterized by infrequent access**

One method of providing short-term storage is computer memory. Another is by specialized boards, called frame buffers, that store one or more images and can be accessed rapidly.

The on-line storage method, allows virtually instantaneous image zoom, as well as scroll (vertica shifts) and pan (horizontal shifts). On-line storage generally takes the form of magnetic disks and optical-media storage. The key factor of on-line storage is frequent access to the stored data.

Finally, archival storage is characterized by massive storage requirements but infrequent need for access.

Components of an Image Processing System

6. Image Displays

The displays in use today are mainly colour (preferably flat screen) TV monitors. Monitors are driven by the outputs of the image and graphics display cards that are an integral part of a computer system.

7. Hardcopy devices

Used for recording images, include laser printers, film cameras, heat-sensitive devices, inkjet units and digital units, such as optical and CD-Rom disks.

8. Networking

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 is bandwidth.

In dedicated networks, this typically is not a problem, but communications with remote sites via the internet are not always as efficient.