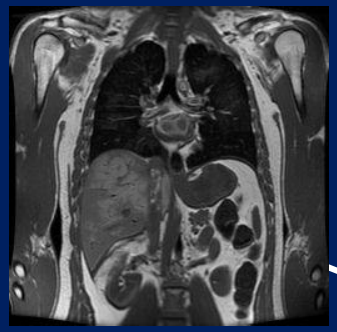
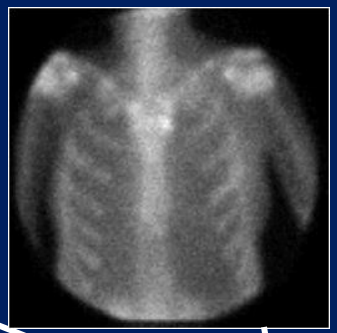
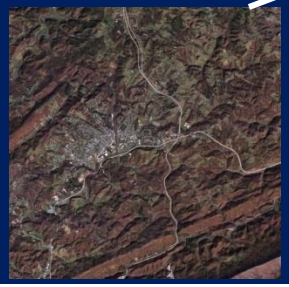
CSE411: Digital Image Processing



Processing

Description of the world

Dr A S Jalal

ECS 702 General Information

Suggested textbook:

- R.C. Gonzalez and R.E. Woods, "**Digital Image Processing**", 3rd edition, Prentice-Hall'2007

References Book

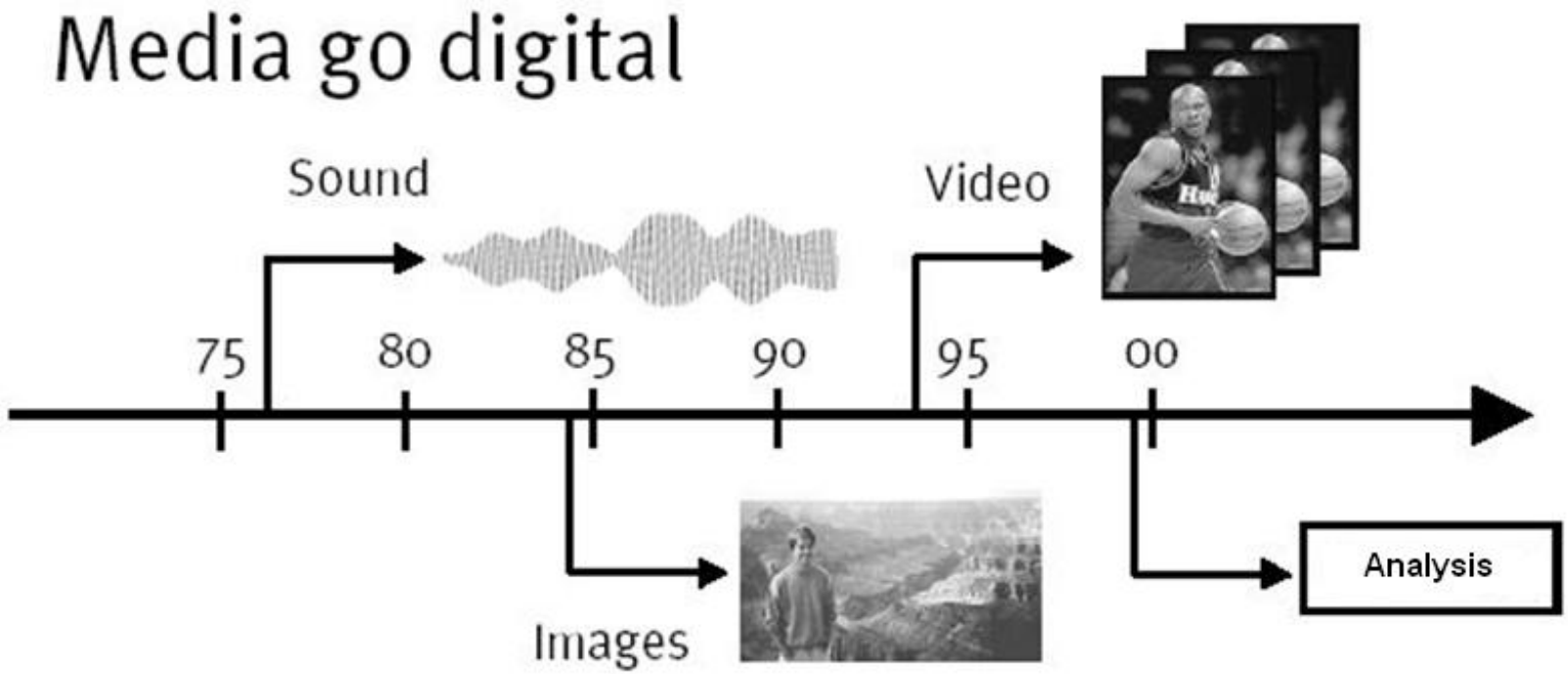
- Chanda, Bhabatosh, Majumder, Dwijesh Dutta "**Digital Image Processing And Analysis**" 2nd edition, PHI Learning

- **Prerequisites**
  - Knowledge of the following three areas:
    - Linear algebra, Elementary probability theory, Digital Signal Processing

Teaching Objectives

- **By the end of this semester, you will**
  - Know basics of digital image processing including image acquisition, perception, transformation, compression, enhancement, interpolation, restoration, Segmentation, analysis, and so on …..
  - Be able to use C and MATLAB to implement basic image processing algorithms and get familiar with some functions provided by C and MATLAB image processing toolbox

Media



More than 80% of information is received by visual perception

A Picture in worth a

1,000 words

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

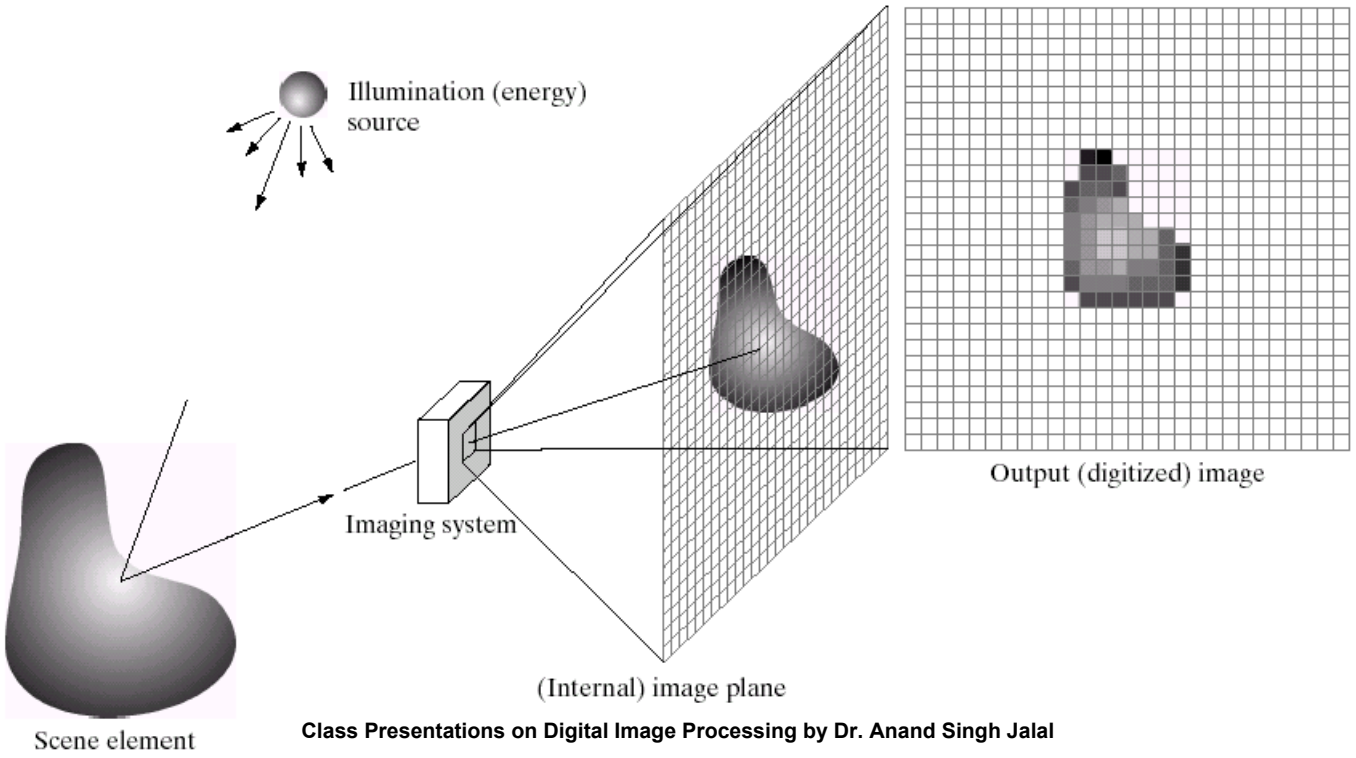
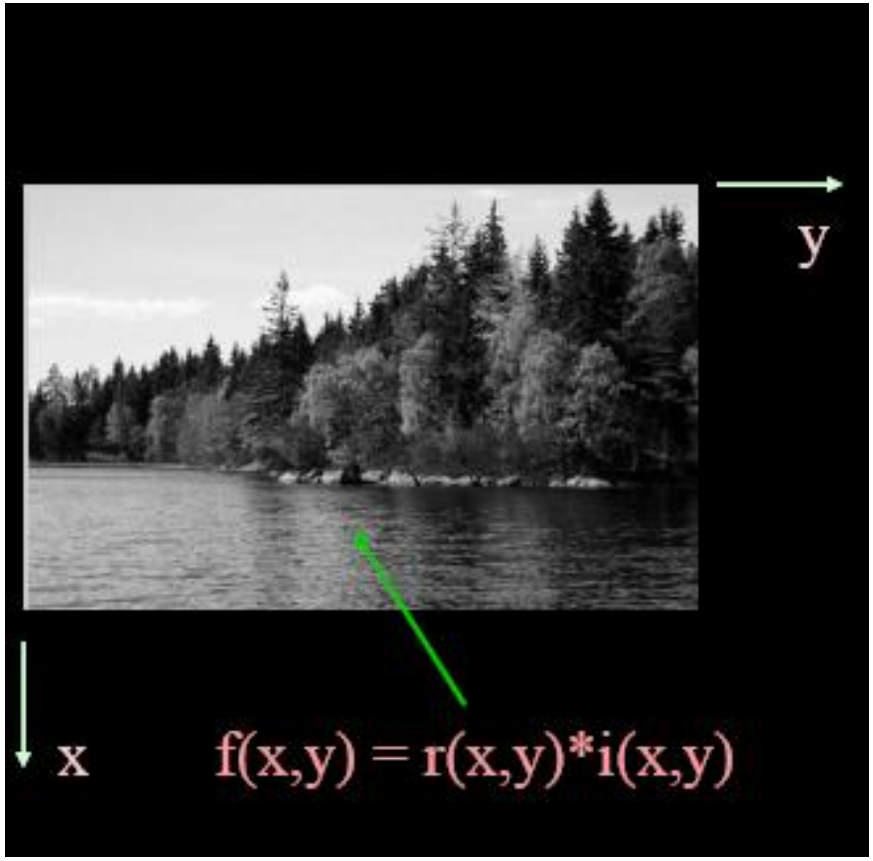


Image Representation



- An image is a 2-D light intensity function f(x,y)
- A digital image f(x,y) is discretized both in spatial coordinates and brightness
- It can be considered as a matrix whose row, column indices specify a point in the image and the element value identifies gray level value at that point
- These elements are referred to as pixels or pels

r(x,y) – reflectance of surface (0-1)
i(x,y) – intensity of light (0-infinite)

Image Representation …

- Spatial discretization by grids
- Intensity discretization by quantization

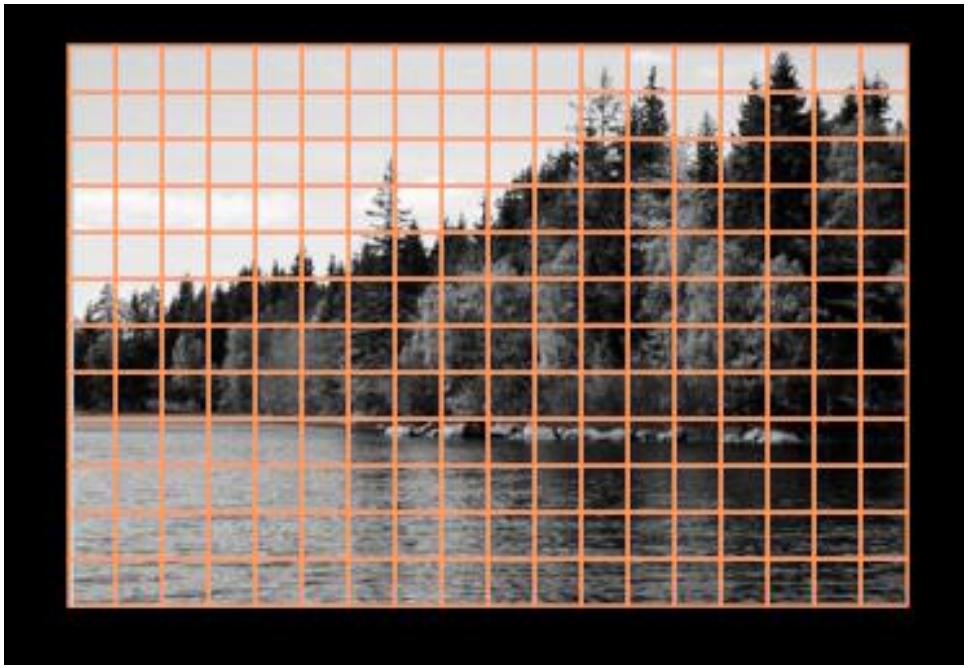
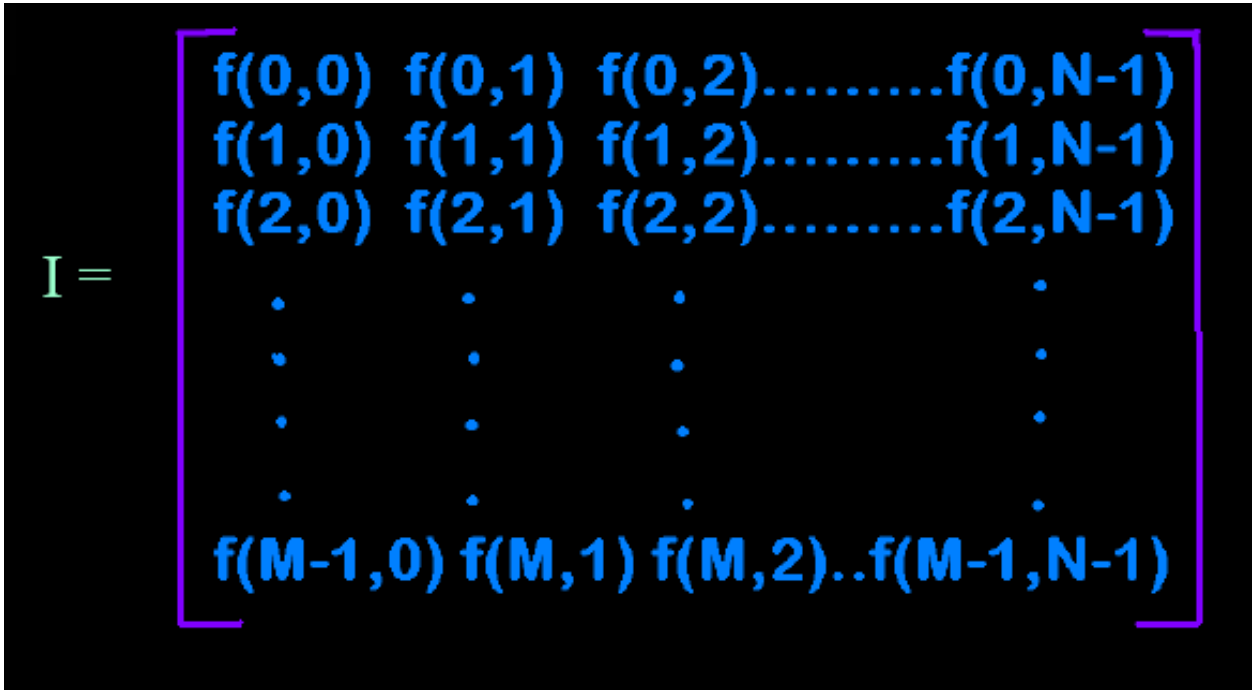
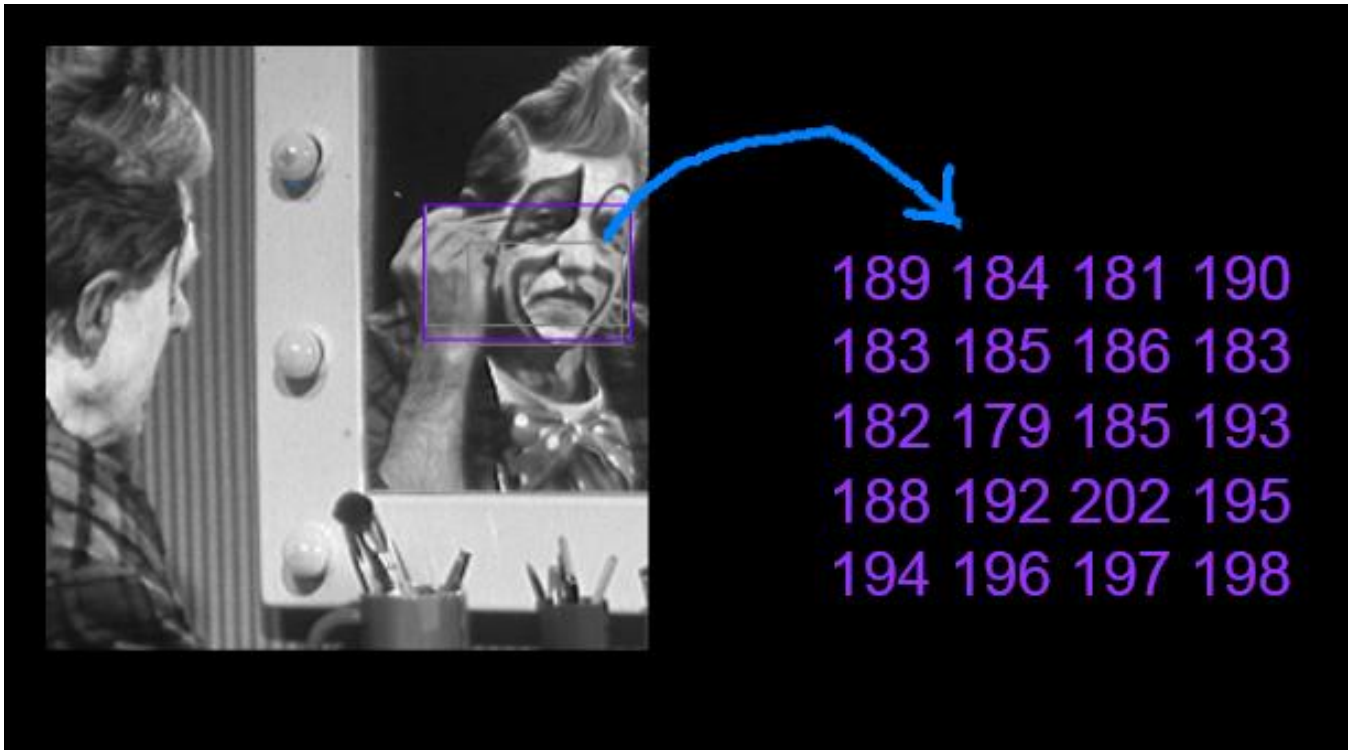


Image Representation …



- Image Size : 256x256, 512x512, 1024x1024 etc
- Quantization: 8 bits

Image Representation …



Problems studied in Digital Image Processing

Sensing

- How do sensors obtain images of the world?
- How do images encode properties of the world, such as material, shape, illumination, and spatial relationships?

Encoded Information

How do images yield information for understanding the 3D world, including the geometry, texture, motion, and identity of objects in it?

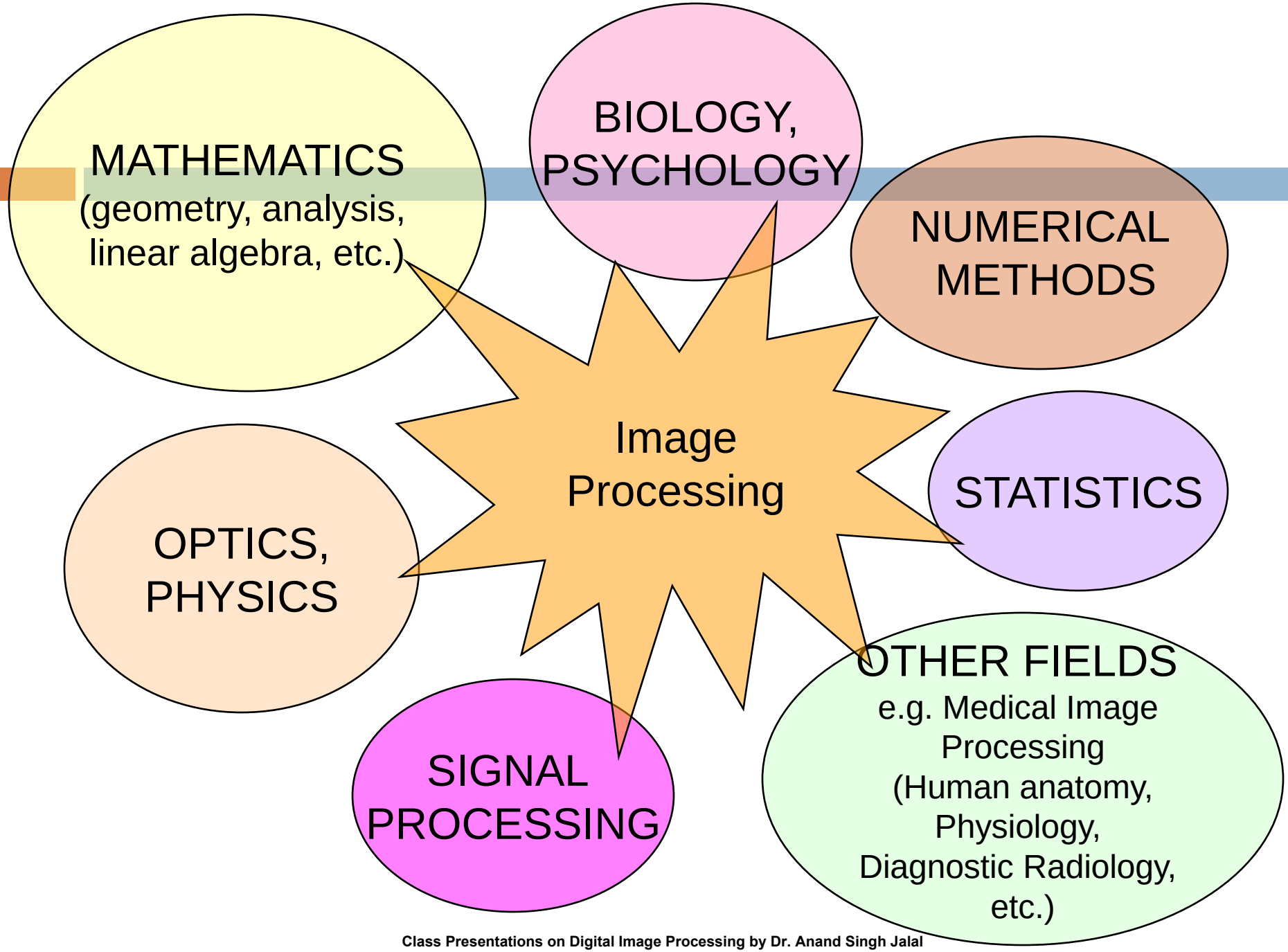
Problems studied in Digital Image Processing

Representations

What representations should be used for stored descriptions of objects, their parts, properties, and relationships?

Algorithms

What methods are there to process image information and construct descriptions of the world and its objects?


MATHEMATICS
(geometry, analysis, linear algebra, etc.)
BIOLOGY, PSYCHOLOGY
NUMERICAL METHODS
Image Processing
STATISTICS
OPTICS, PHYSICS
SIGNAL PROCESSING
OTHER FIELDS
e.g. Medical Image Processing
(Human anatomy, Physiology, Diagnostic Radiology, etc.)

History of Digital Image Processing

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

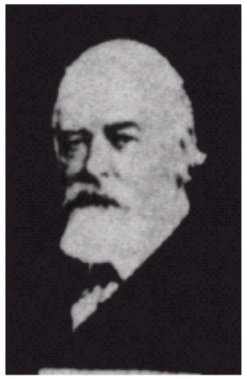
Early digital image

- 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

History of Digital Image Processing …

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



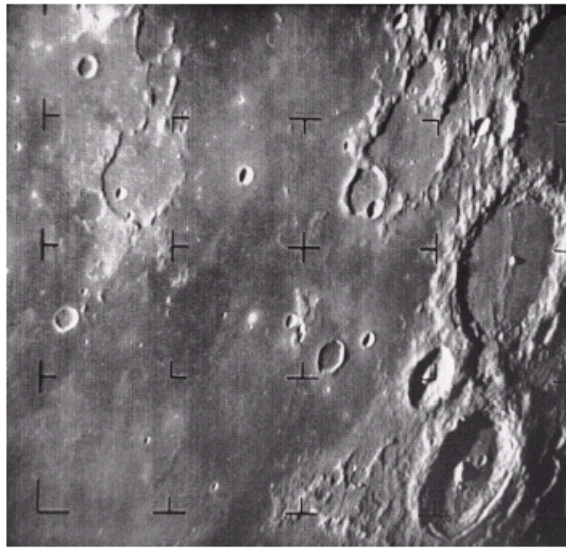
Improved digital image

Early 15 tone digital image

History of Digital Image Processing …

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

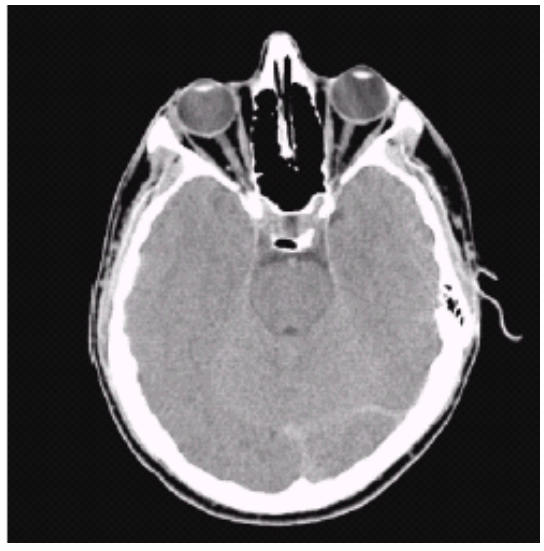


A picture of the moon taken by the Ranger 7 probe minutes before landing

History of Digital Image Processing …

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

History of Digital Image Processing …

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

Why do we need Image Processing?

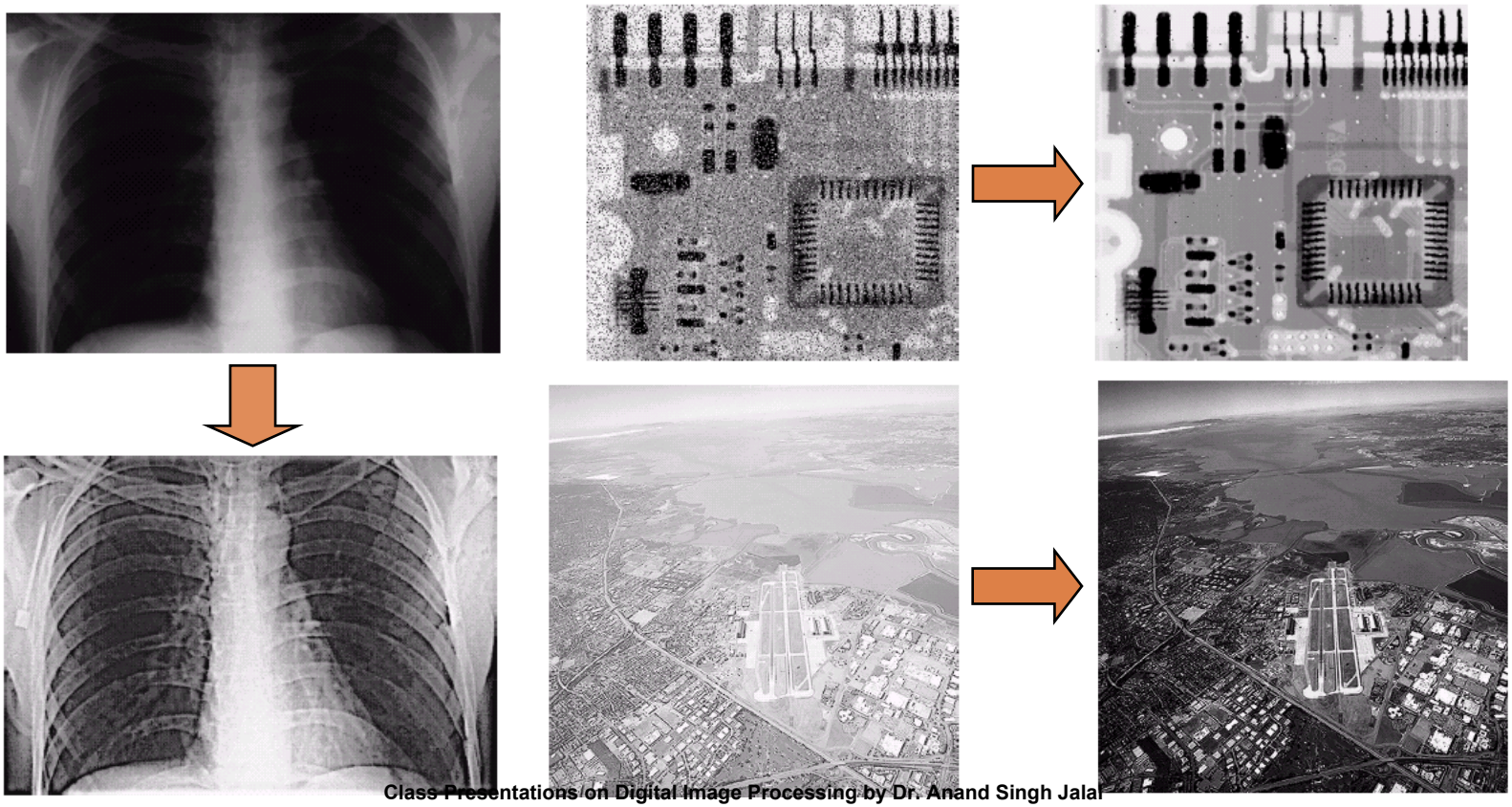
- What do we mean by *Digital Image Processing*
  - **Processing digital images by a digital computer**

It is Motivated by three major applications-

- Improvement of pictorial information for human perception
- Image processing for autonomous machine application
- Efficient storage and transmission

Examples: Image Enhancement

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



Human Perception

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

- Typical applications:
  - Noise filtering
  - Content enhancement
    - Contrast enhancement
    - Deblurring

Filtering

Filtering

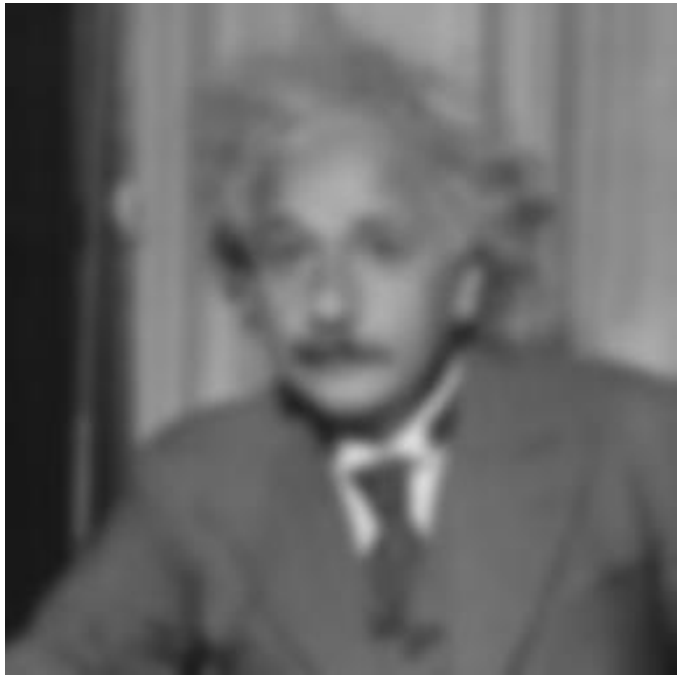
Noisy Image

Filtered Image

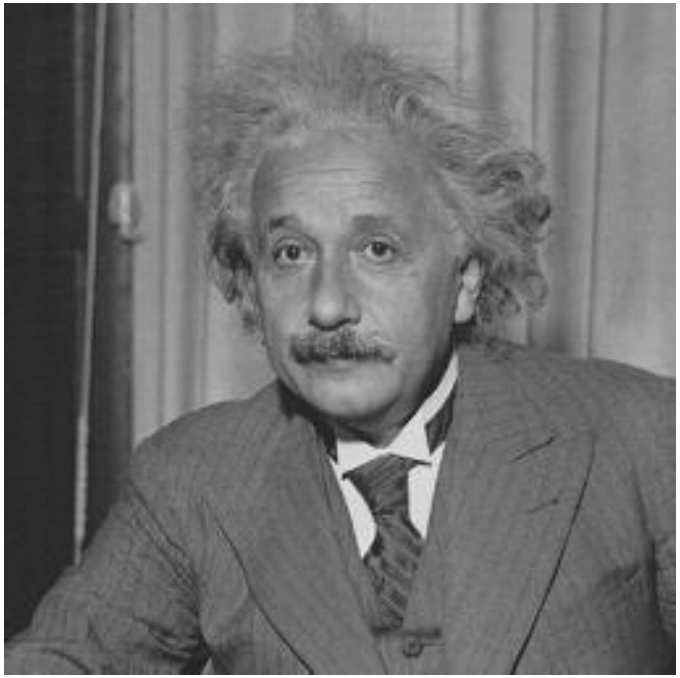
Image Enhancement

Enhance

Image Deblurring



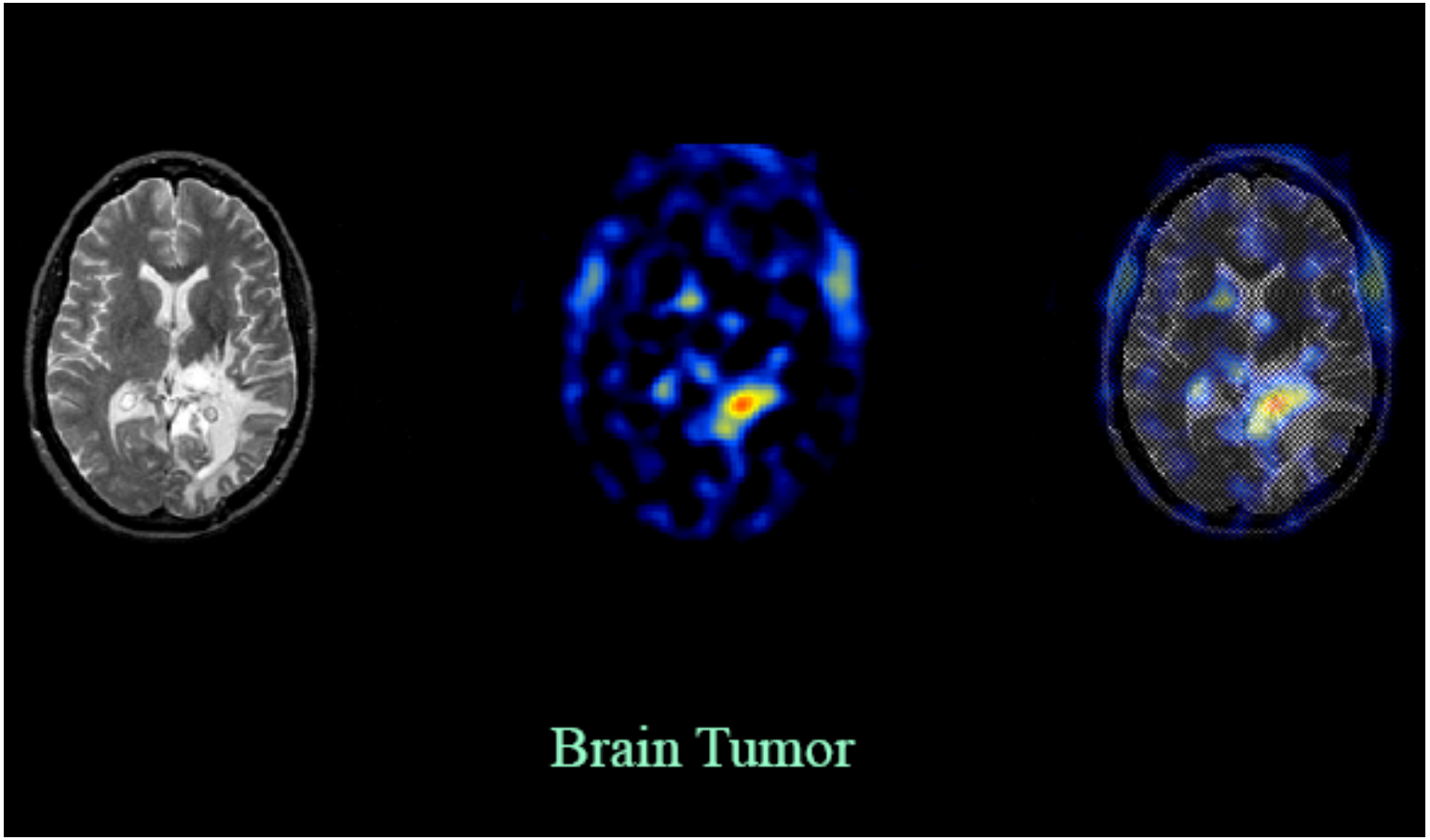
Deblurring



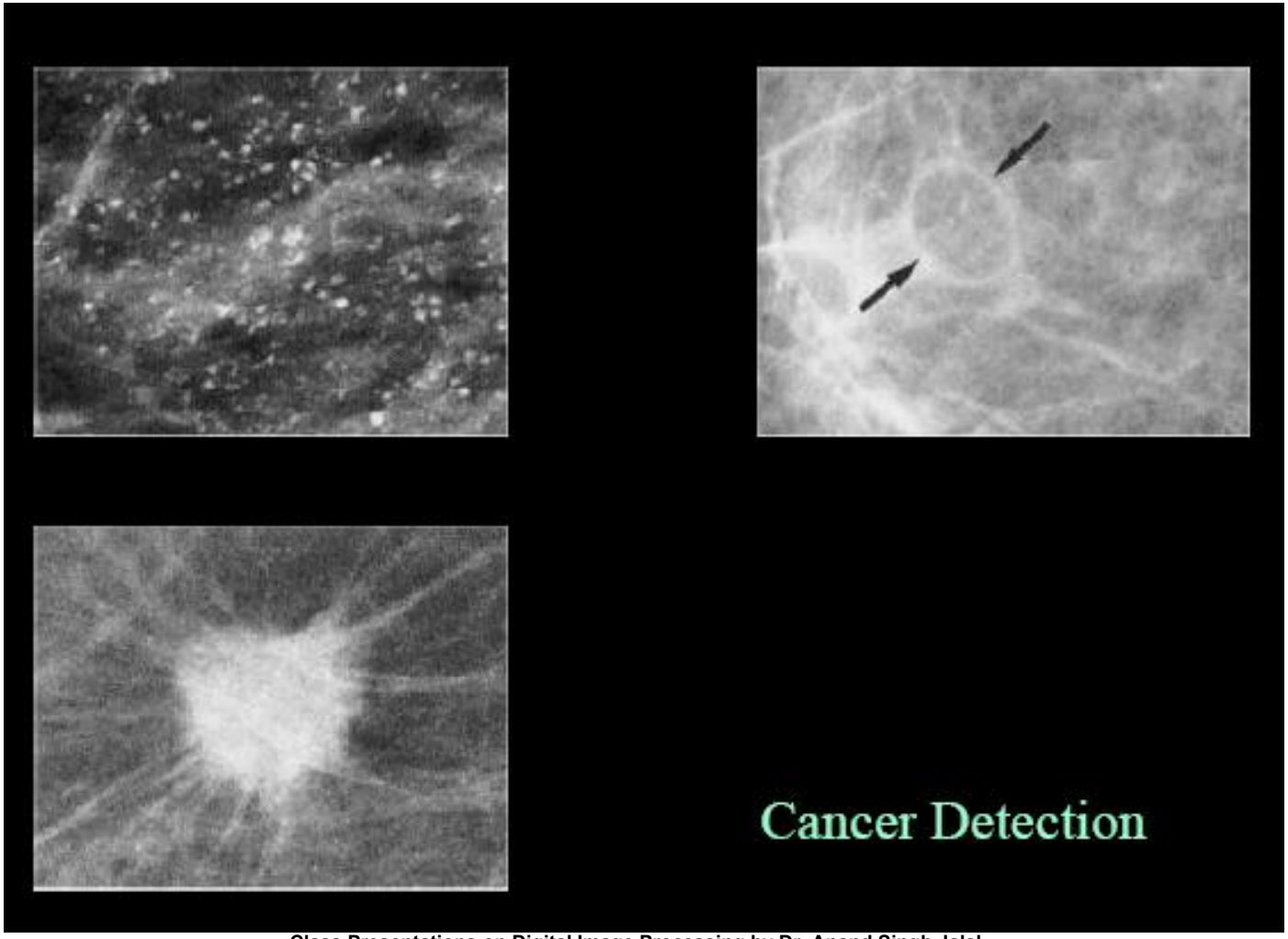
Blurred

Deblurred

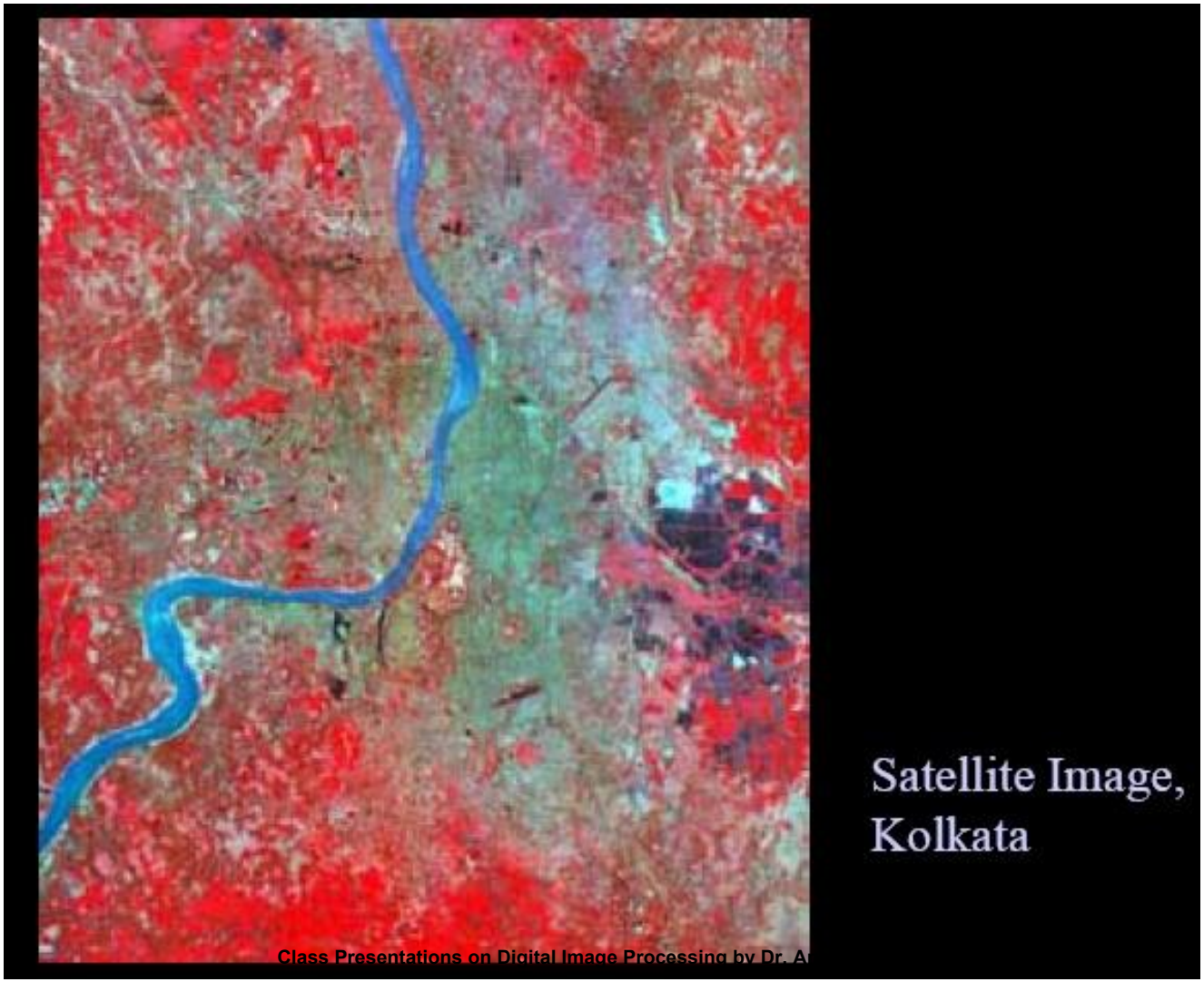
Medical Imaging



Medical Imaging

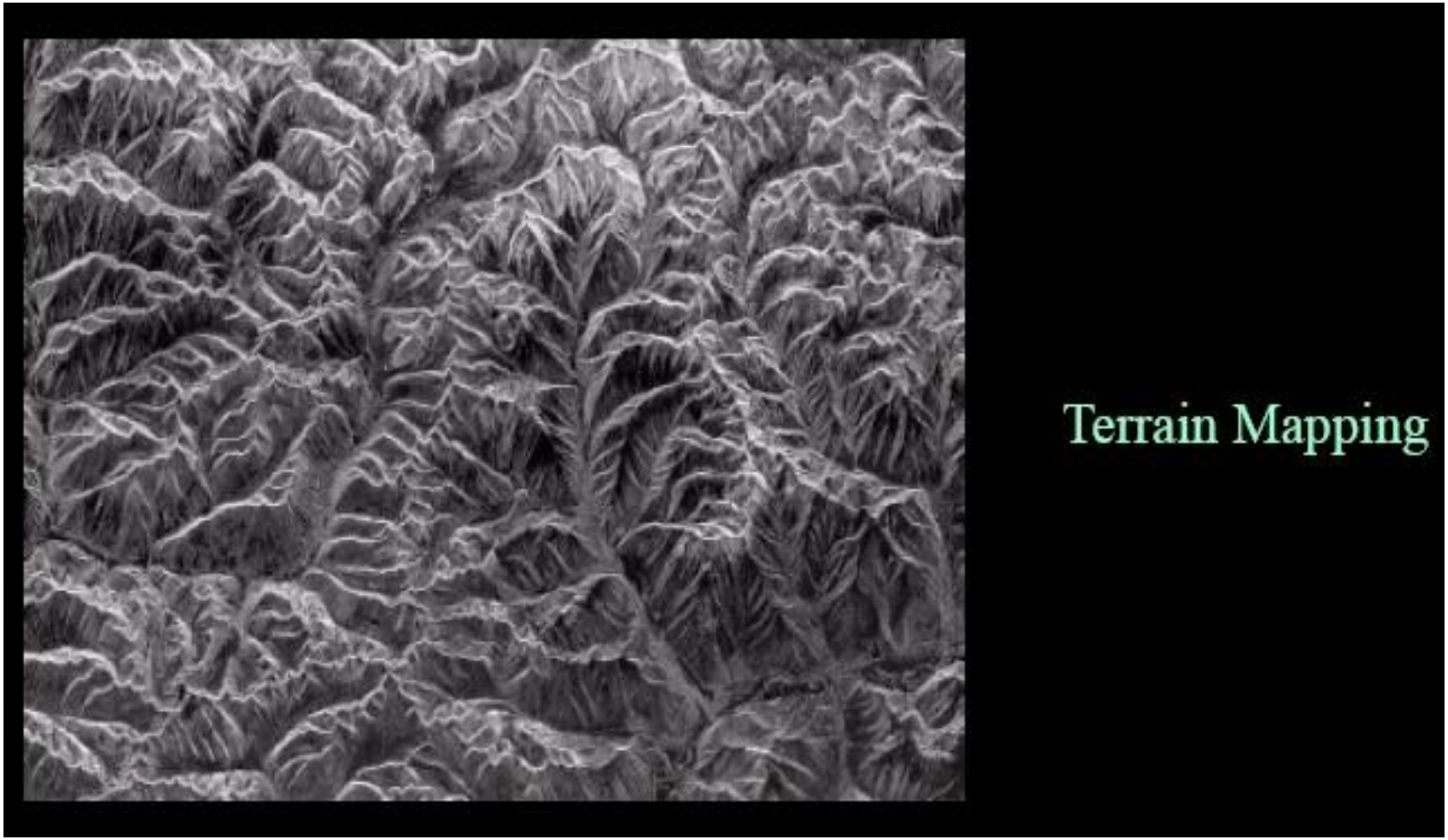


Remote Sensing



Satellite Image,
Kolkata

Remote Sensing …



Weather Forecasting

Astronomy

Image Compression

- An image usually contains lot of redundancy that can be exploited to achieve compression
  - Pixel redundancy
  - Coding redundancy
  - Psychovisual redundancy
- Applications:
  - Reduced storage
  - Reduction in bandwidth

Image Compression …

Image Compression …

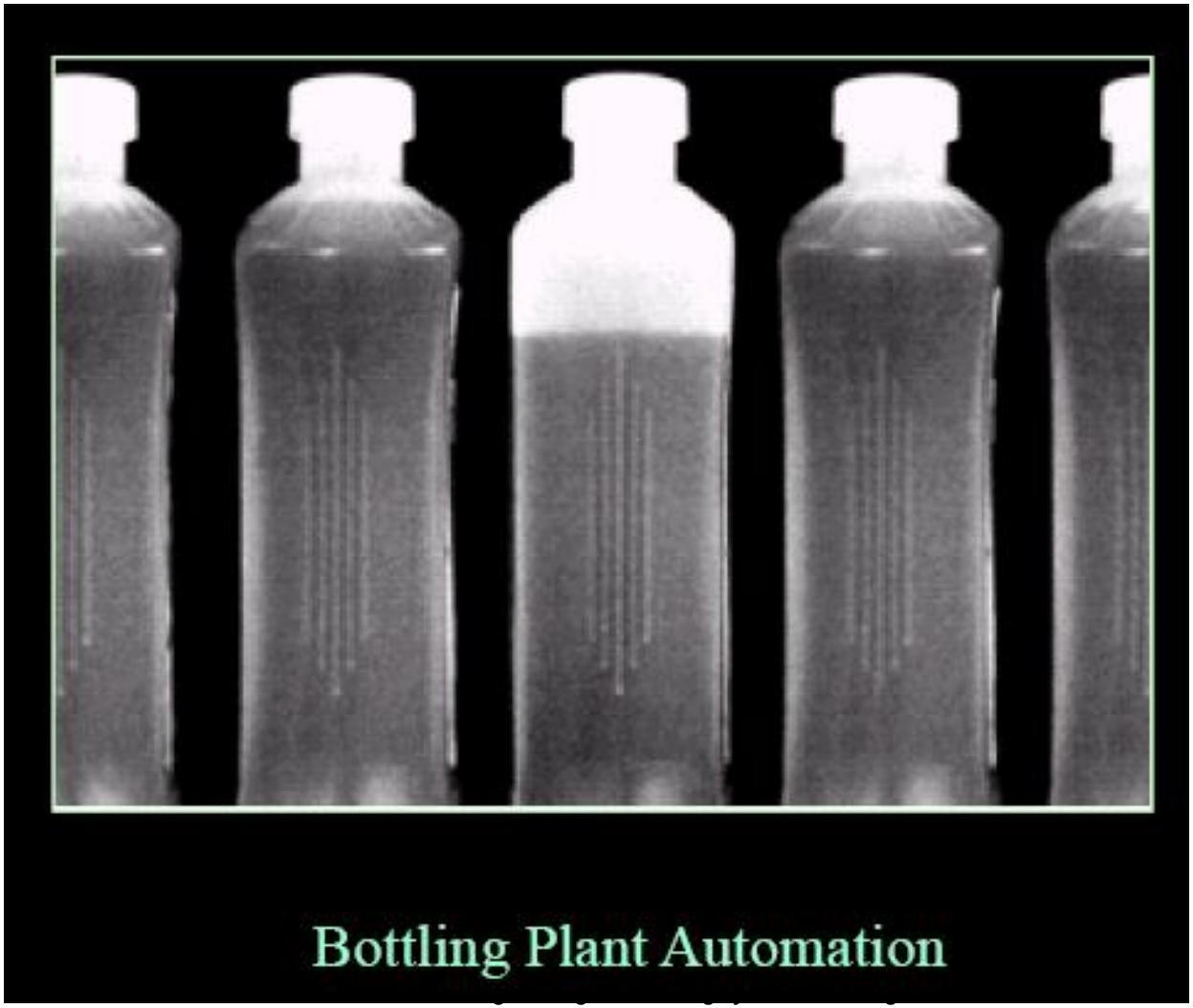
Image Compression …

Low quality (Q = 10), filesize 4787 B. Lowest quality (Q = 1), filesize 1523 B.

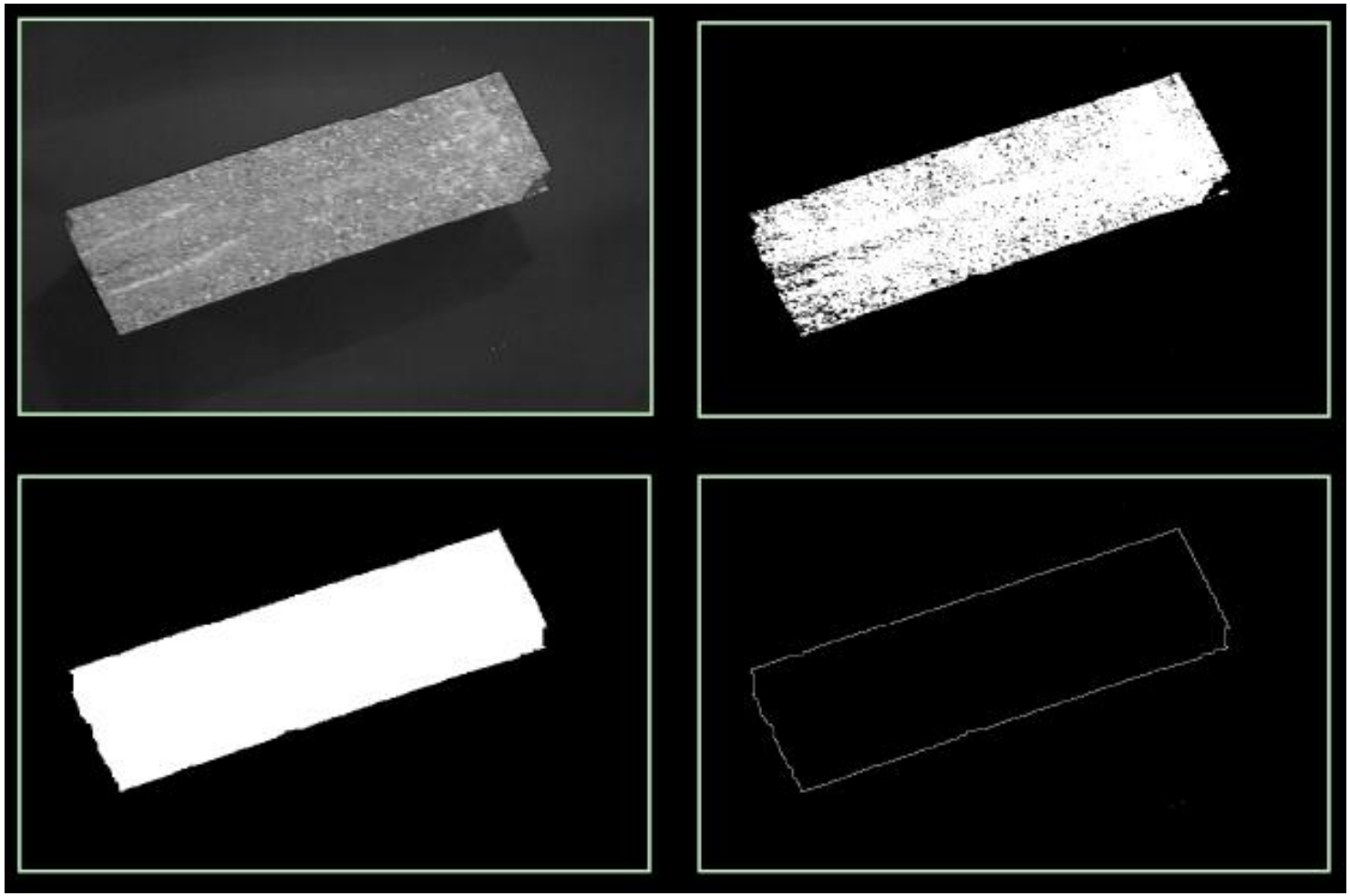
Machine Vision Applications

- Here the interest is on procedures for extraction of image information suitable for computer processing
- Typical Applications:
  - Industrial Machine vision for product assembly and inspection
  - Automated Target detection and tracking
  - Finger print recognition
  - Machine processing of aerial and satellite imagery
  - Weather prediction and crop assessment etc

Automated Inspection

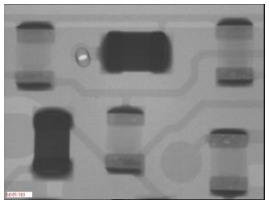


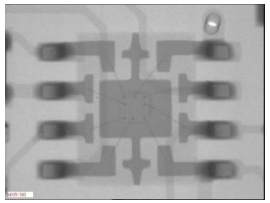
Automated Inspection

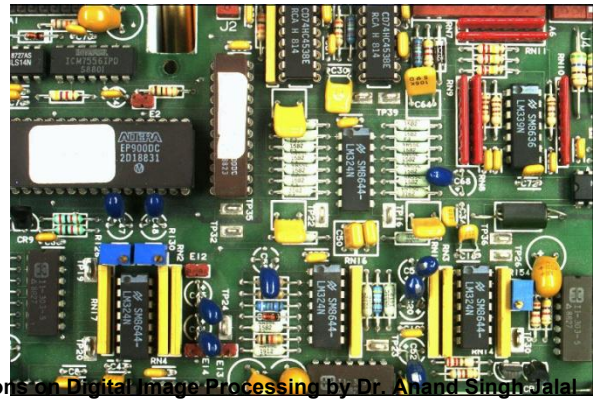


Examples: PCB Inspection

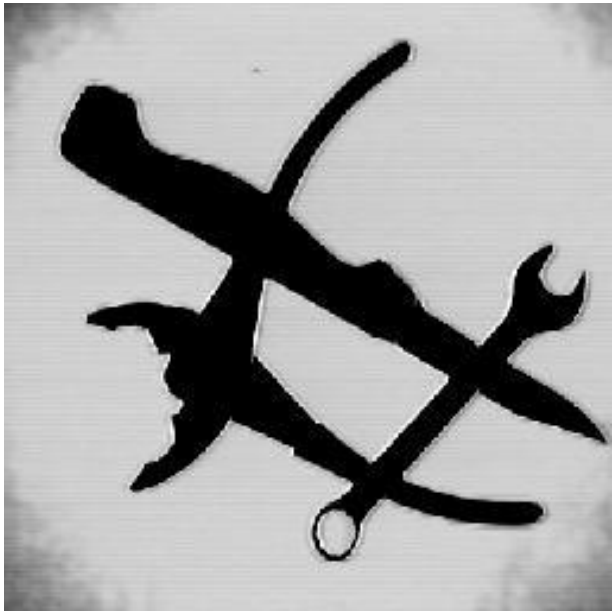
- Printed Circuit Board (PCB) inspection
  - Machine inspection is used to determine that all components are present and that all solder joints are acceptable
  - Both conventional imaging and x-ray imaging are used

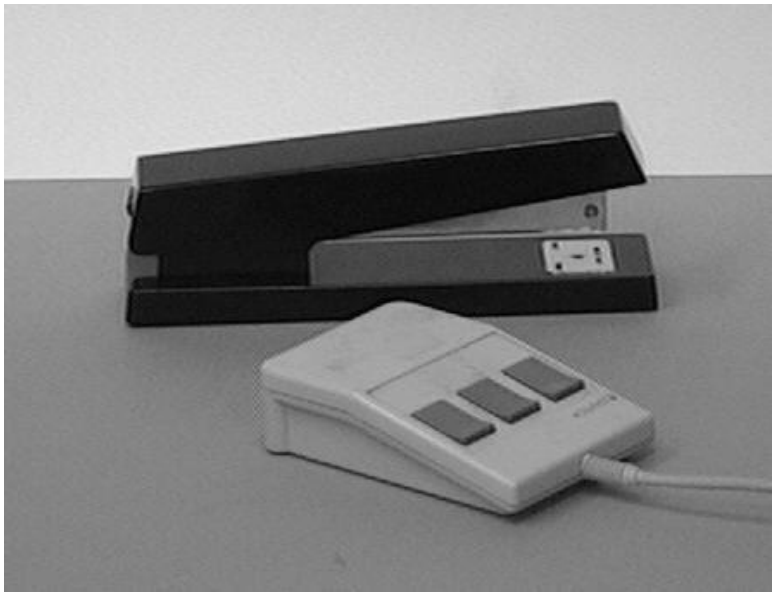






Object Recognition



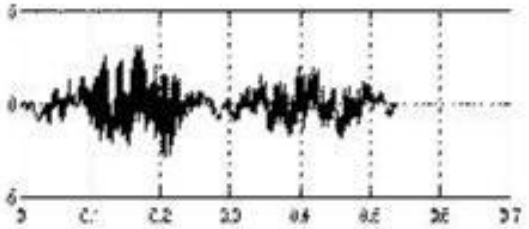


Indexing into Databases (cont'd)

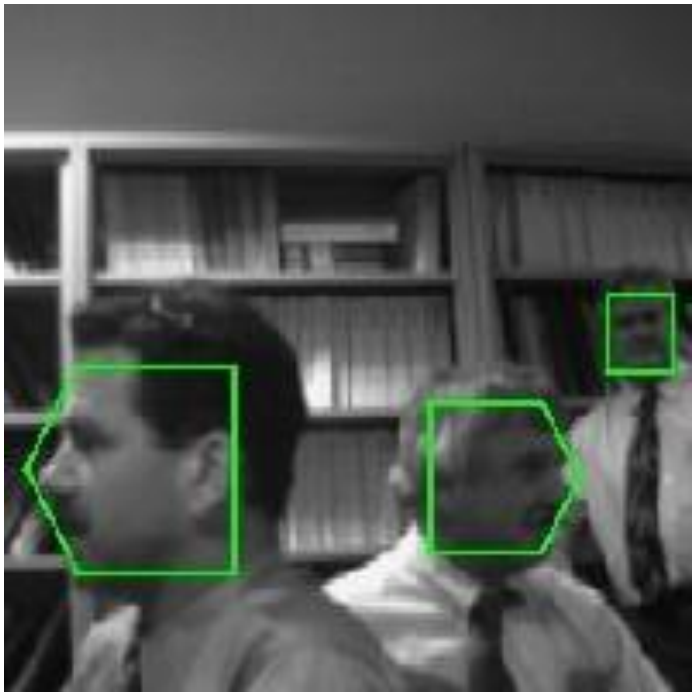
- Color, texture

$T = 33.6\text{s}$, found 2 of 2

Biometrics



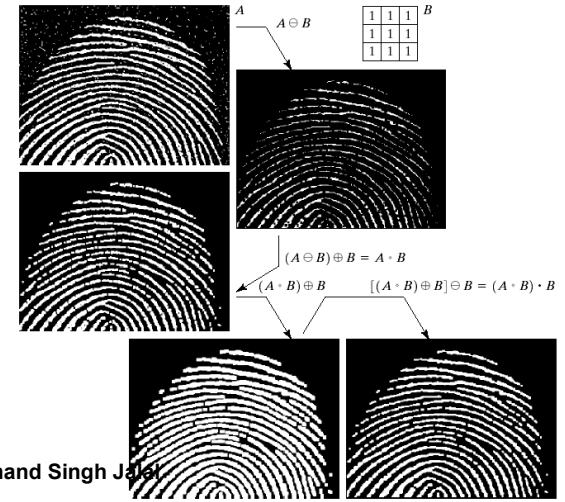
Face Detection



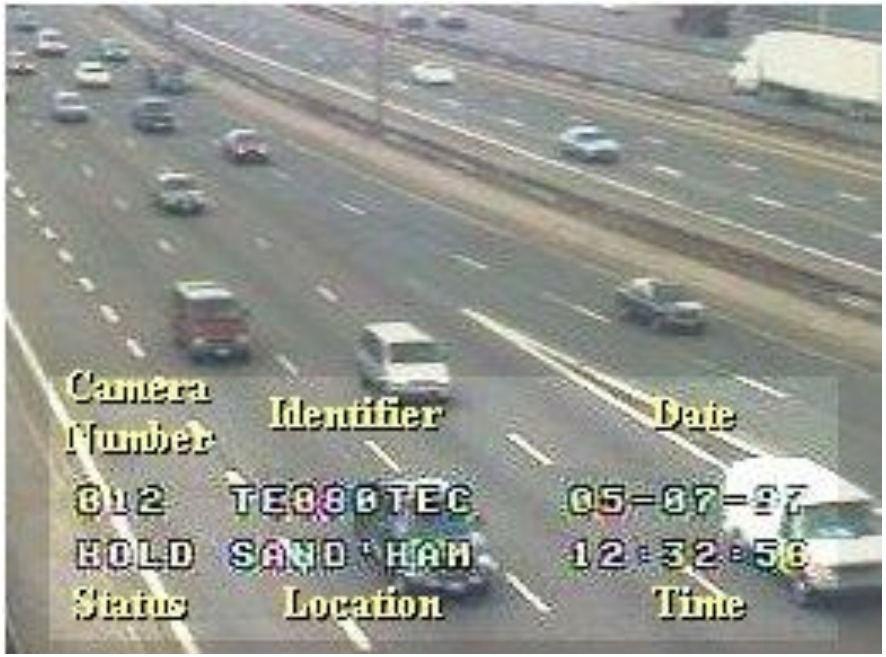
Face Recognition

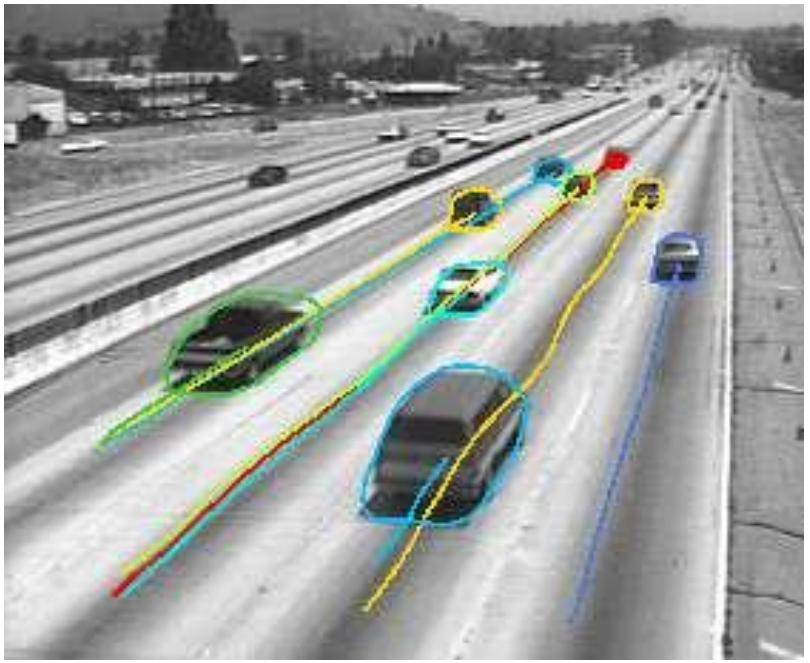
Examples: Law Enforcement

- Image processing techniques are used extensively by law enforcers
  - Number plate recognition for speed cameras/automated toll systems
  - Fingerprint recognition
  - Enhancement of CCTV images



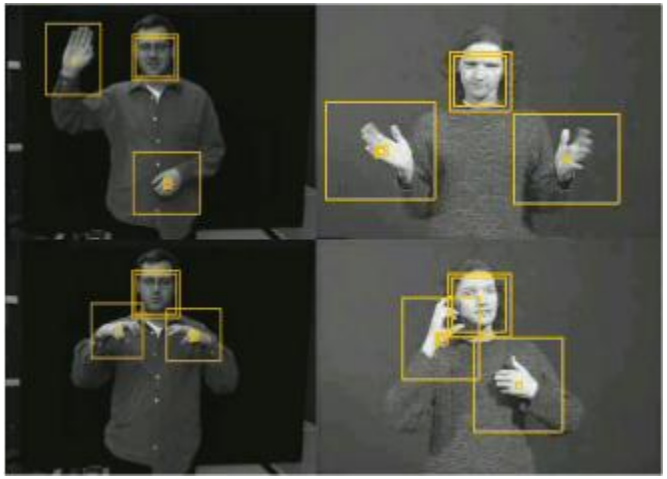
Traffic Monitoring

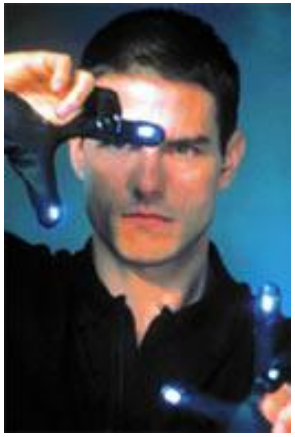


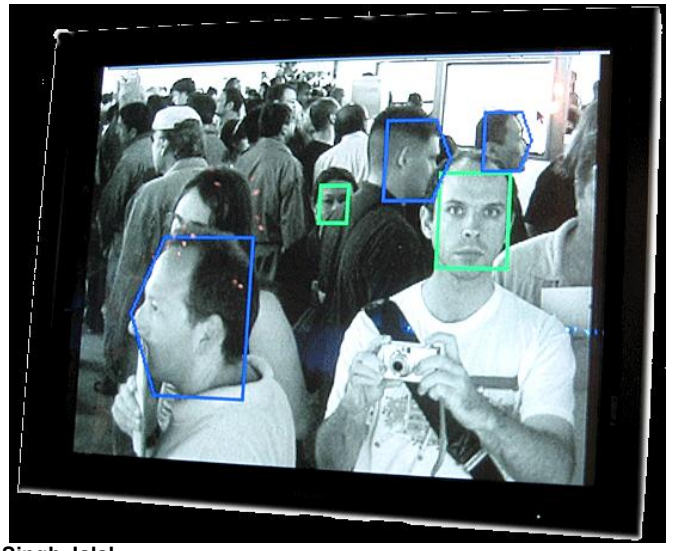


Examples: HCI

- 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





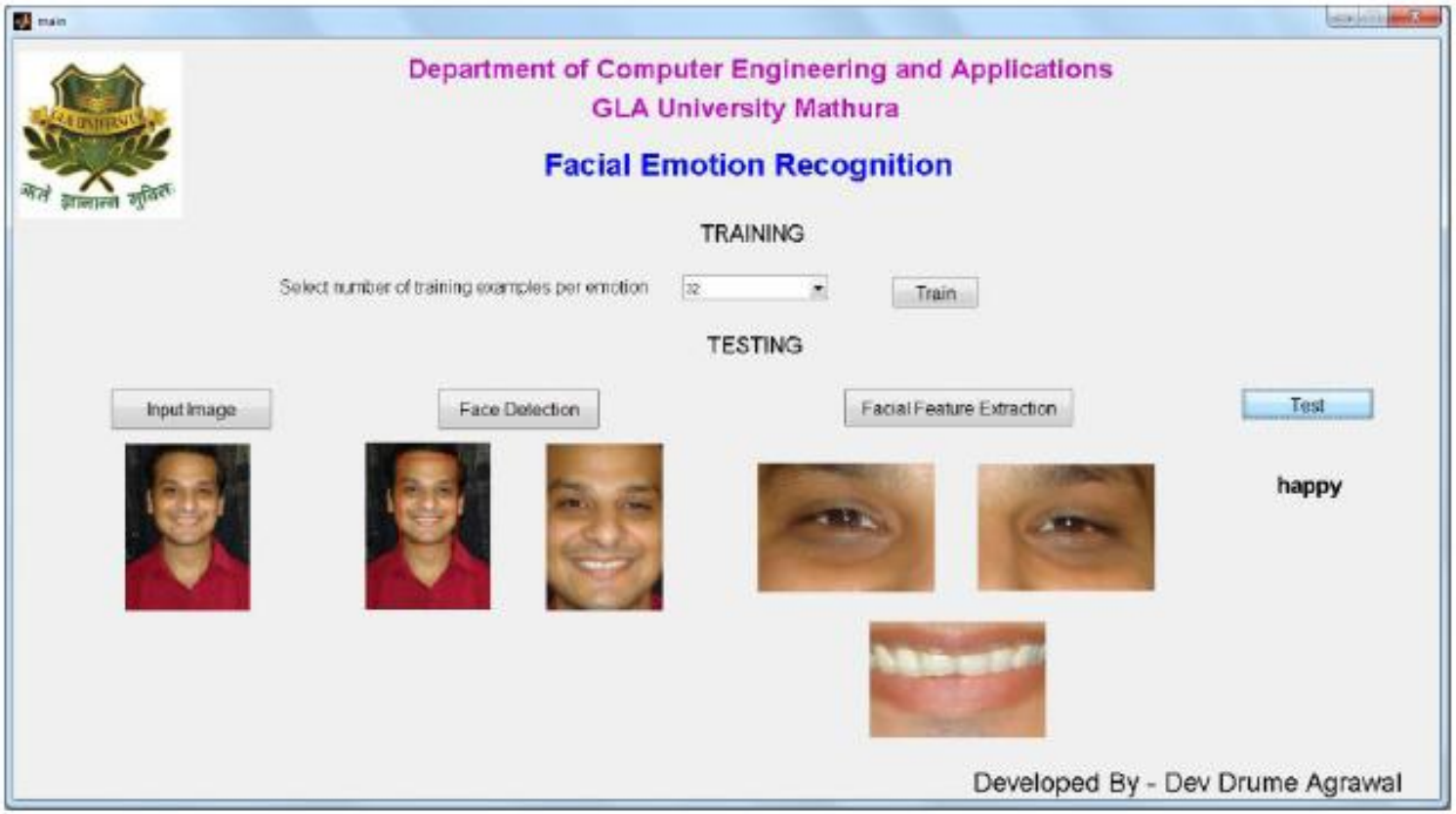


Machine Vision Applications …

- Video surveillance is the task of analyzing video data to identify unusual or suspicious activities in security-sensitive areas such as banks, department stores, parking lots.
- Manual surveillance requires the system to be monitored continuously by a person and is costly and problematic.

Machine Vision @ GLA

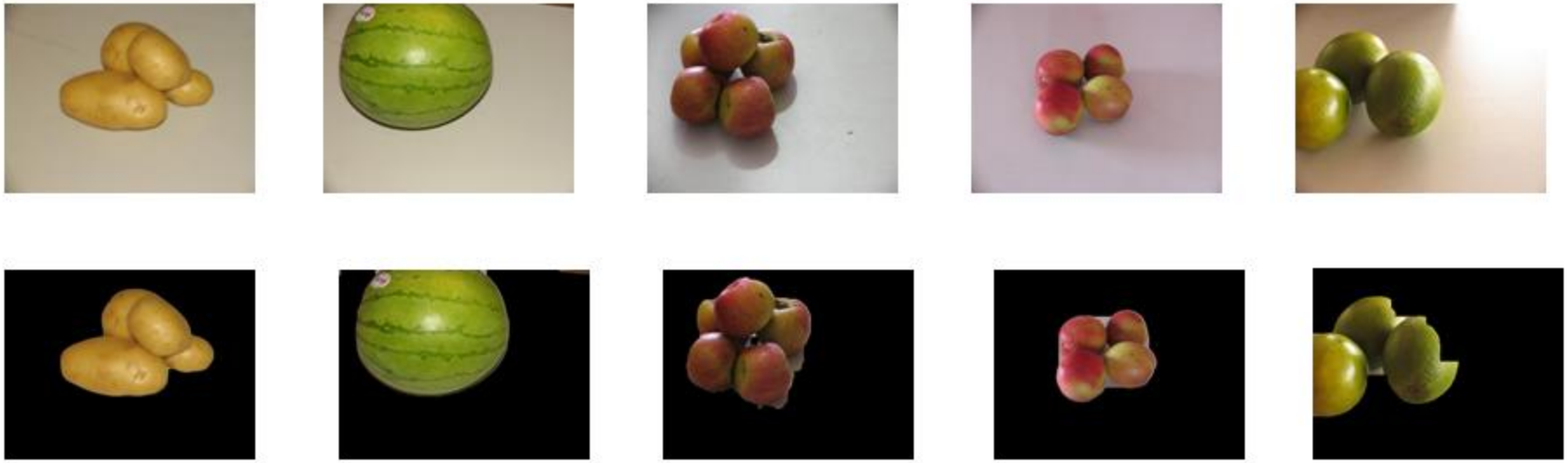
Machine Vision Applications ..



Machine Vision Applications ..

Machine Vision Applications ..

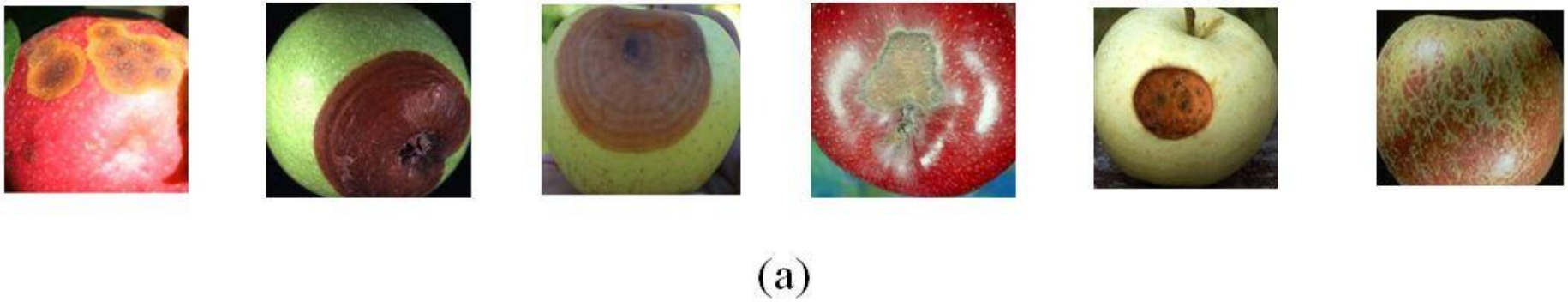
- **Applications in Agriculture**
  - Fruit and Vegetable Classification



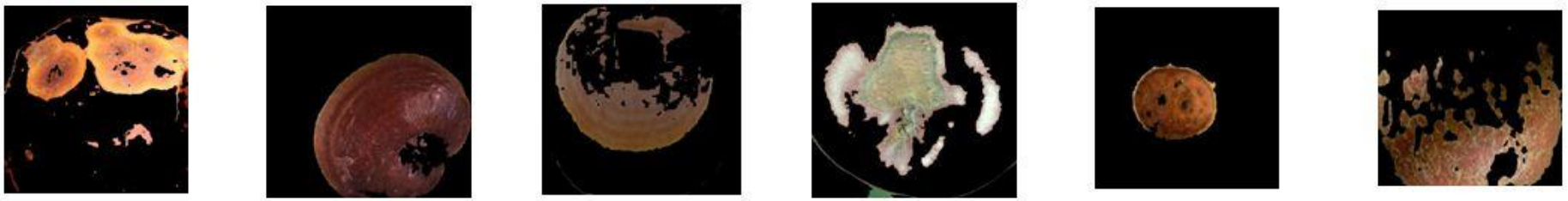
Machine Vision Applications ..

- **Applications in Agriculture …**

  Automatic Detection and Classification of Fruit Diseases



(a)



(b)

Machine Vision Applications ..

Video Sequence Processing

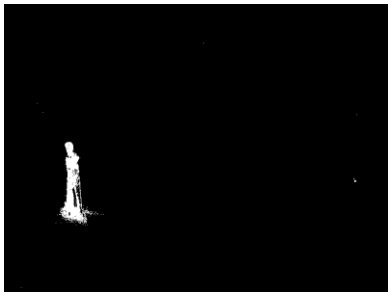
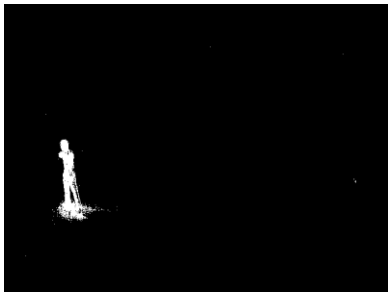
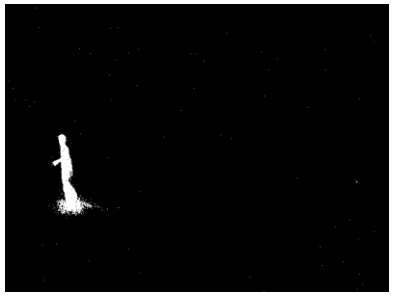
- The major emphasis of image sequence processing is detection of moving parts
- This has various applications
  - Detection and tracking of moving targets for security surveillance purpose
  - To find out the trajectory of a moving target
  - Monitoring the movements of organ boundaries in medical applications etc.

Machine Vision Applications ..

Movement Detection



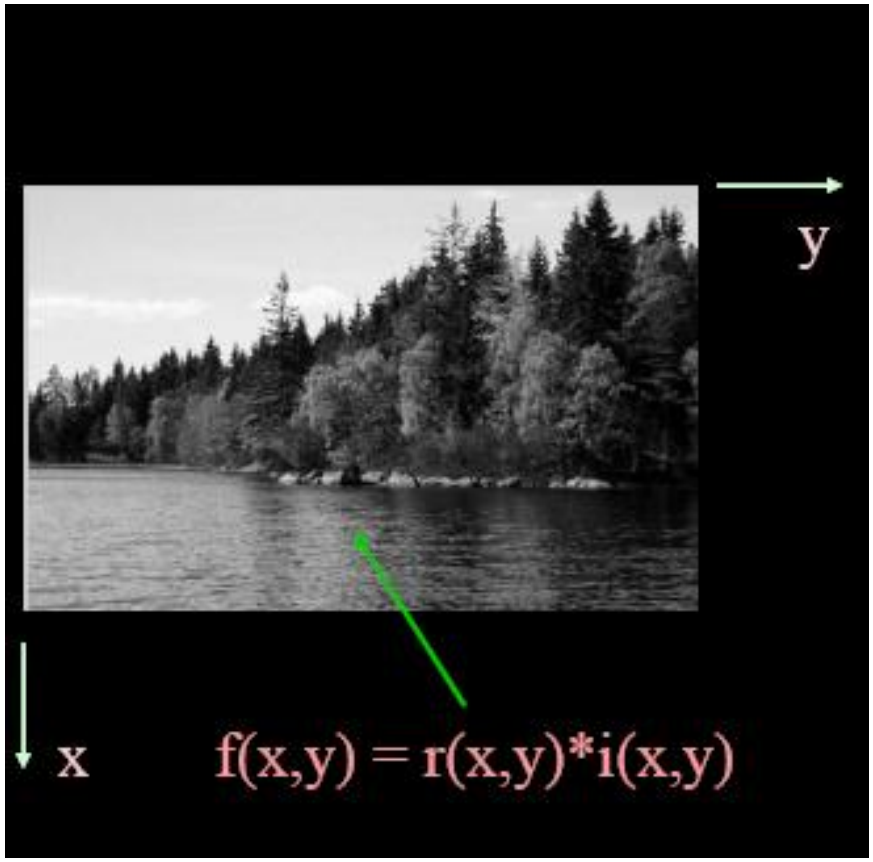


Machine Vision Applications ..

Human Activity Identification

Image Representation



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r(x,y) – reflectance of surface (0-1)
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Image Representation …

- Spatial discretization by grids
- Intensity discretization by quantization

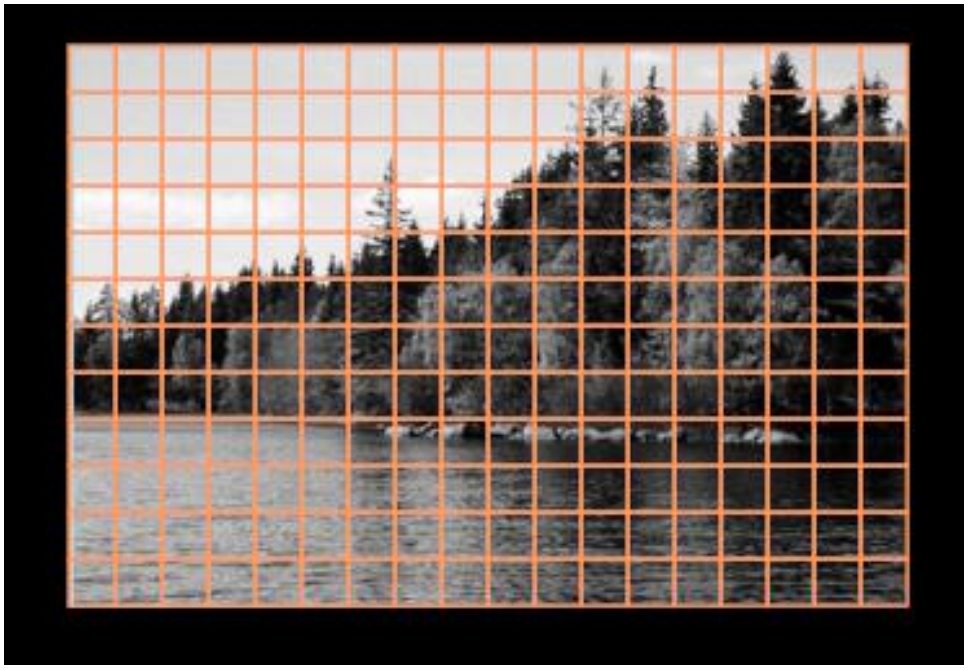
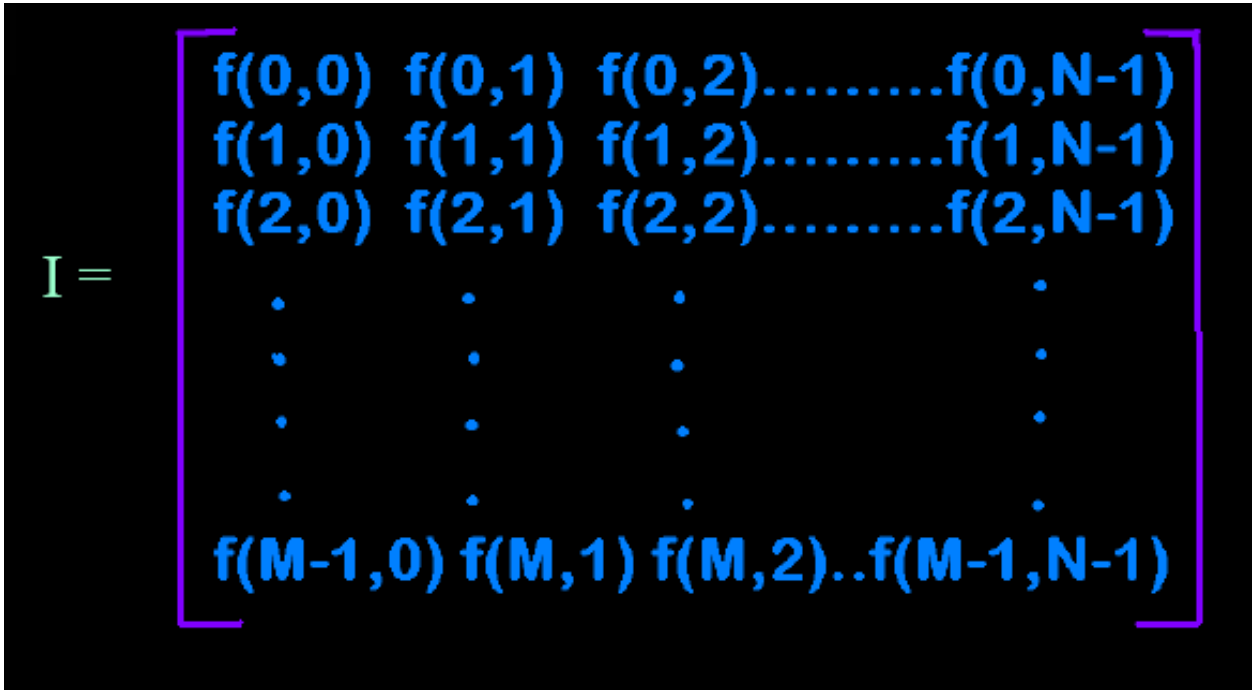


Image Representation …



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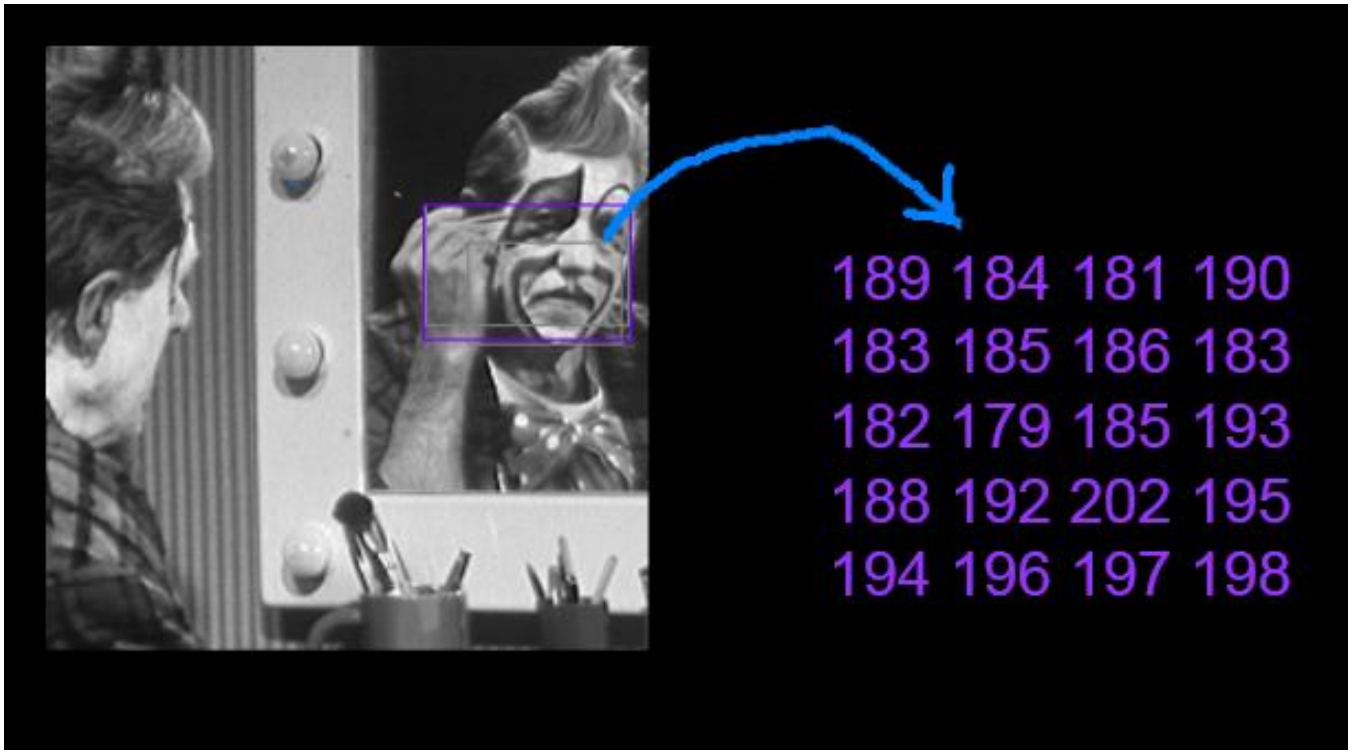
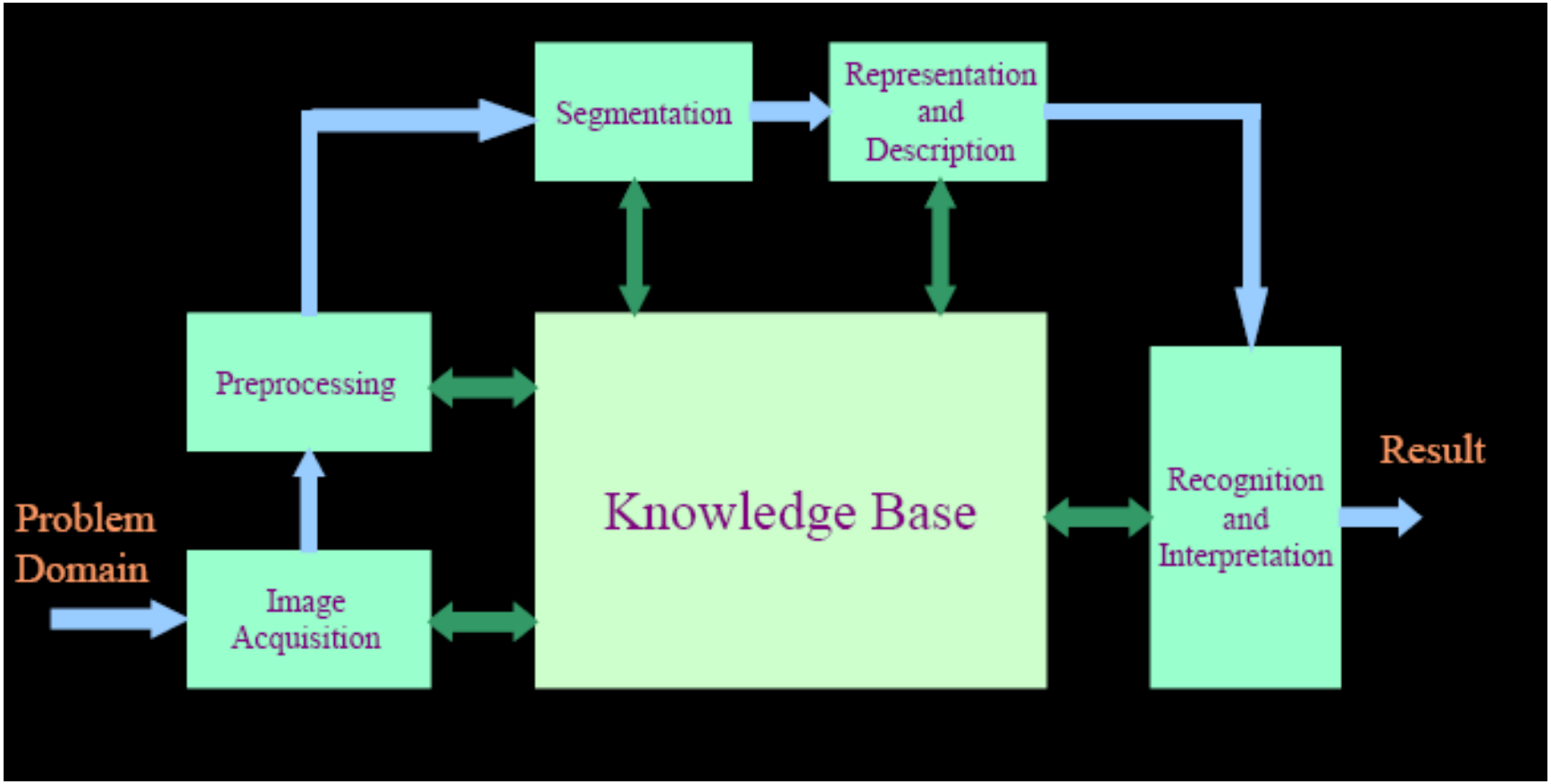


Steps in Digital Image Processing

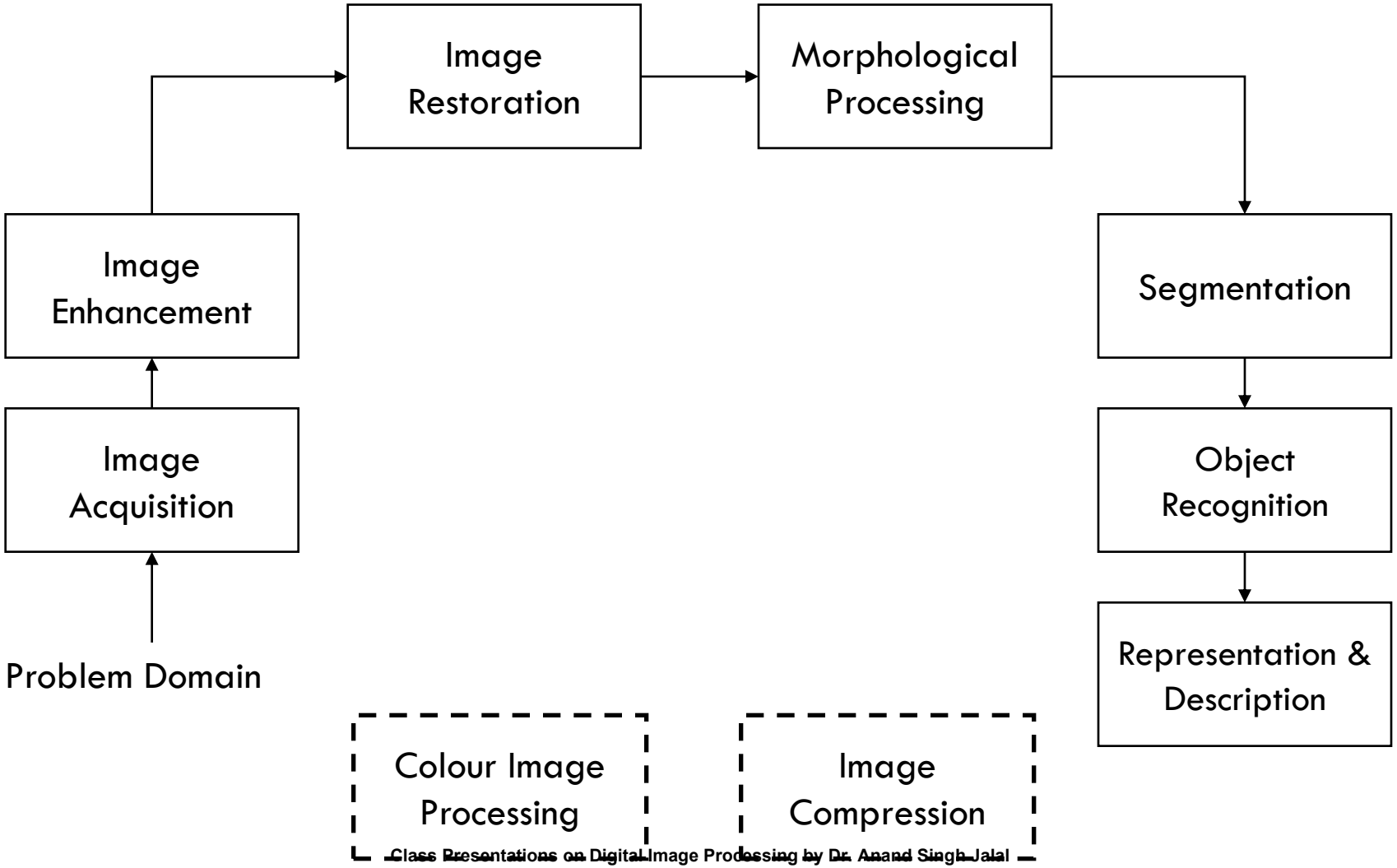
Digital Image Processing involves following basic tasks

- **Image Acquisition:-** An imaging sensor and the capability to digitize the signal produced by the sensor
- **Preprocessing:-** Enhances the image quality, filtering, contrast enhancement etc.
- **Segmentation:-** Partitions an input image into constituent parts of objects
- **Description/ Feature Selection:-** Extracts description of image objects suitable for further computer processing
- **Recognition & Interpretation:-** Assigning a label to the object based on the information provided by its descriptor. Interpretation assigns meaning to a set of labeled objects.
- **Knowledge Base:-** Knowledge Base helps for efficient processing as well as inter module cooperation

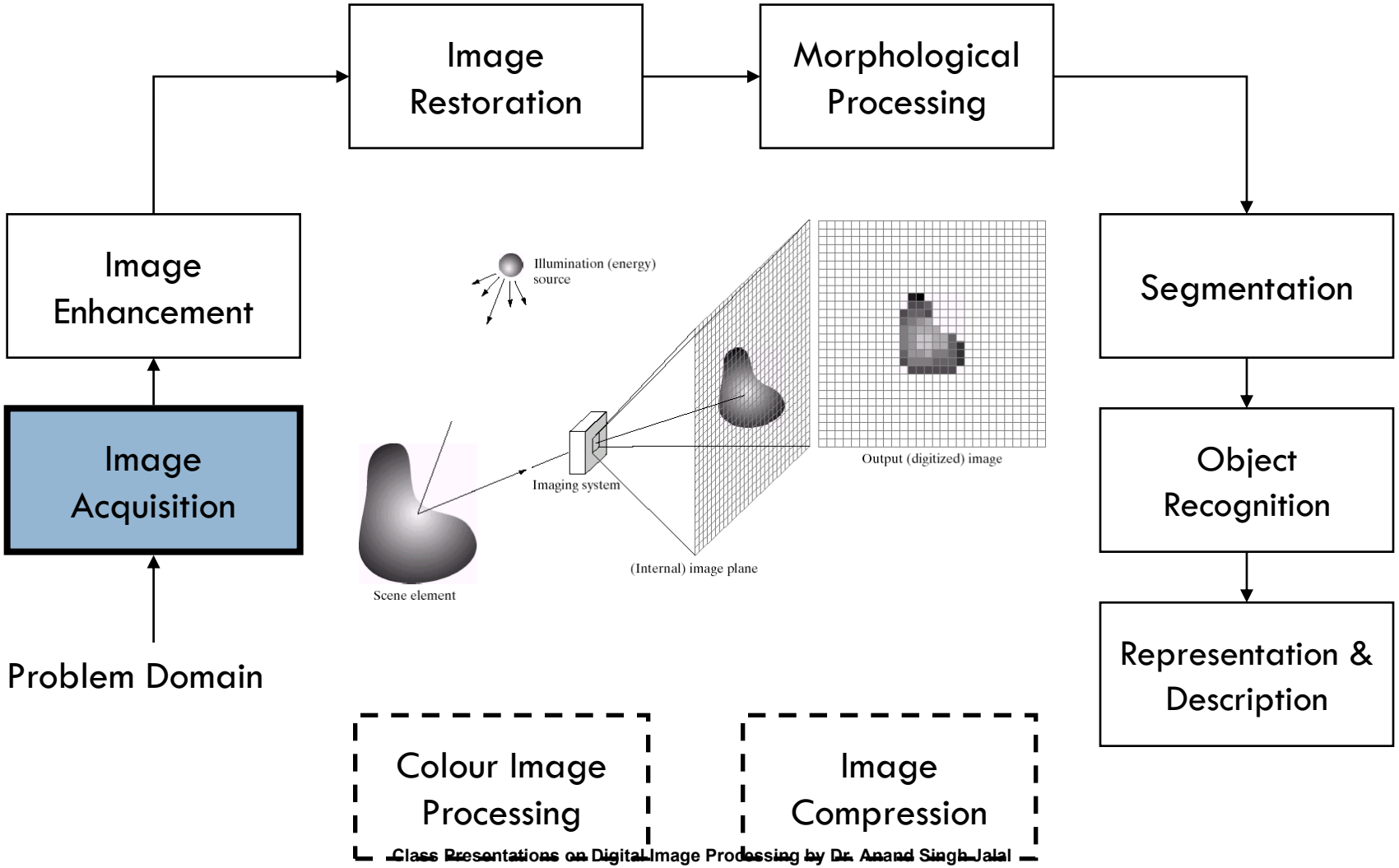
Steps in Digital Image Processing



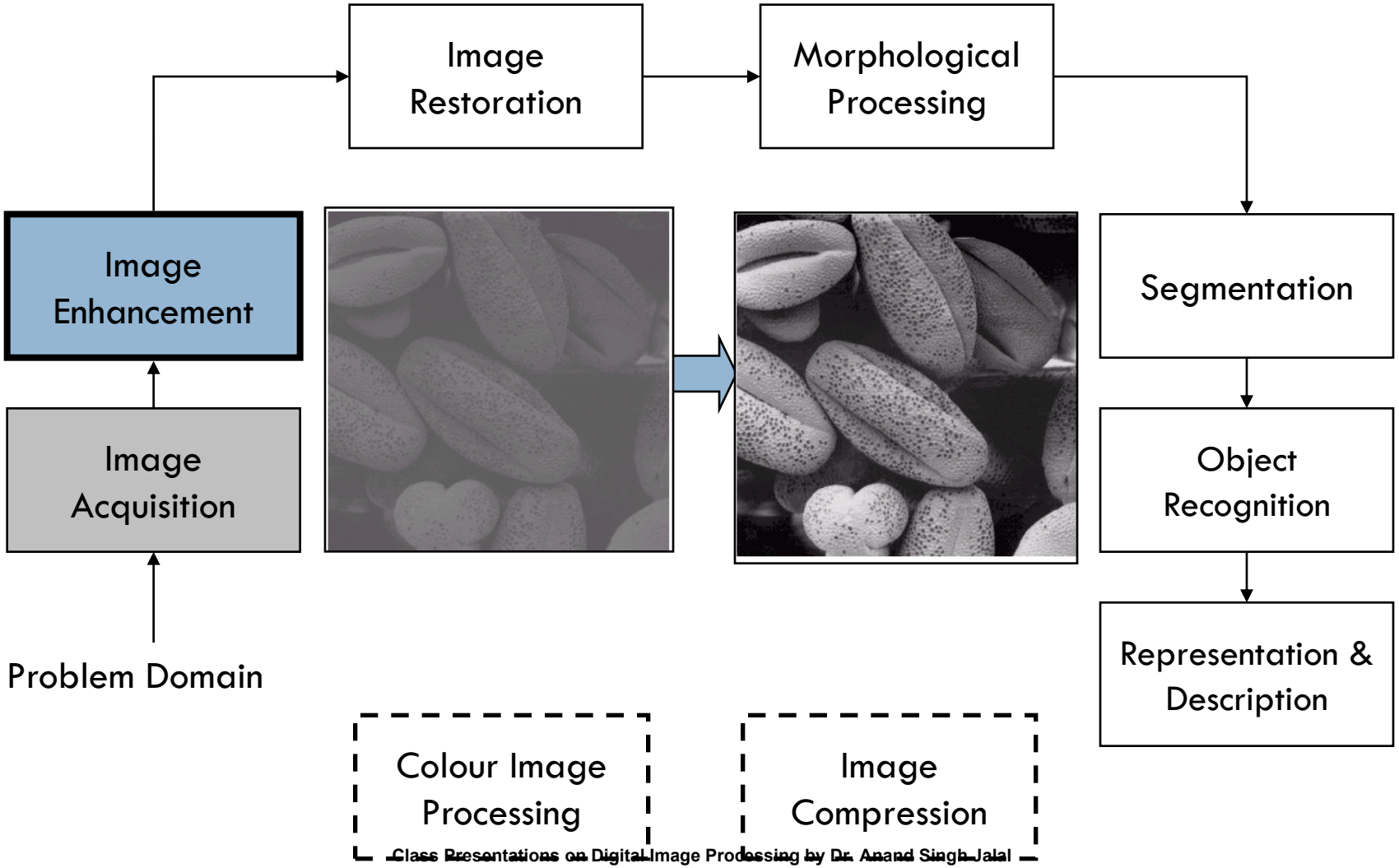
Key Stages in Digital Image Processing



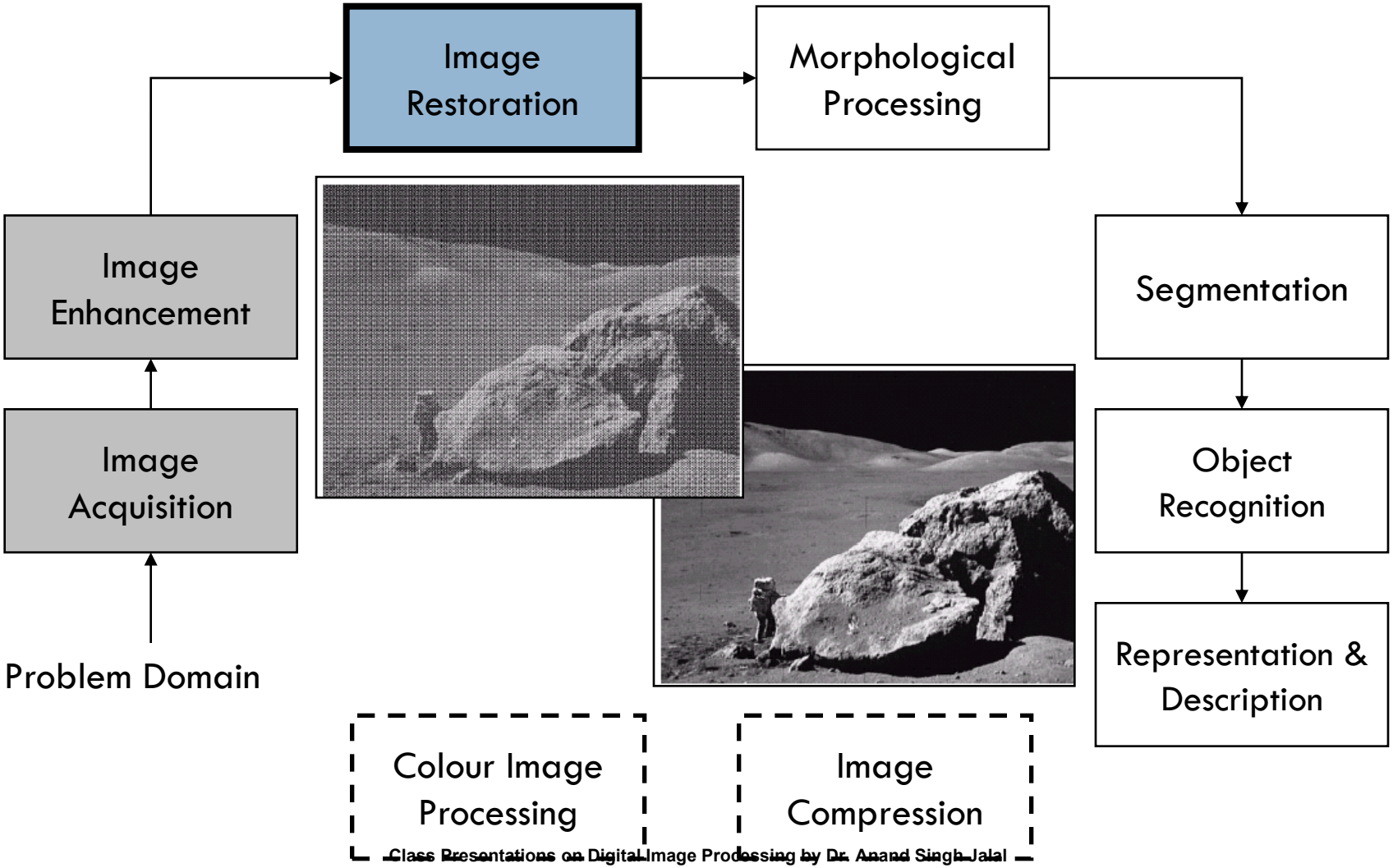
Key Stages in Digital Image Processing: Image Aquisition



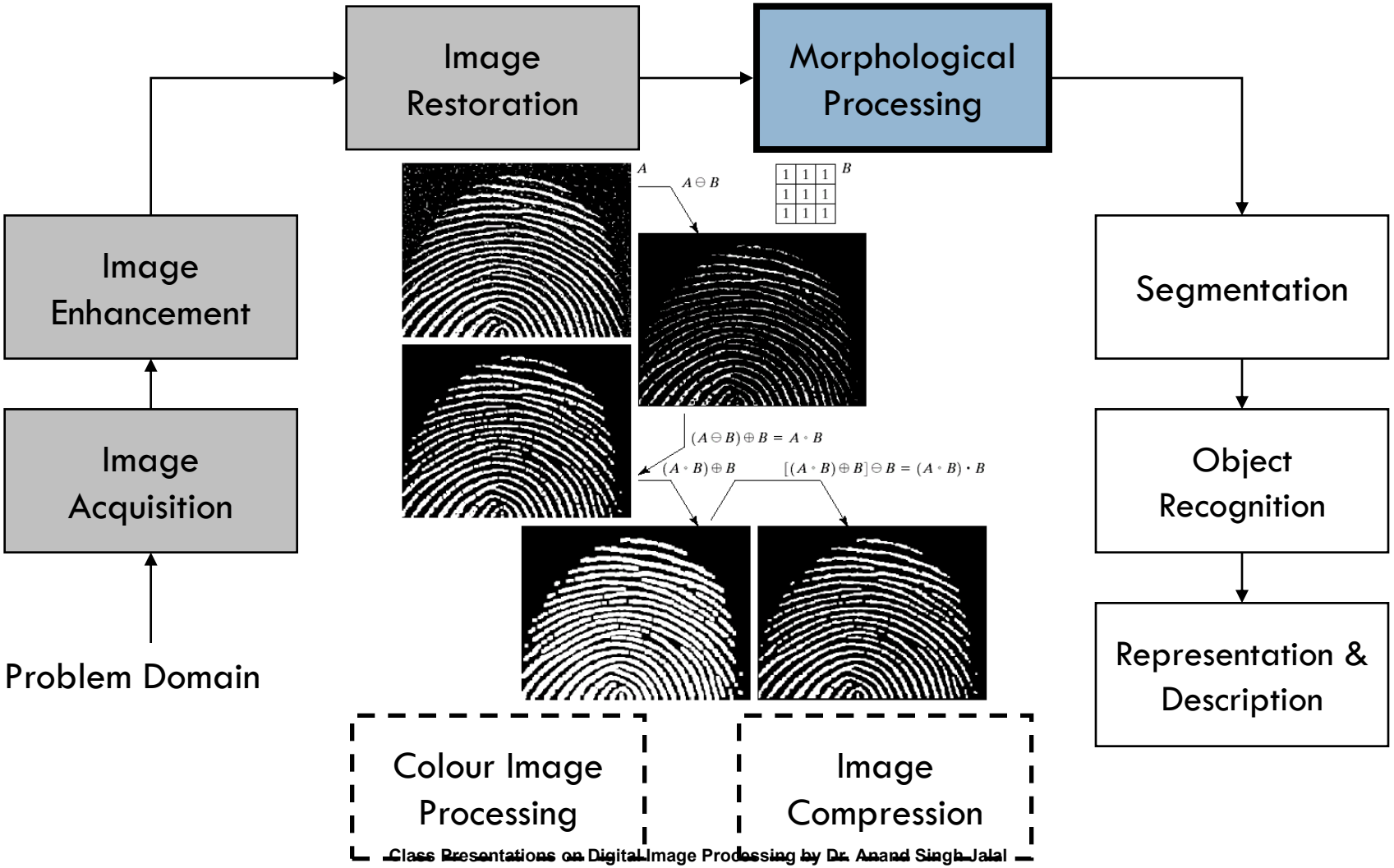
Key Stages in Digital Image Processing: Image Enhancement



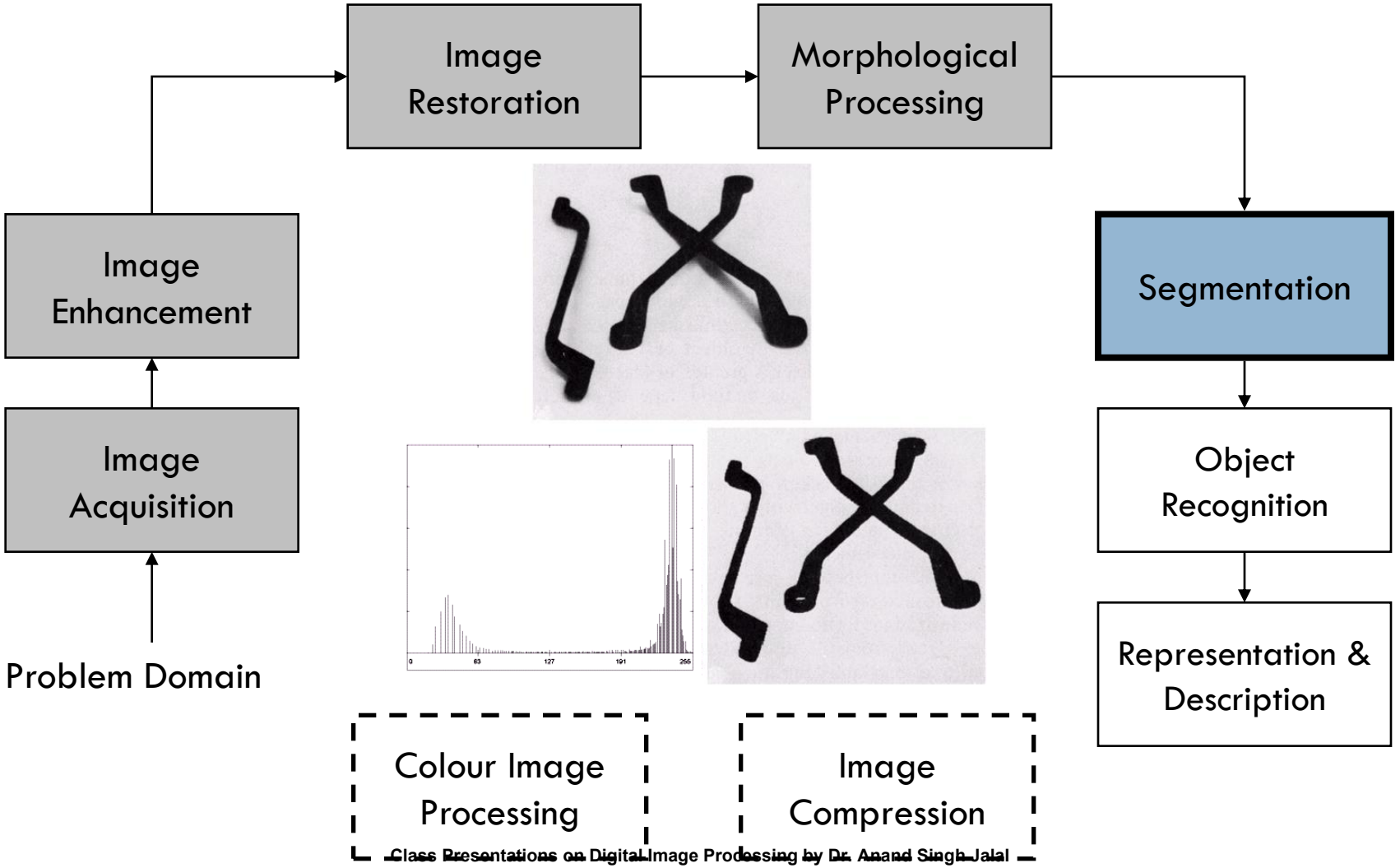
Key Stages in Digital Image Processing: Image Restoration



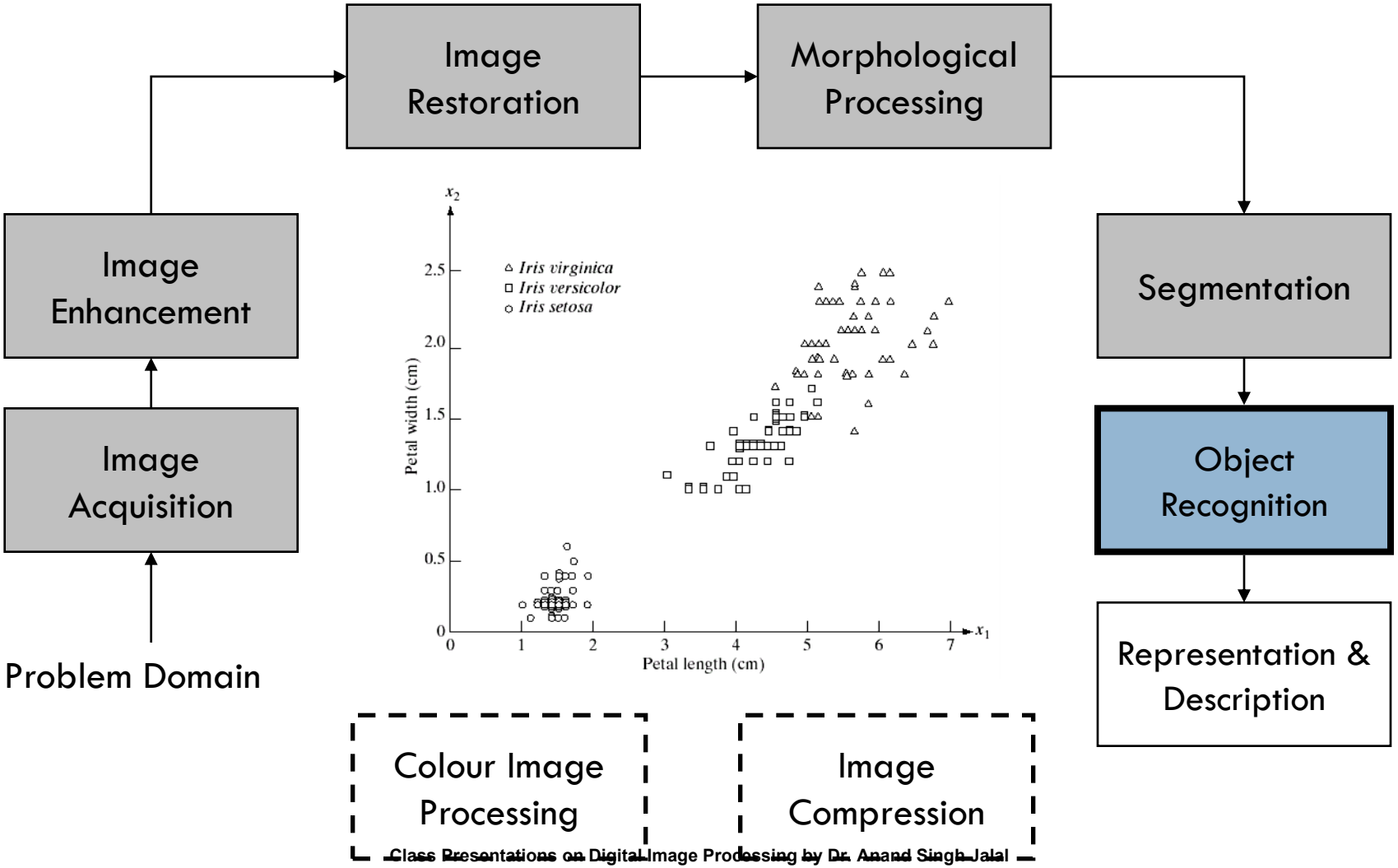
Key Stages in Digital Image Processing: Morphological Processing



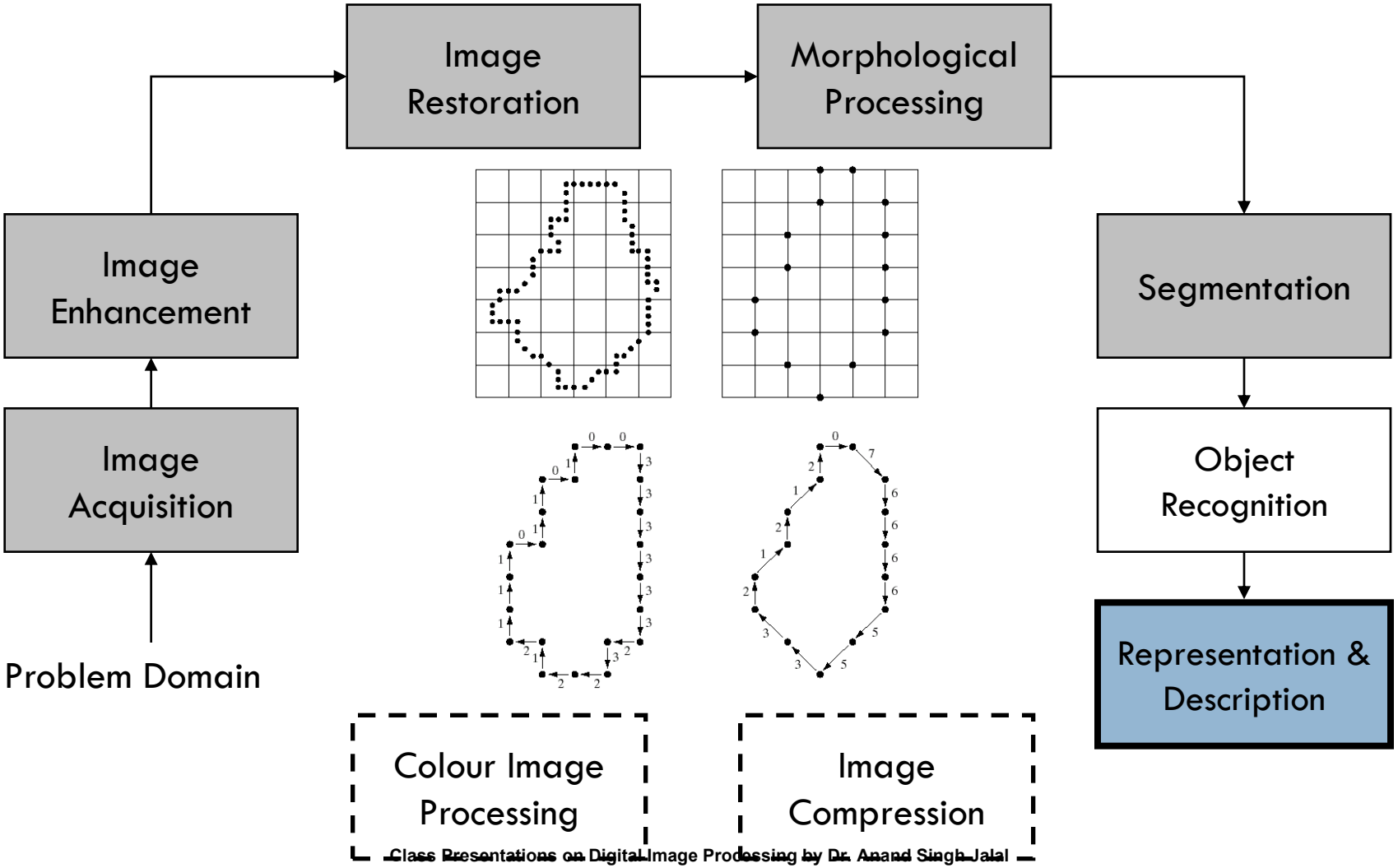
Key Stages in Digital Image Processing: Segmentation



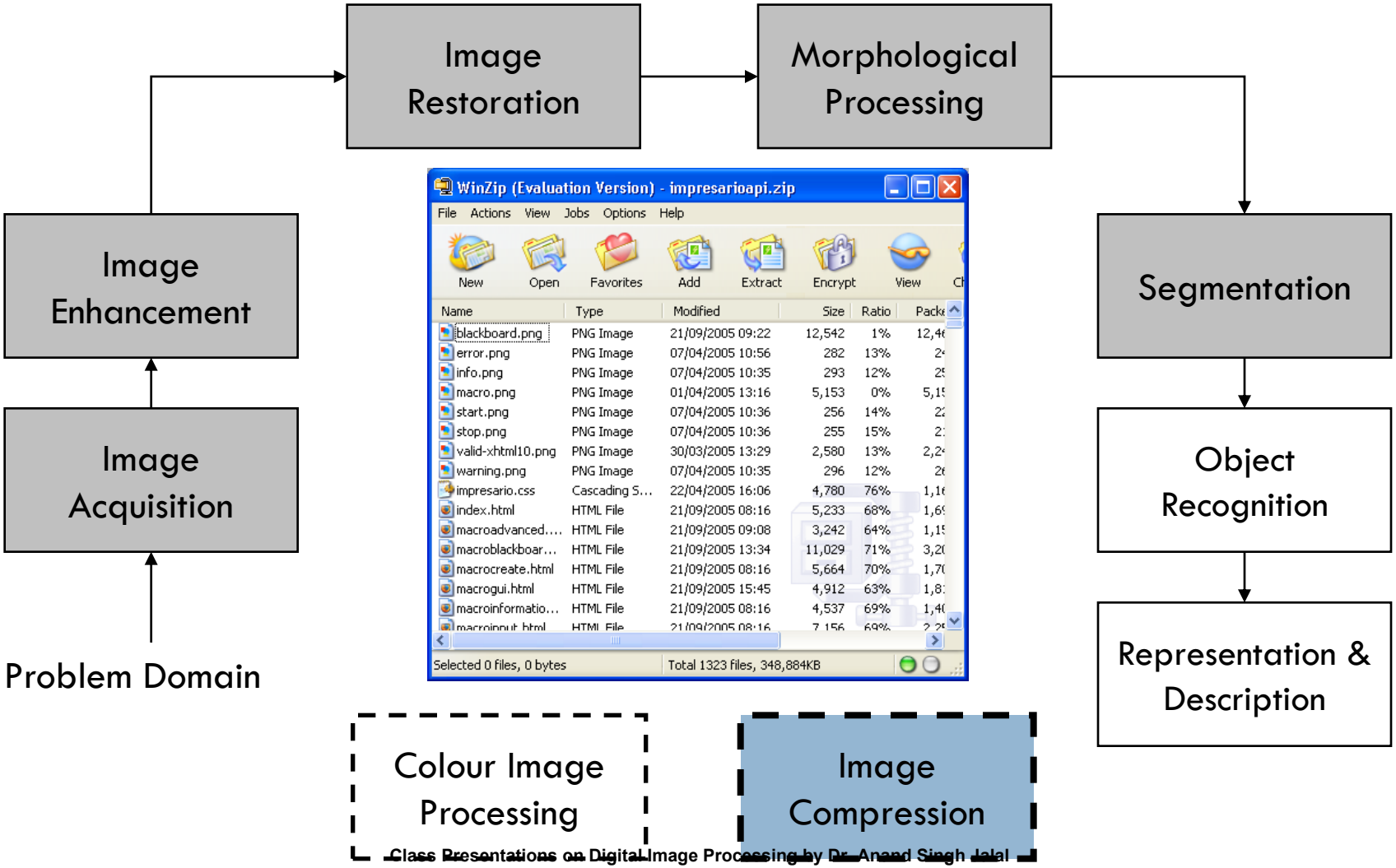
Key Stages in Digital Image Processing: Object Recognition



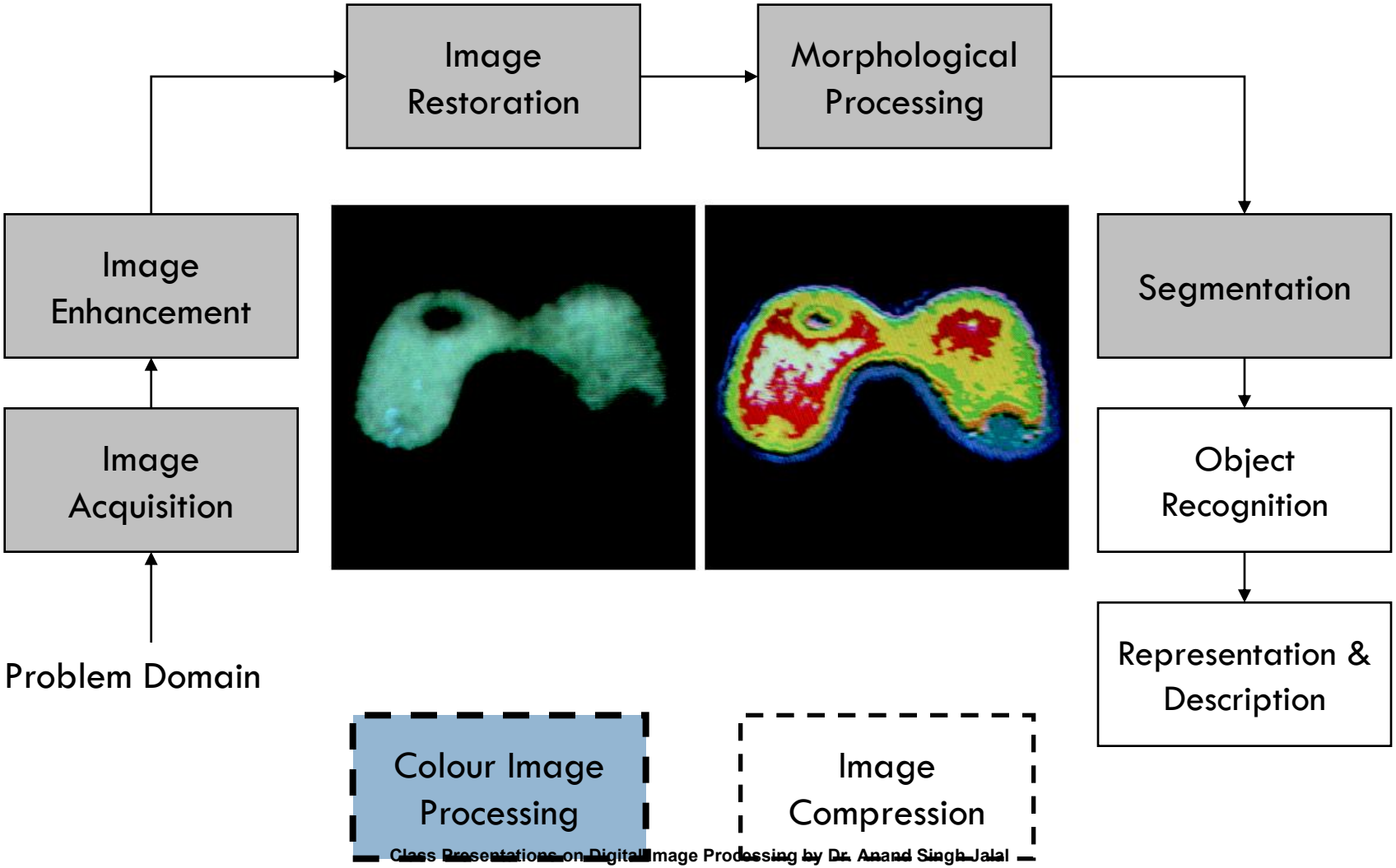
Key Stages in Digital Image Processing: Representation & Description



Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Colour Image Processing



Another Example

Image processing stages – acquisition

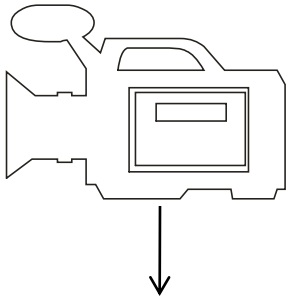


Image processing stages – filtering

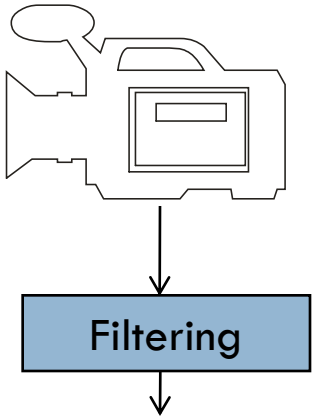
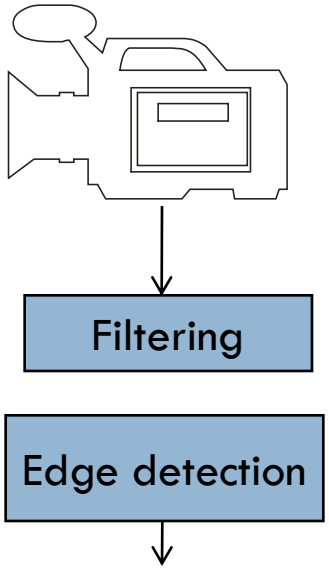


Image processing stages – edge detection



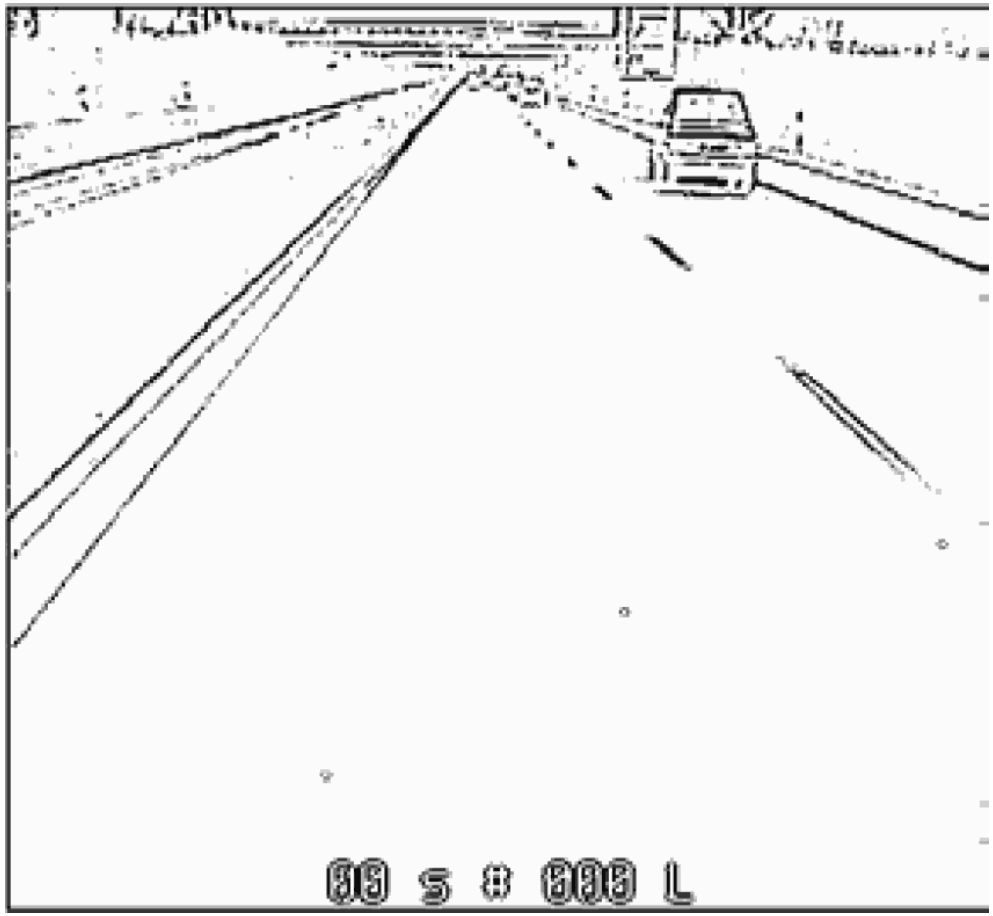
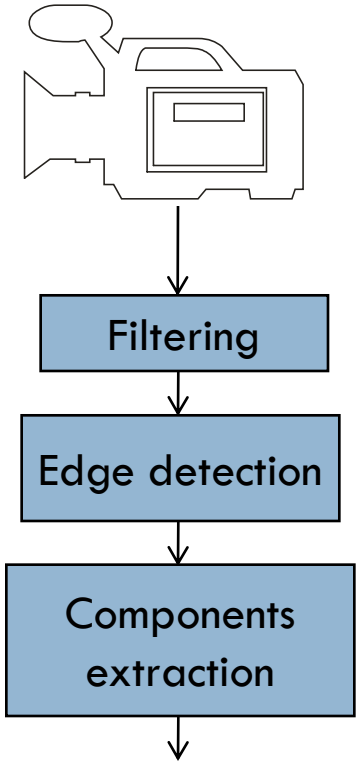


Image processing stages – components extraction



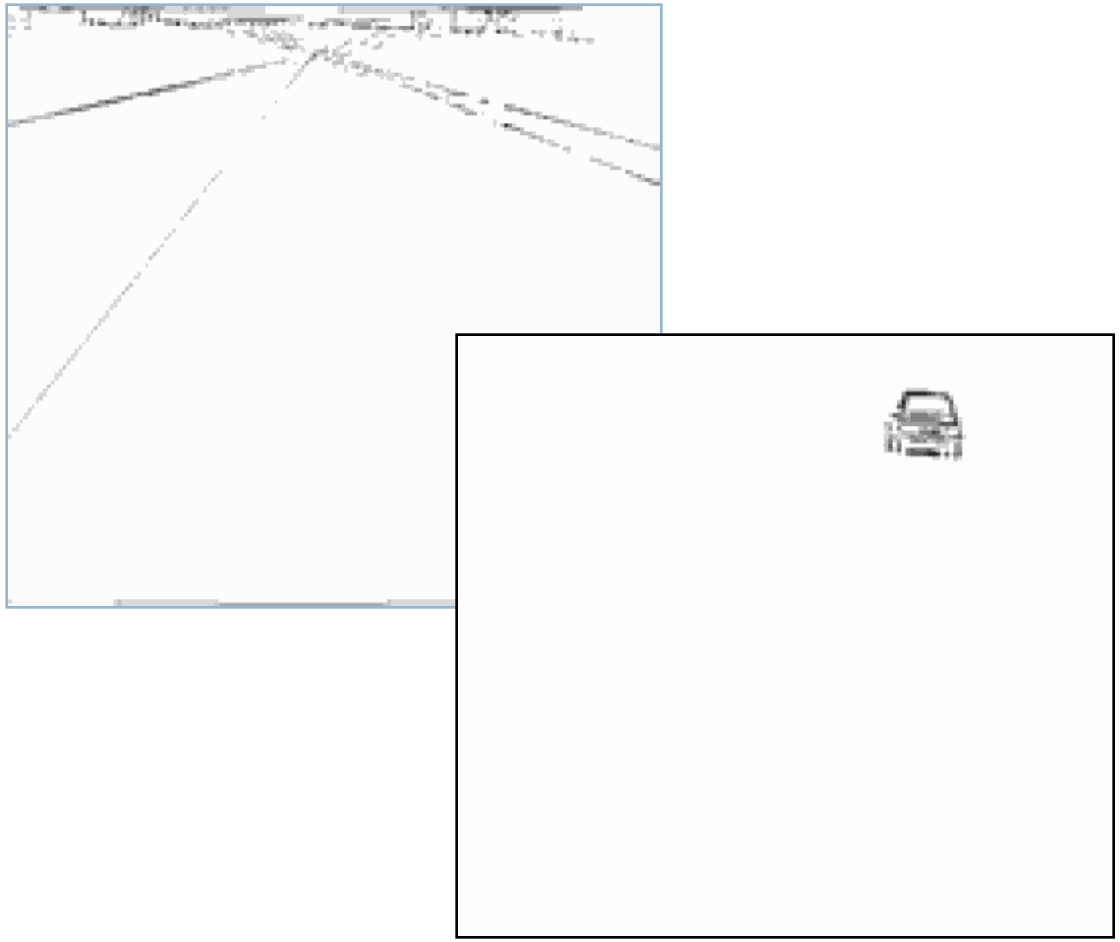
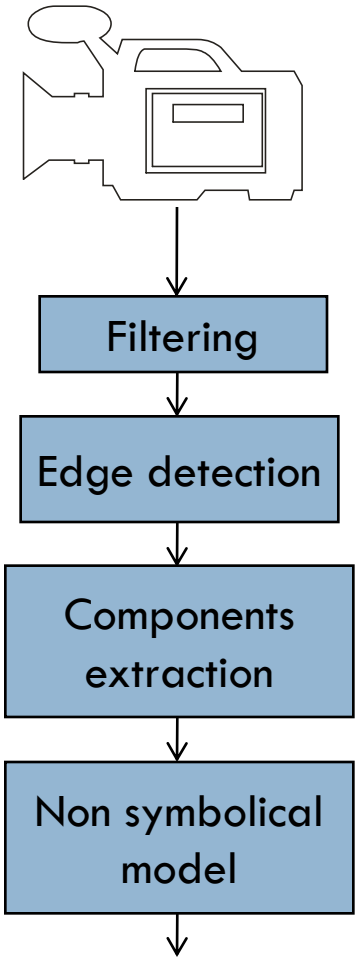
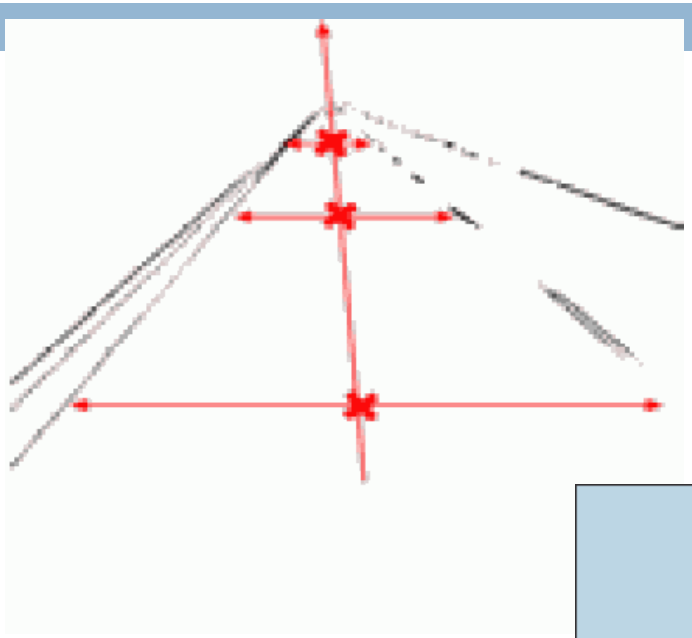
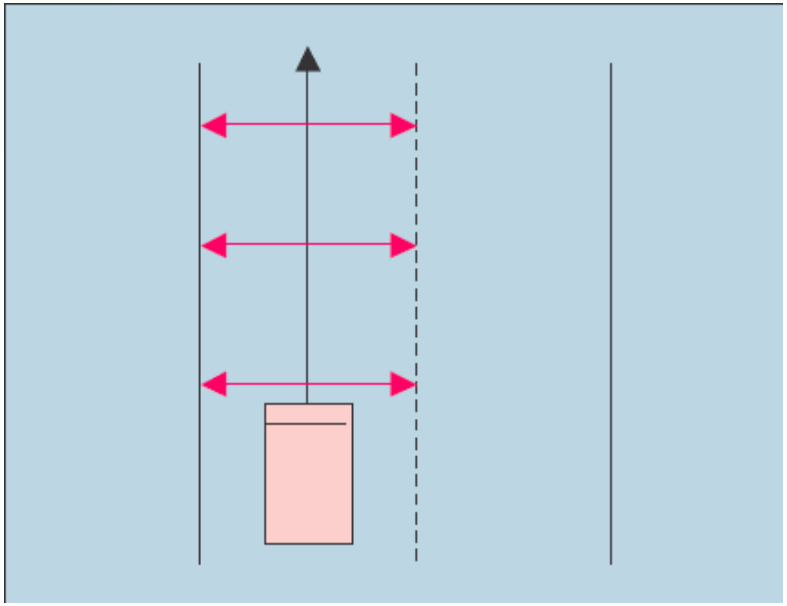


Image processing stages – non-symbolical



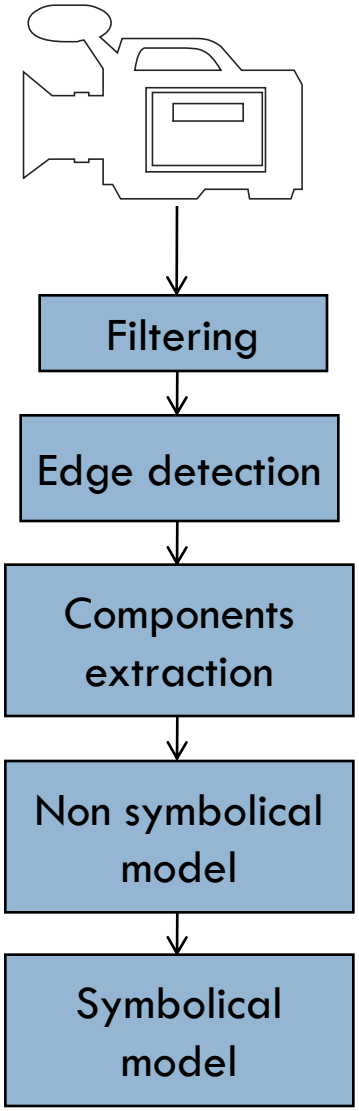


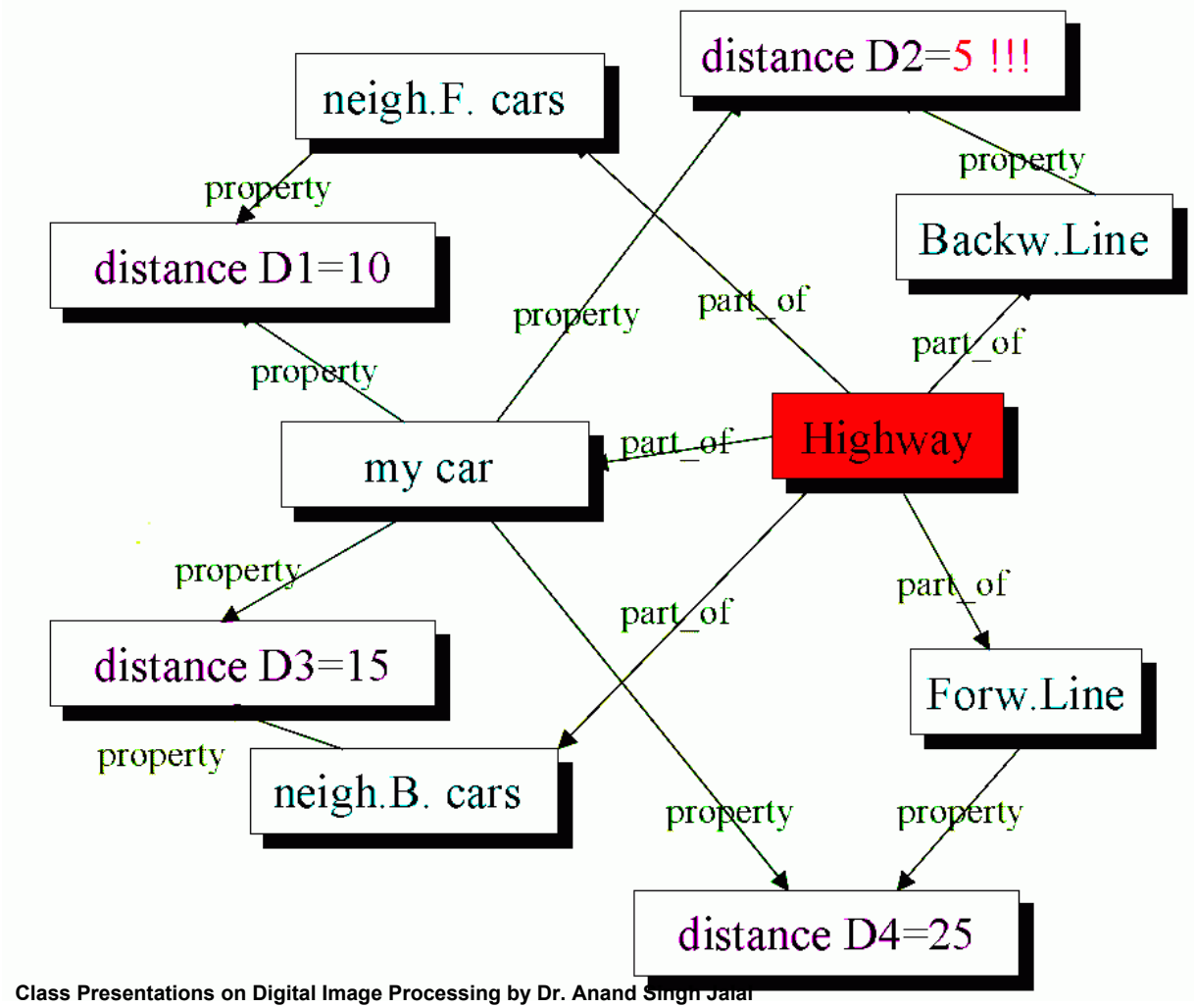
The image



Iconical mode

Image processing stages – symbolical model





Components of Image Processing System

I. Image Sensor

- Physical device, sensitive to a band in the electromagnetic energy spectrum (e.g. the x-ray, ultraviolet ray, visible etc).
- It intercepts the radiant energy propagating from the scene.
- Produces an electrical signal o/p proportional to the level of energy sensed.
- E.g. cameras, multispectral scanner, radar, ultrasonic ranger etc.

II. Digitizer

- Converts the electrical o/p of the physical sensing device, into digital form.

Most sensors have suitable built in digitizers or provide signal that can directly be digitized by an A/D converter.

Some sensors (e.g. camera) are purely analog

Microdensitometer & Flying Spot Scanner

Used to digitize transparency, photograph or printed material

III. Processor

Microcomputers

to

General purpose large computers

Dedicated image processing systems also used

IV. Storage

An 8-bit image of 1024 x 1024 pixels requires 1 million bytes of storage!!!!!

In the design of image processing system, providing adequate storage is a big ***CHALLENGE***

Categories of digital storage for image processing applications:

1. Short term storage for use during processing. (frame buffers)
2. On-line storage for relatively fast recall. (hard disks)
3. Archival storage, characterized by infrequent access. (CDs etc)

V. Display Unit

- Produces & shows a visual form of numerical values stored in a computer as image array.
- E.g. TV monitor, CRTs, printer etc.

Any erasable raster graphics display device can be used as display unit

Flicker

A major problem

Screen must be refreshed ~25/sec

Frame Buffer

Memory where entire image is kept. It is scanned through DMA unit, independent of CPU

Many general purpose computers not able to transfer data at such a high speed

Summary

- We have looked at:
  - What is a digital image?
  - What is digital image processing?
  - History of digital image processing
  - State of the art examples of digital image processing
  - Key stages in digital image processing
- Next time we will start to see how it all works…

Any Questions ?