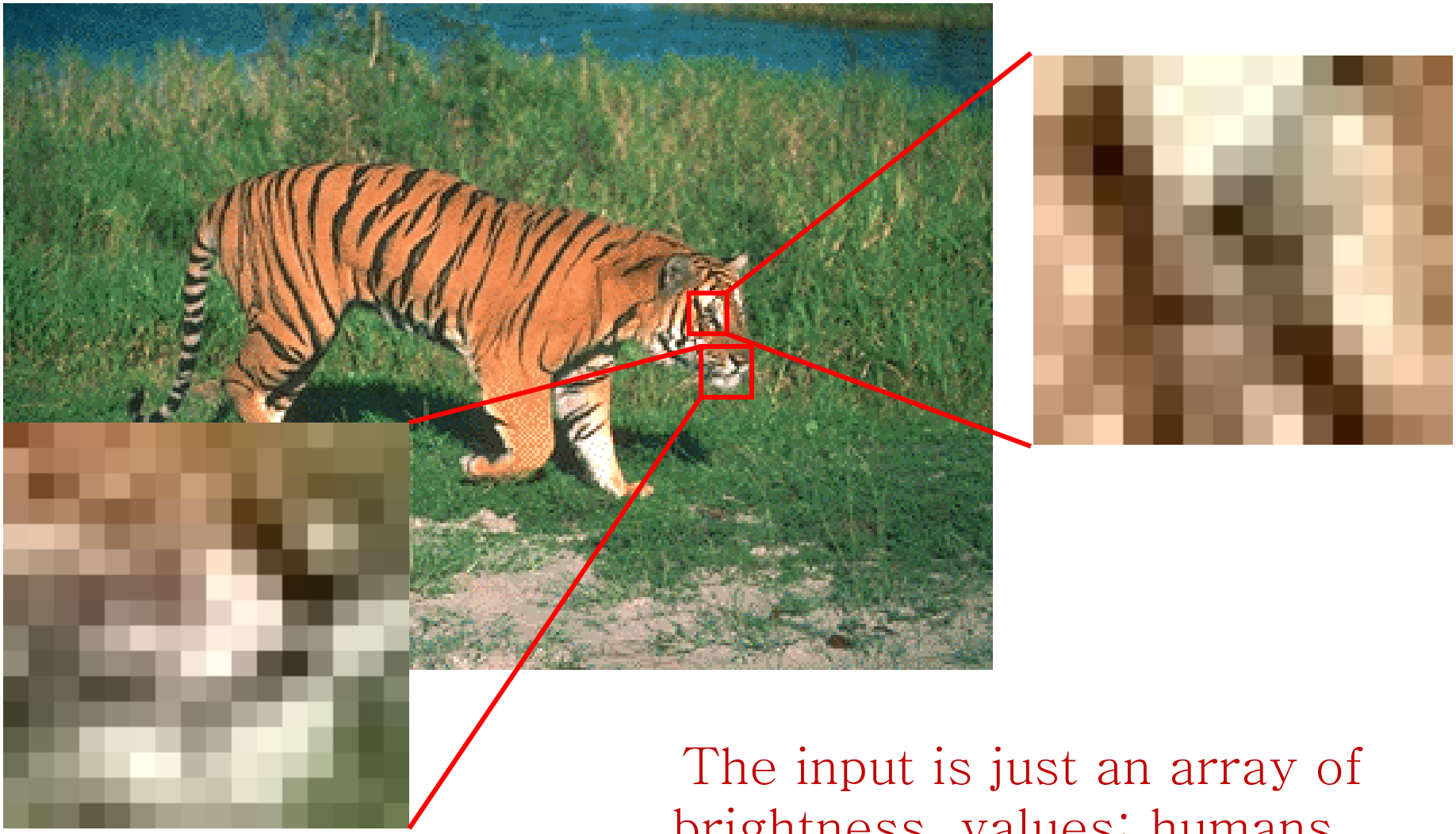
Digital Image Processing
Introduction

What is an Image?

- ***Image*** is a two dimensional light-intensity function, *f(x,y)*, where the value of *f* at a spatial location *(x,y)* is the intensity of the image at that point.
- When *x*, *y* and amplitude values of *f* are all finite, discrete quantities, it is called a ***digital image***.

What is in an image?



The input is just an array of brightness values; humans perceive structure in it.

What is Digital Image Processing?

Processing of images which are digital in nature by a digital computer to extract meaningful information from the images

Sources of Images

- Electromagnetic (EM) energy spectrum
- Acoustic
- Ultrasonic
- Electronic
- Synthetic images produced by computer

Electromagnetic (EM) Energy Spectrum

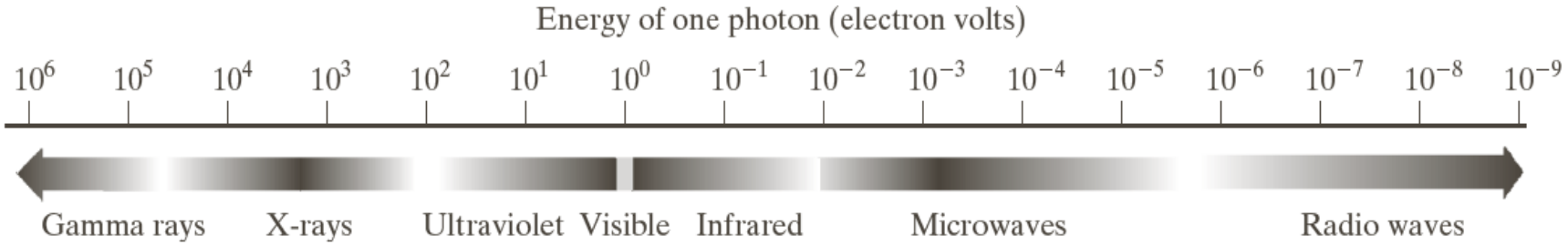


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

- **Major uses**
  - **Gamma-ray imaging**: nuclear medicine and astronomical observations
  - **X-rays**: medical diagnostics, industry, and astronomy, etc.
  - **Ultraviolet**: lithography, industrial inspection, microscopy, lasers, biological imaging and astronomical observations
  - **Visible and infrared bands**: light microscopy, astronomy, remote sensing, industry, and law enforcement
  - **Microwave band**: radar
  - **Radio band**: medicine (such as MRI) and astronomy

Introduction

- **Why we need image processing**?

It is motivated by three major applications-

1. Improvement of pictorial information for human perception.
2. Image processing for autonomous machine application.
3. Efficient storage and transmission.

1. Human Perception

- **Employ methods capable of enhancing pictorial information for human interpretation and analysis**

Typical applications:

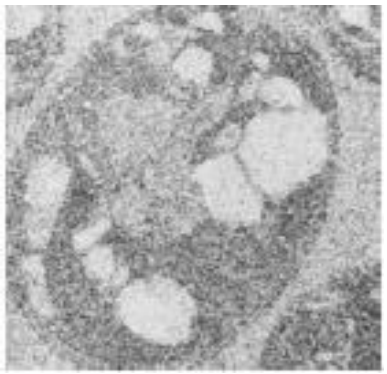
a. Noise filtering

b. Content enhancement

   1. Contrast enhancement
   2. Deblurring
   3. Remote Sensing
   4. Archeology, Astronomy, Biology, Medical Imaging, Space program etc.

Filtering

Image of a cell corrupted by electronic noise



Result after filtering

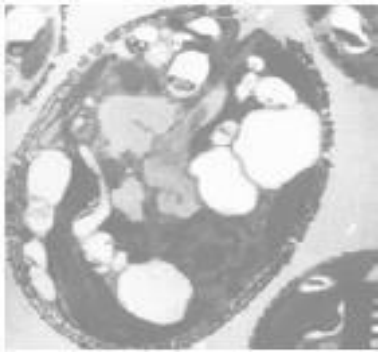
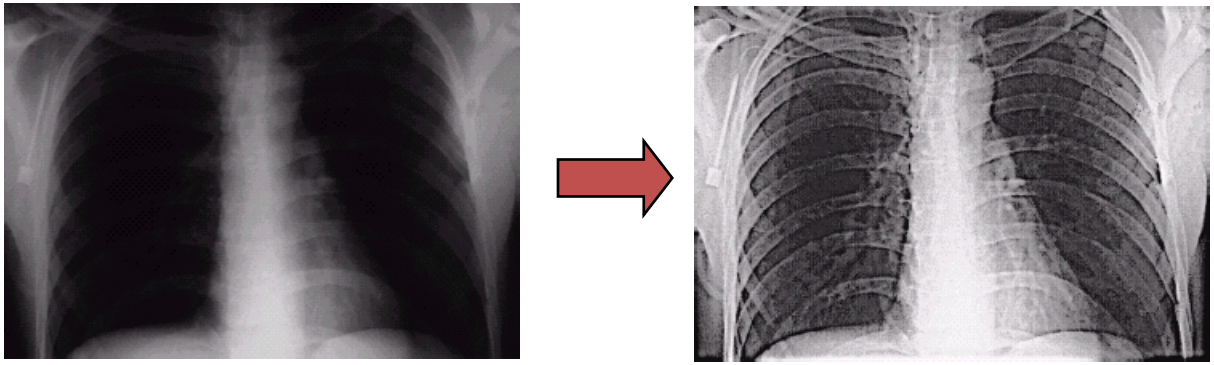


Image Enhancement

An X-Ray image



An aerial image

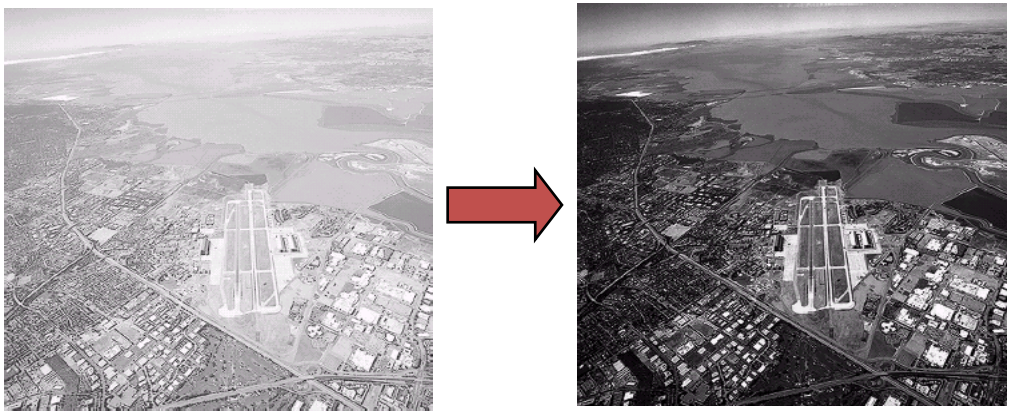


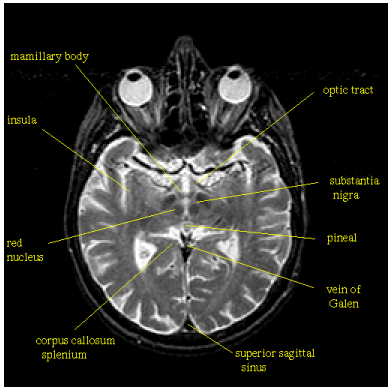
Image Deblurring

Image of a human face blurred by uniform motion during exposure

Resulting image after application of a deblurring algorithm

Medical Imaging

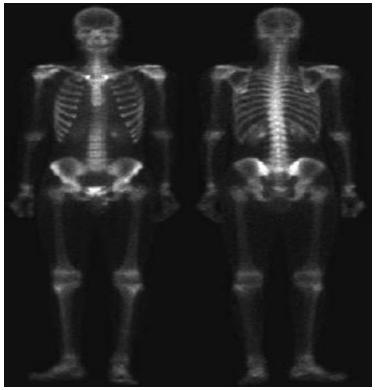
MRI of normal brain



Knee X-Ray

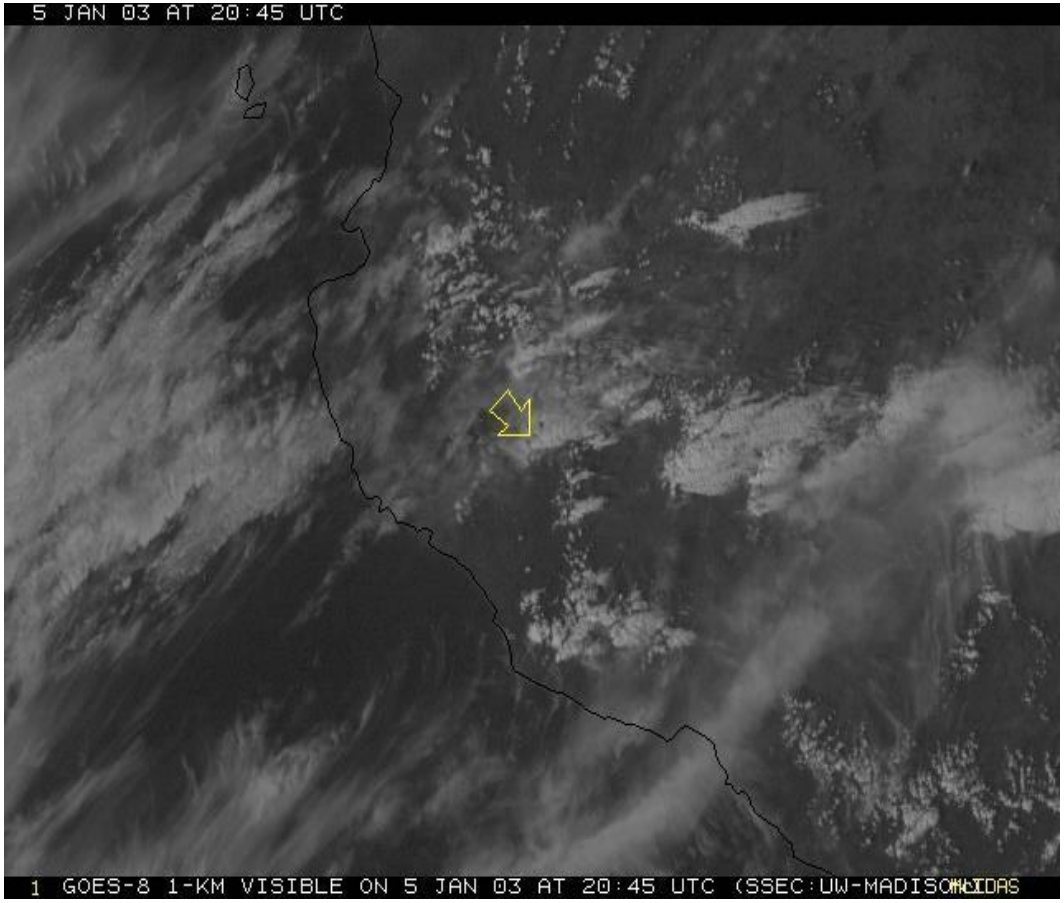
Ultrasound of 5 moths foetus

Bone scan (Gamma ray imaging)



Remote Sensing

Satellite image (Volcano in Alaska)

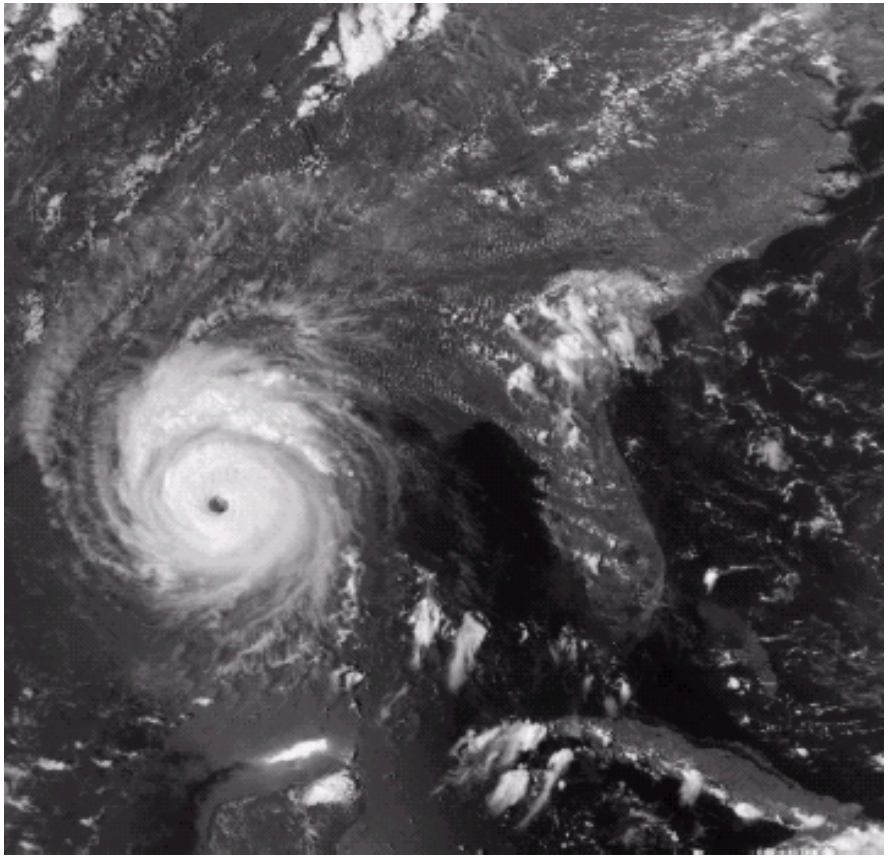


Remote Sensing

Satellite image (Kolkata)

Weather Forecasting

Multispectral image of a hurricane



Astronomy

Galaxy

Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1

ESO PR Photo 37d/98 (23 September 1998)

2. Machine Perception

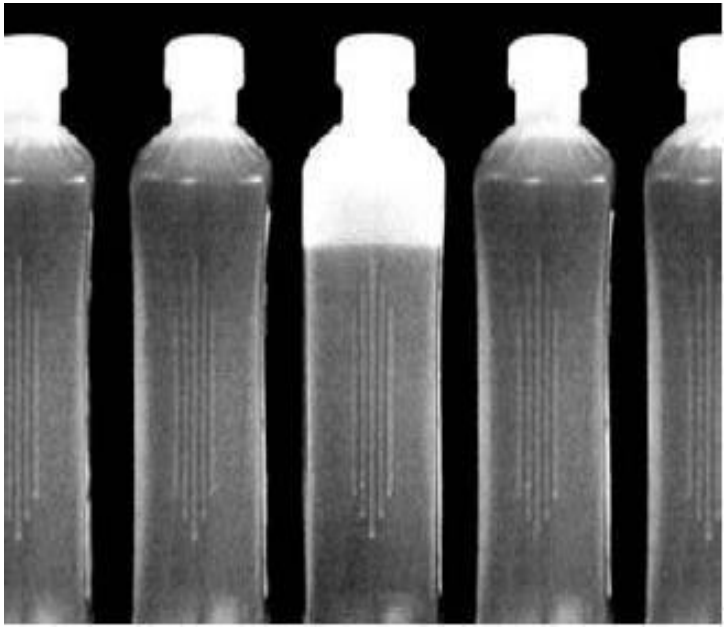
- **Here the interest is on procedures for extraction of image information suitable for computer processing**

Typical applications:

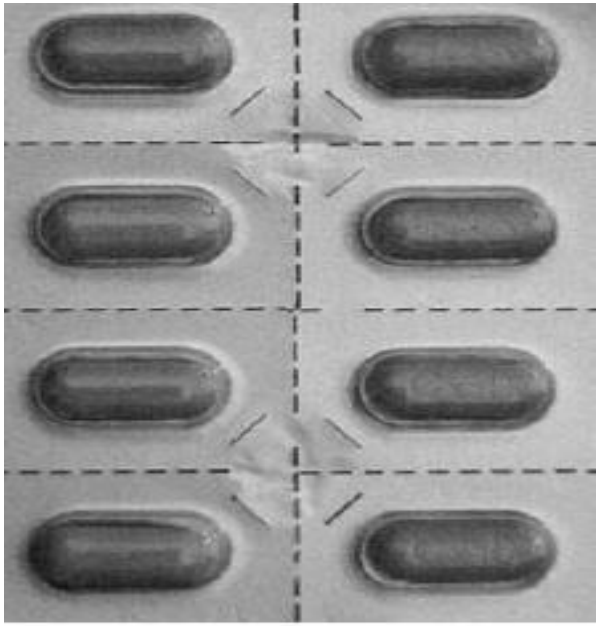
- Automatic Optical Character Recognition
- Industrial machine vision for product assembly and inspection
- Automatic fingerprint recognition
- Automatic target detection and tracking
- Machine processing for satellite imagery for weather prediction and crop assessment.

Automated Inspection

Bottling plant automation

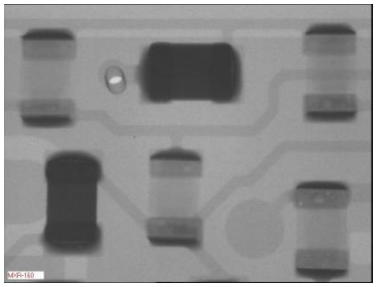


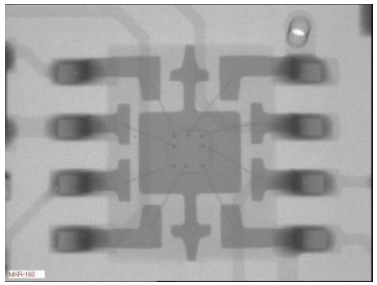
Packaged pills

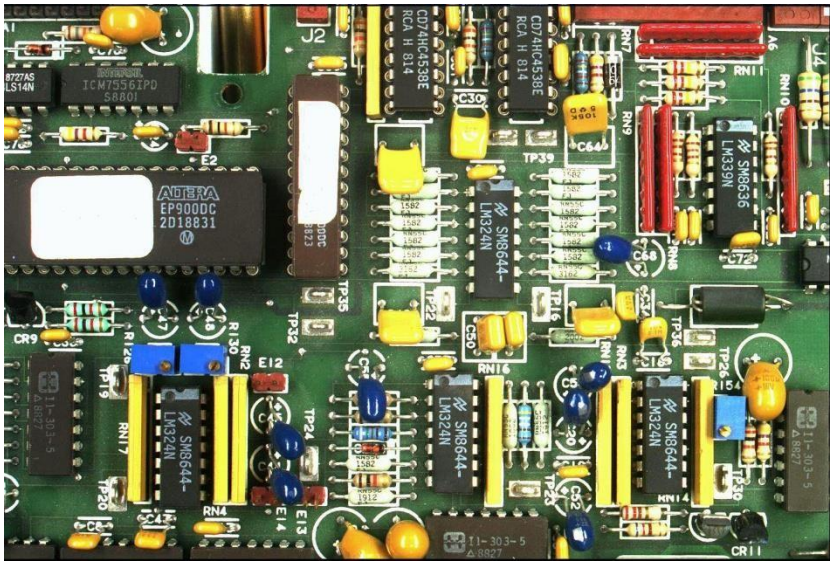


Automated Inspection

PCB inspection

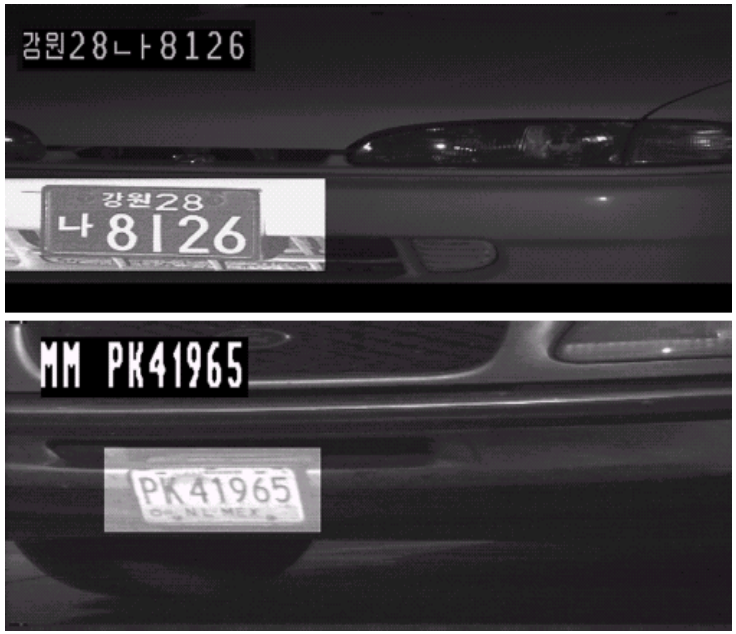






Law Enforcement

License plate recognition



Finger print recognition

3. Image Compression

- **An image usually contains lot of redundancy that can be exploited to achieve compression**

  An image contains:

  – Information

  – Redundancy

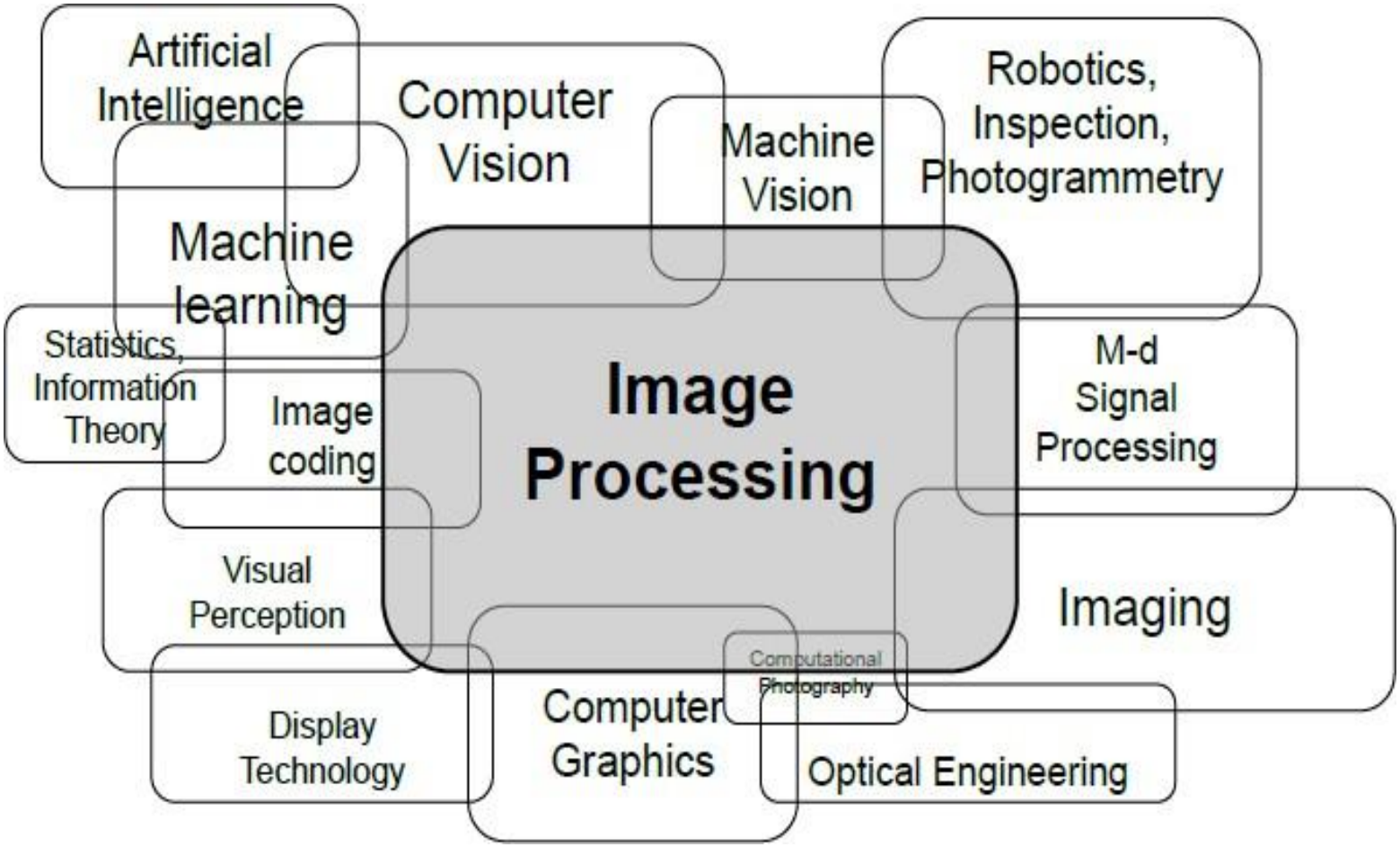
    - Pixel redundancy
    - Coding redundancy
    - Psychovisual redundancy

  Applications:

  – Reduced storage

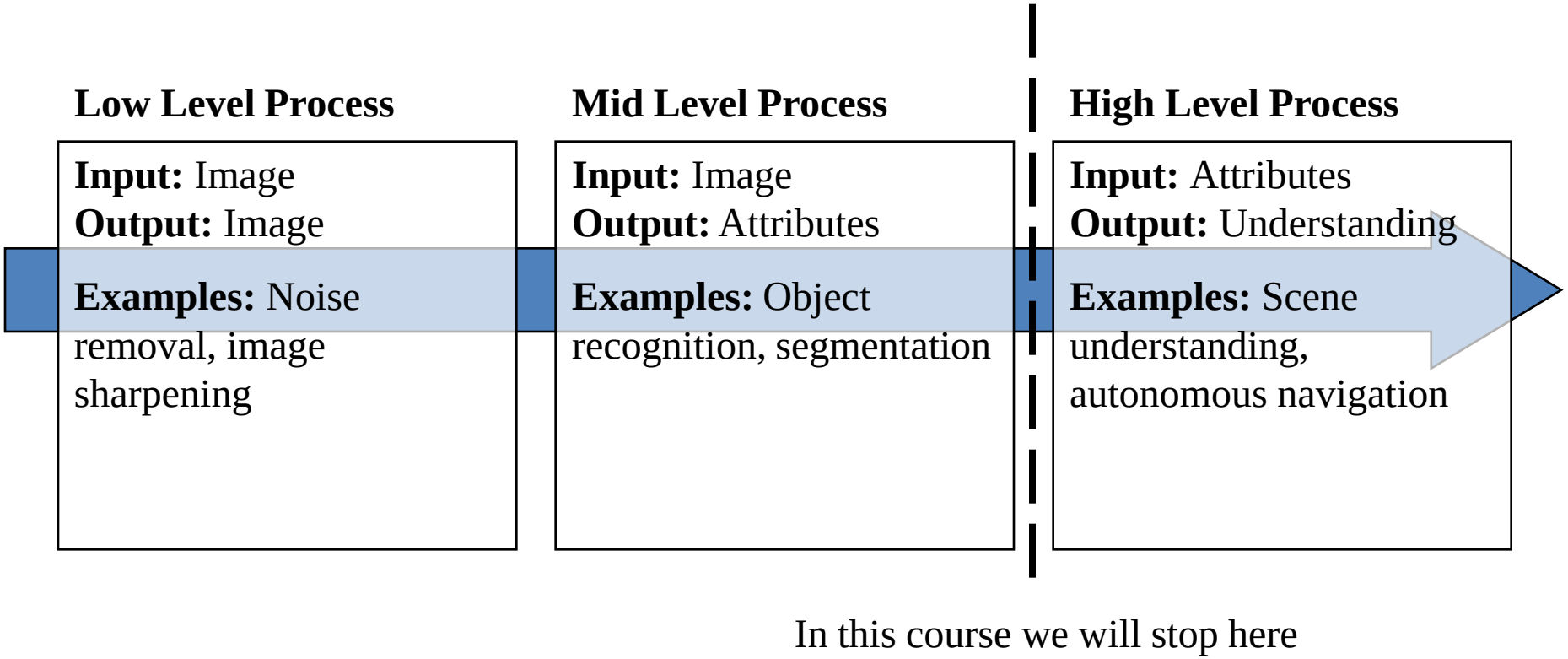
  – Reduction in bandwidth

Connections to other disciplines

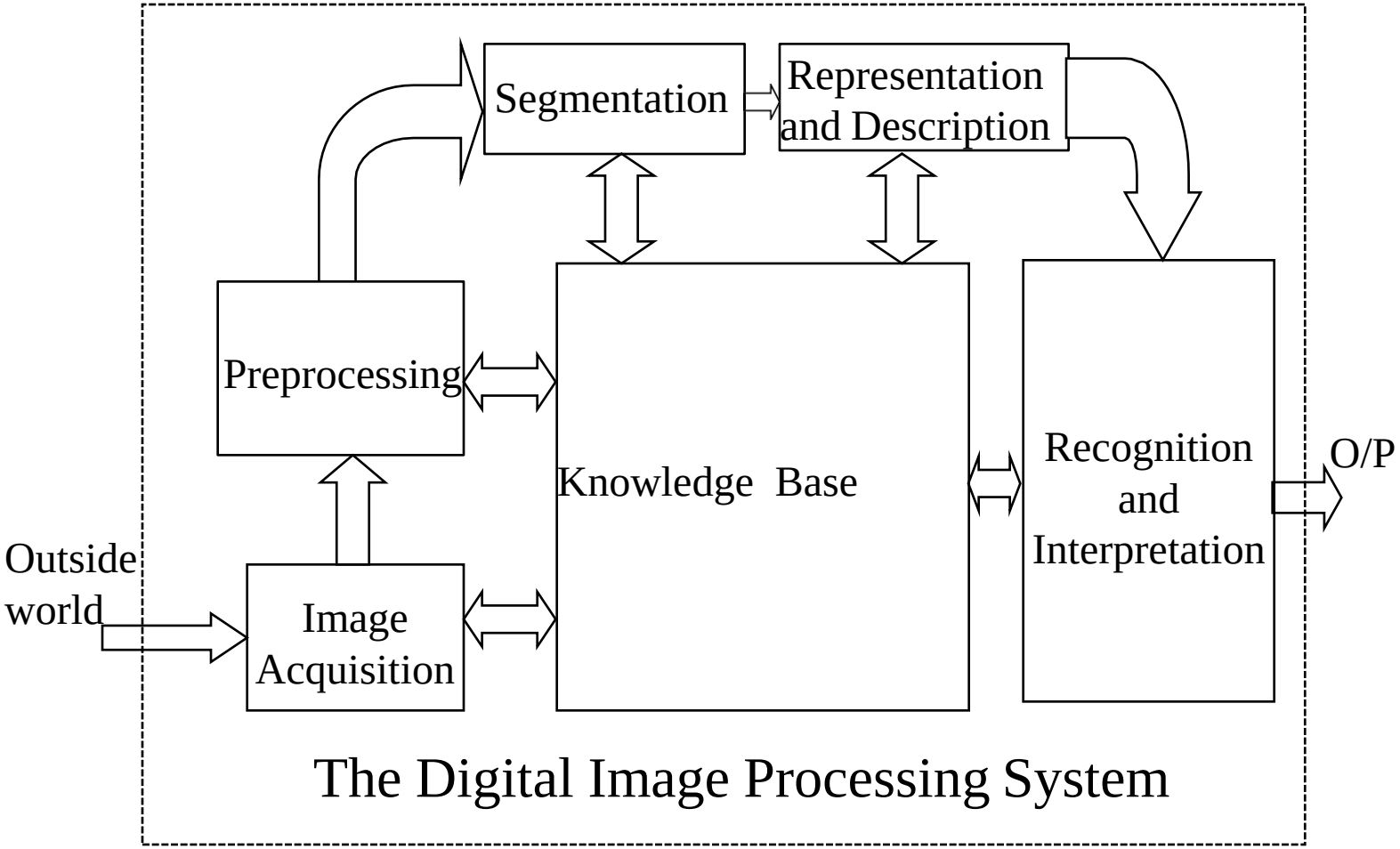


Connections to other disciplines

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



Fundamental Steps in Digital Image Processing



The DIP system takes inputs from the outside world and produces desirable (application dependent) outputs.

Step 1: Image Sensing and Acquisition

- **Two elements are required to acquire a digital image:**

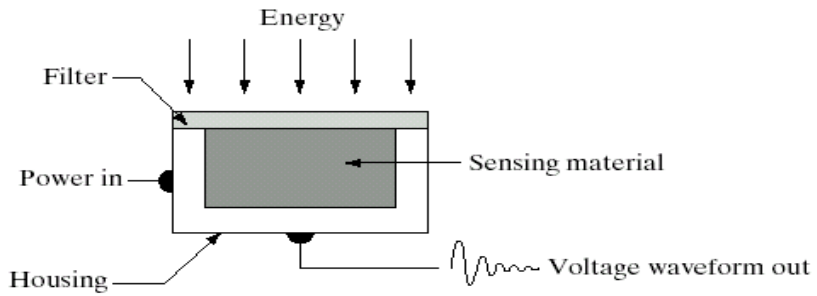
1. A physical device that is sensitive to a band in the electromagnetic spectrum (X-ray, Ultra Violet, Visible, Infrared) to produce an electrical signal proportional to the level of energy sensed (i.e. sensors or detectors)
2. A digitizer to convert this signal into digital form.

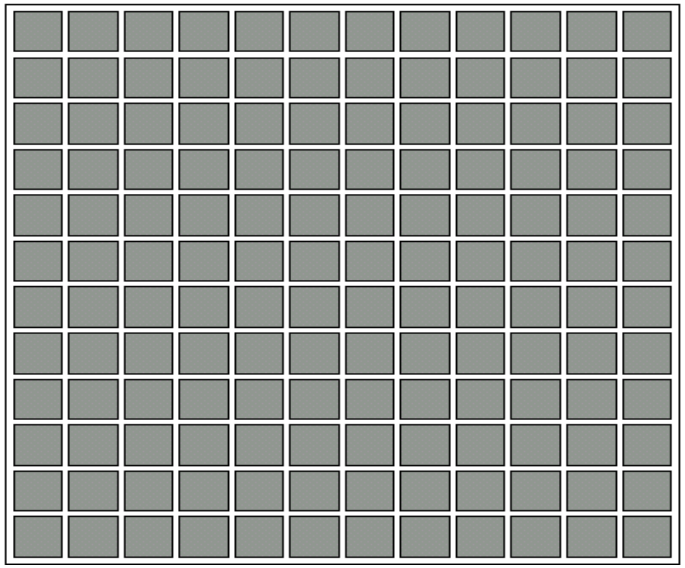
   NOTE: There are sensors available that directly give digital output.

Step 1: Image Sensing and Acquisition

a
b
c

FIGURE 2.12
(a) Single imaging sensor.
(b) Line sensor.
(c) Array sensor.





Step 1: Image Sensing and Acquisition

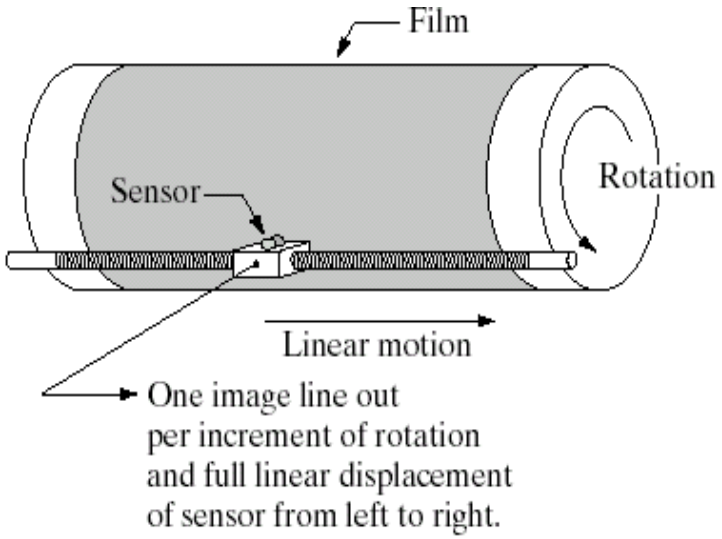
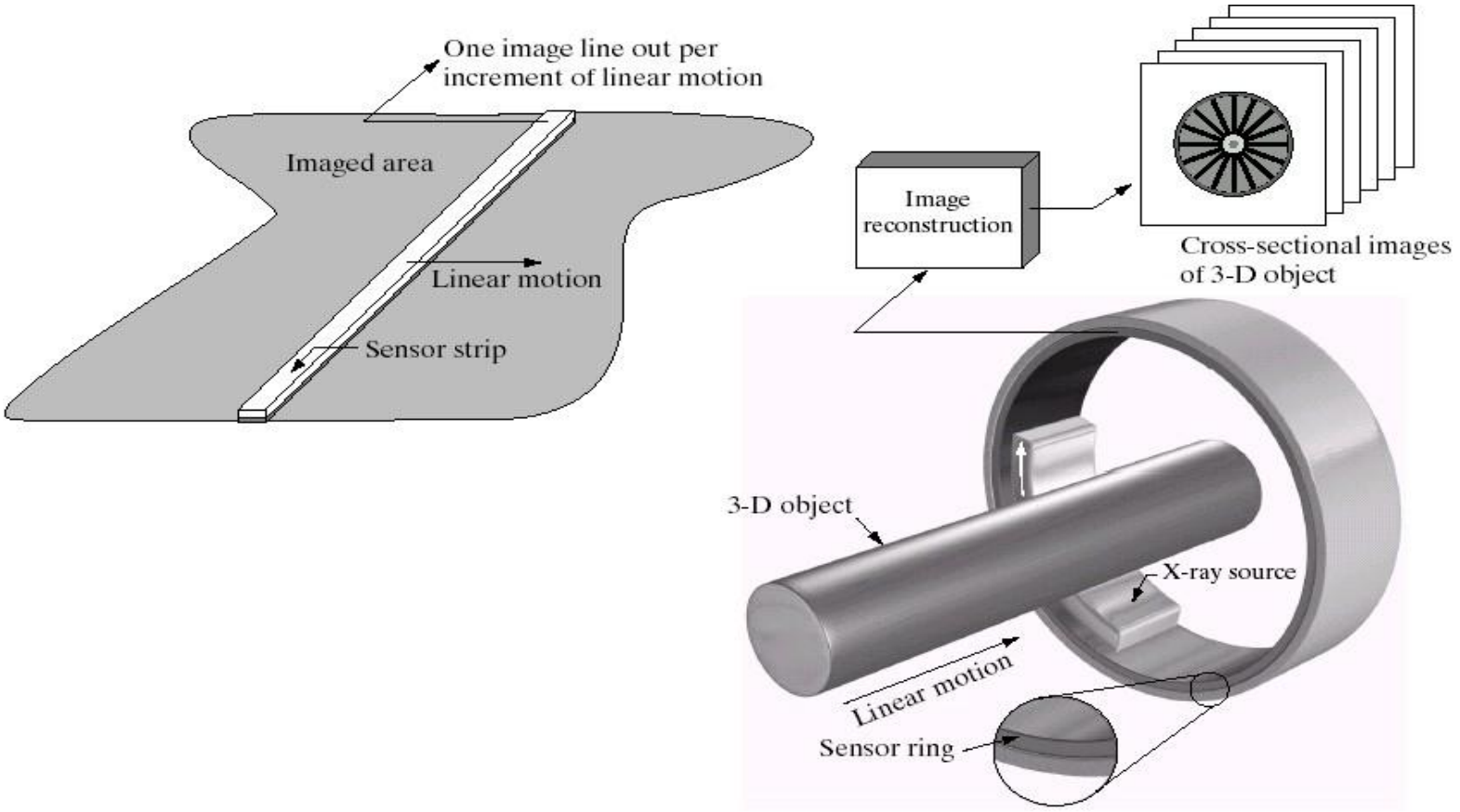


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

Step 1: Image Sensing and Acquisition



a b

FIGURE 2.14 (a) Image acquisition using a linear sensor strip. (b) Image acquisition using a circular sensor strip.

Step 2: Image Preprocessing

- Enhances the image quality
- For example
  - Enhancing contrast
  - Removing noise
  - Isolating regions of interest (ROI).

Step 3: Segmentation

- It partitions an input image into its constituent parts or objects.

NOTE:

1. Autonomous segmentation is one of the most difficult tasks in digital image processing.
2. Good segmentation ensures ease in achieving successful solution to an imaging problem.
3. Bad segmentation guarantees eventual failure to an imaging problem.

Step 4: Representation and Description

- Representation implies conversion of the data to a form suitable for computer processing e.g. boundary representation or complete region representation.

- Description (or feature selection) deals with extracting features that result in some quantitative information of interest or features that can differentiate one class of objects from another.

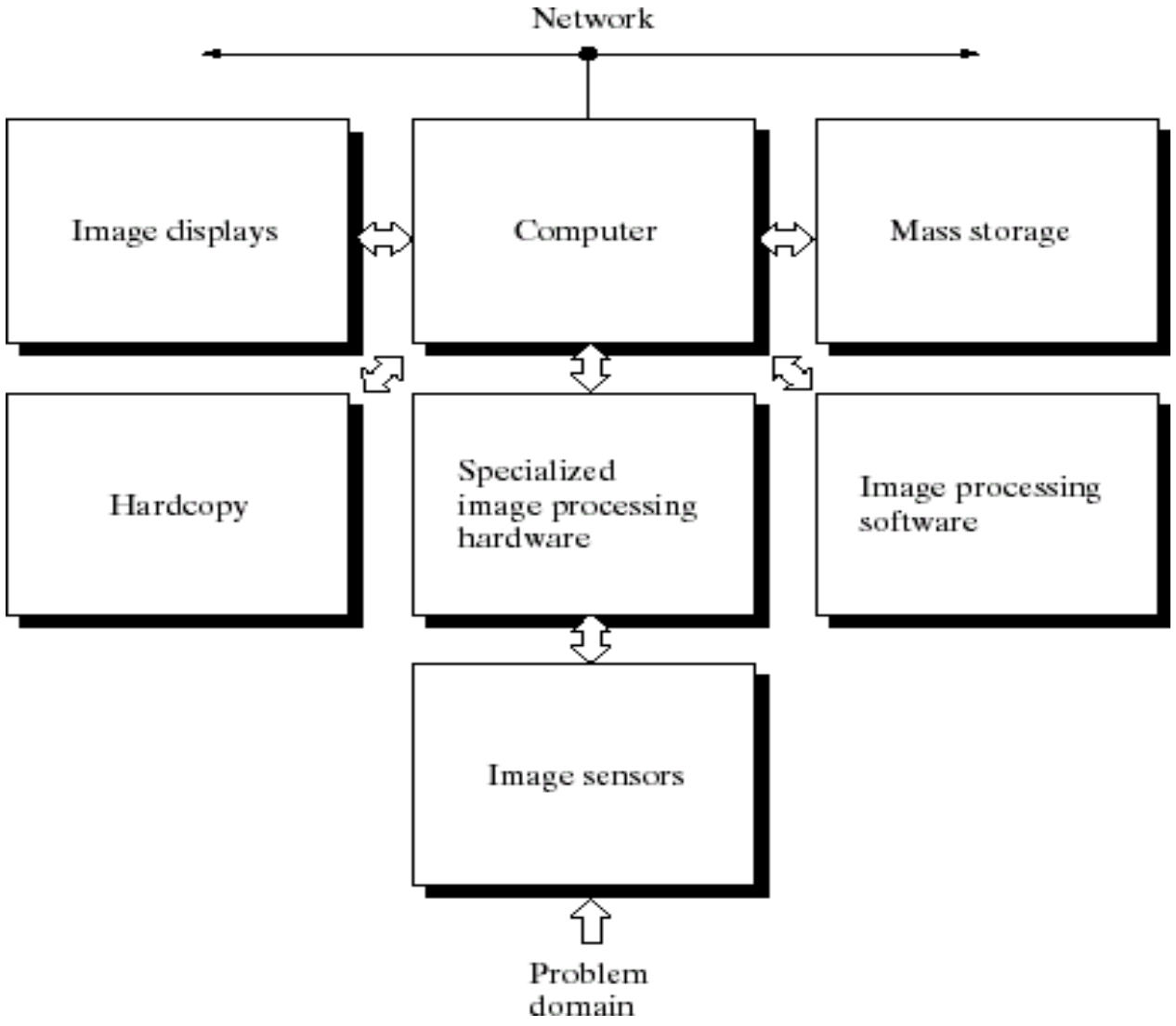
Step 5: Recognition and Interpretation

- Recognition implies assigning of a label to an object based on information provided by its descriptors.
- Interpretation implies assigning of a meaning to an ensemble of recognized objects

Image Knowledgebase

- The knowledgebase stores the prior knowledge about the outside world (the problem domain).
- The processing modules interact with the knowledge base to aid in the processing.

Components of Image Processing System



Components of Image Processing System

- **Image acquisition**
  - Scanners, video camera, CCD cameras, digitizers, etc.
- **Storage**
  - Short term storage, on-line storage and archival storage
- **Processing**
  - Small personal computers to dedicated processing hardware.
- **Communication**
  - Local communication between the processing systems
  - Remote communication for transmission of images
- **Display**
  - Monochrome Monitors to sophisticated display devices