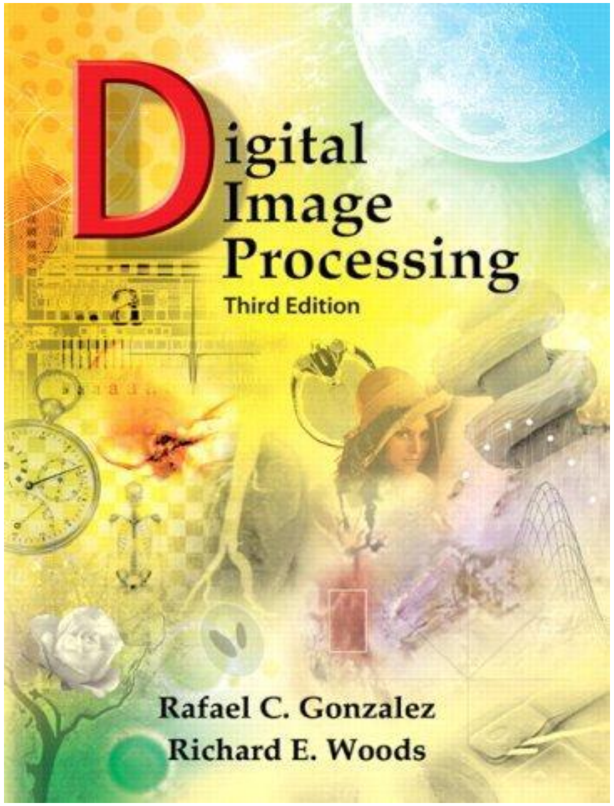
Digital Image Processing

CS-340

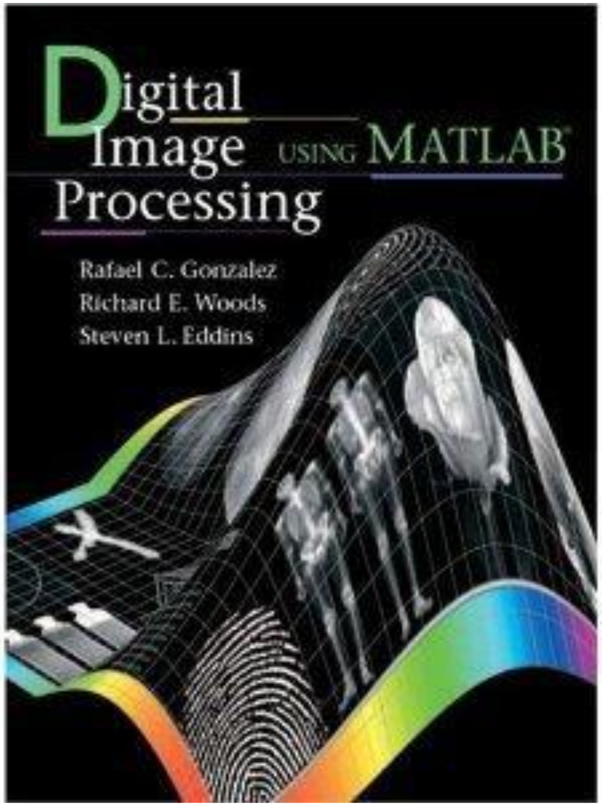
Lecture 1

Introduction

Books



Gonzalez, R. C. and Woods, R. E., Digital Image Processing, Third Edition, Pearson-Prentice Hall, Inc., 2008.



Gonzalez, R. C., Woods, R. E., and Eddins, S. L., Digital Image Processing Using MATLAB®, Pearson-Prentice Hall, Inc., 2004, ISBN 81-7758-898-2.

Links and Reference Material

- http://www.mathworks.com/index.html

Grading Criteria

- Mid Exam - 20%
- Final Exam - 40%
- Quiz - 15 %
- Assignment - 10 %
- Project - 15 %

Learning Aspects in DIP

- Digital images and its Applications
- Digital Image Fundamentals
- Image enhancement in spatial domain
- Image enhancement in frequency domain
- Color Image Processing
- Image Compression
- Morphological Image Processing
- Image Segmentation
- Representation and Description
- Object Recognition

A Historical Overview of DIP

- **Bartlane cable picture transmission system** was a technique invented in 1920 to transmit images over cable lines between London and New York in 1920s. It was named after its inventors Harry G. Bartholomew and Maynard D. McFarlane and was first used to transmit a picture across the Atlantic in 1921. Using the Bartlane system, images could be transmitted across the Atlantic in less than three hours.

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

Sent by submarine cable between London and New York, the transportation time was reduced to less than three hours from more than a week

The Born of Digital Computers

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

- DIP has been dependent on the development of digital computers and other supporting technologies (e.g., data storage, display and transmission)

The Born of Digital Computers

- Abacus – 5^{th} century BC - 600BC
- John Von Neumann – 1945
- Summary of advancements from 1940-1980
  - Invention of transistor – 1948-bell laboratory
  - High level programming languages – 1950s & 1960s
  - Invention of IC's – 1958 – Texas
  - Development of OS – 1960s
  - Development of Microprocessor – 1970s – Intel
  - Introduction of PC's by IBM – 1981
  - LI, VLSI, ULSI – 1970s, 1980s

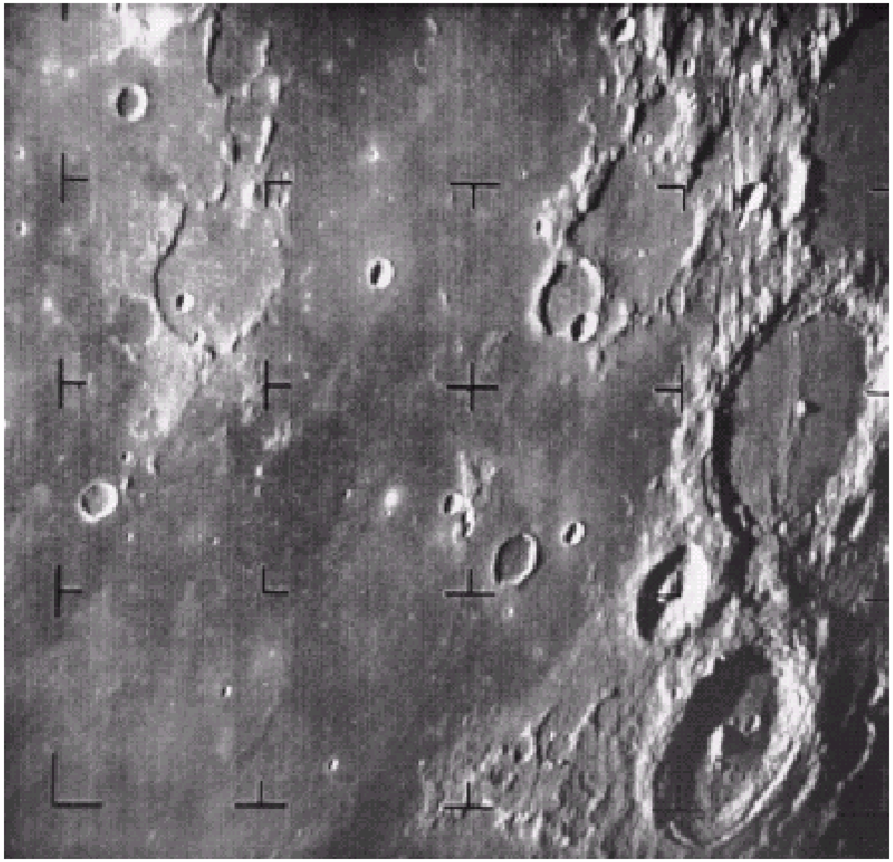
- Concurrent with these advances were developments in areas of mass storage and display systems both of which are fundamental requirements for digital image processing.

The Boom of Digital Images

- First Digital Photograph: Russell Kirsch in 1957 made a 176×176 pixel digital image by scanning a photograph of his three-month-old son

The Boom of Digital Images

- The first picture of moon by US space craft *Ranger 7* on July 31, 1964 at 9:09 AM EDT



The Boom of Digital Images in the Last 20 Years

- Acquisition
  - Digital cameras, scanners
  - Infrared and microwave imaging, etc.
- Transmission
  - Internet, satellite and wireless communication
- Storage
  - CD/DVD
  - Flash memory
- Display
  - Printers, LCD monitor, digital TV
  - PDAs, cell-phone

Image

What is an Image?

- Image is a source of information according to information theory

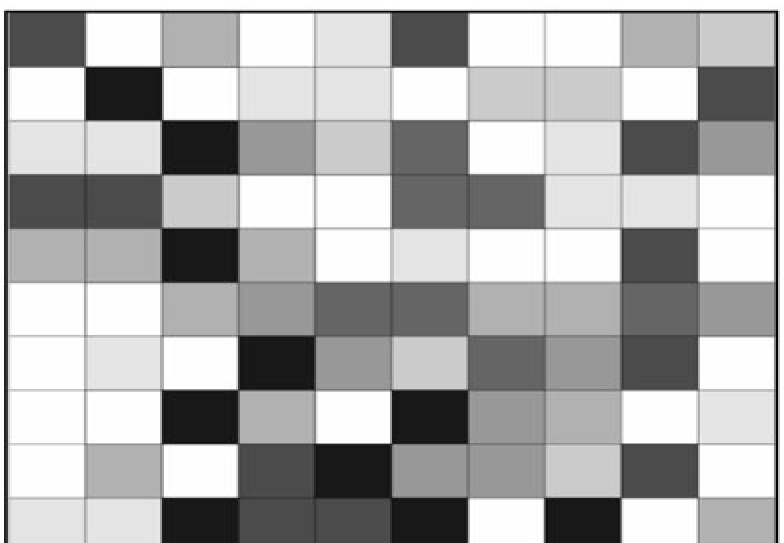
What is a digital Image?

- A digital image is defined as a two dimensional function f(x,y) in a space (plane), where x and y represents the vertical and horizontal coordinates of the plane.
- A digital Image is composed of a finite number of elements each of which has a particular location and value
- These elements are referred to as Picture Elements, Image Elements, Pels or Pixels.
- In digital imaging, a pixel is the smallest piece of information in an image.

Pixel

- Pixels are normally arranged in a regular 2-dimensional grid, and are often represented using dots or squares.

- The intensity of each pixel is variable; in gray scale images we have one color value while in color systems, each pixel has typically three or four components such as red, green, and blue, or cyan, magenta, yellow, and black



Digital Image Representation

Digital image is expressed as

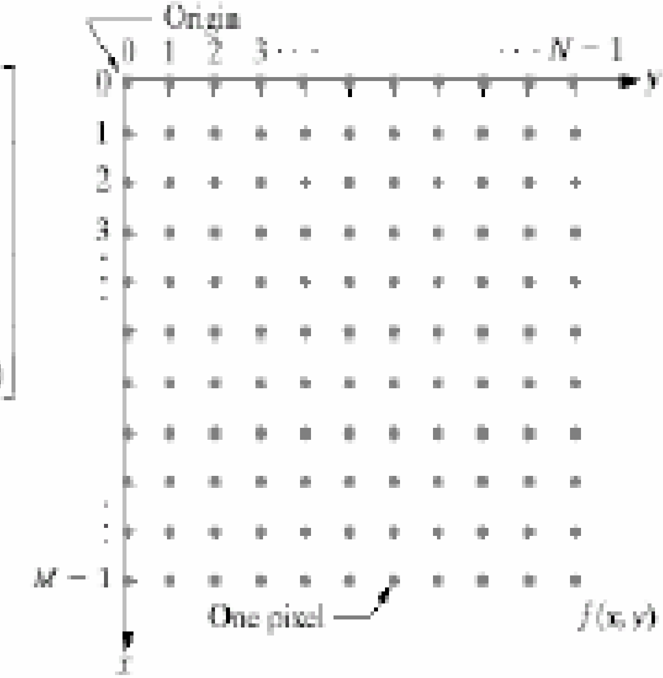
Columns →

Rows ↓

$$\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & \cdots & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

N : No of Columns

M : No of Rows

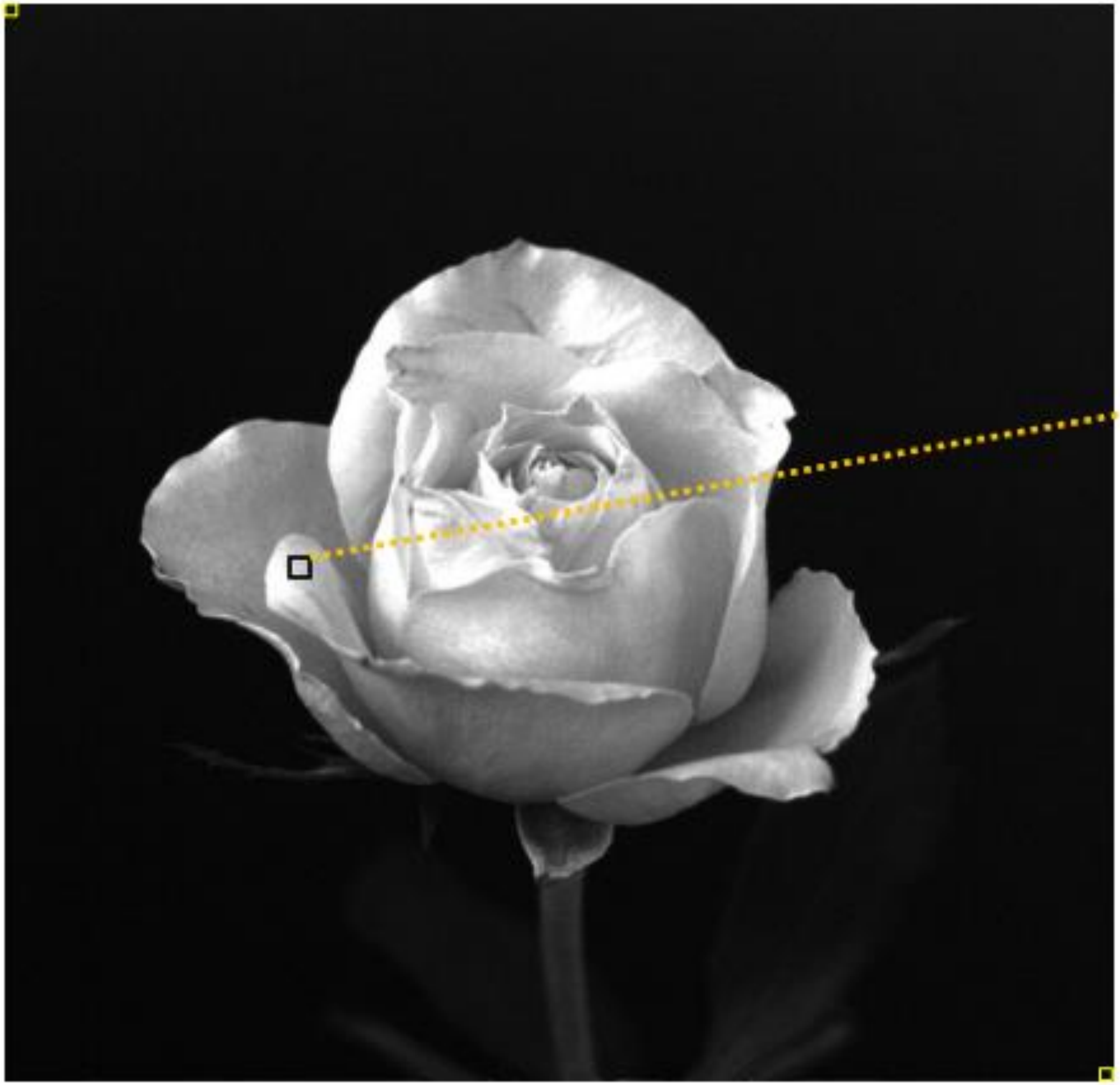


*Consider the following image (1024 x1024 pixels) to be 2D function or a **matrix** with **rows** and **columns***

Pixel location

Pixel intensity value

$f(1,1) = 21$



rows

columns

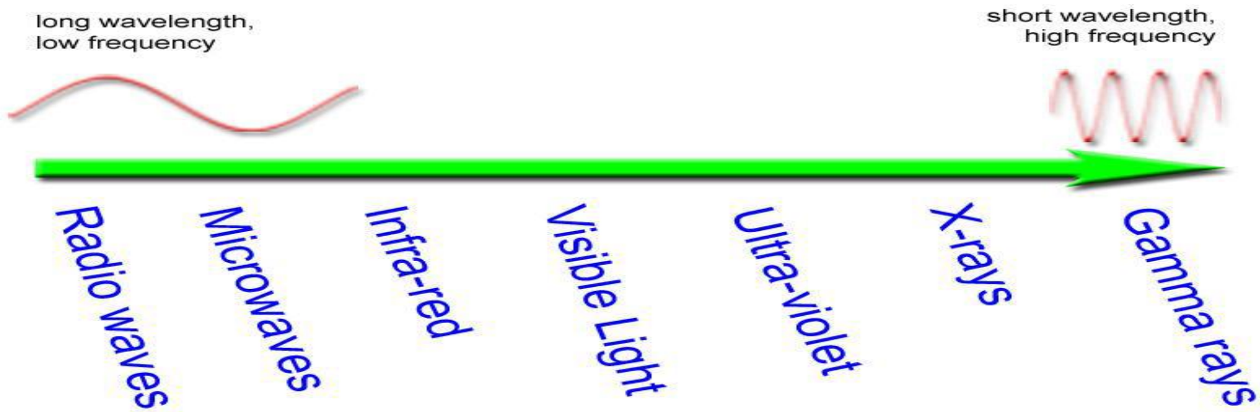
$f(520{:}525, 375{:}380) =$

152	148	144	152	181	203
144	138	156	152	184	208
141	141	138	156	181	203
136	138	144	158	177	196
144	138	148	154	177	208
149	138	152	160	188	205

$f(1024,1024) = 15$

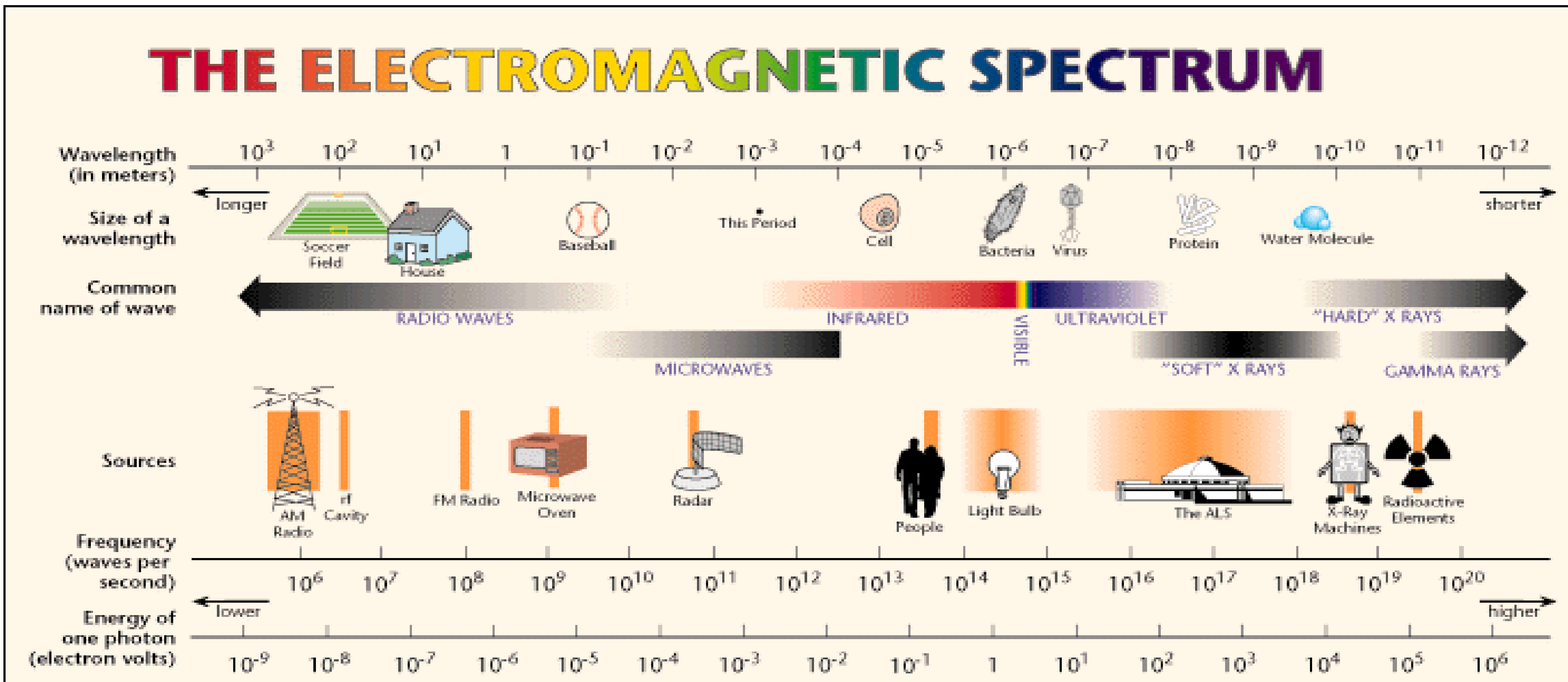
EM Spectrum

- The principal source for the images is the electromagnetic (EM) energy spectrum.
- EM waves can be conceptualized as propagating sinusoidal waves of varying wavelengths, or a stream of massless particles travelling in a wave like pattern at a speed of light.
- Each massless particle contains certain amount (bundle) of energy called photon
- Following spectrum is obtained when the spectral bands are grouped according to energy per photon ranging form the gamma rays (highest energy) to the radio waves (lowest energy).



EM Spectrum

- EM waves are mass less particles propagates at speed of light
- We can specify waves through frequency and wavelength
- Human beings can see only the visible band portion
- Specific imaging systems have been designed for other EM Spectrum



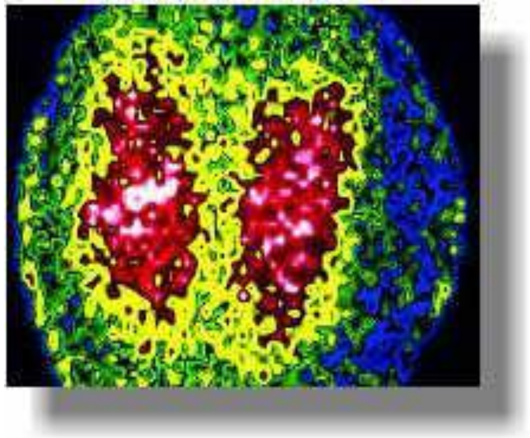
Gamma Rays

- Gamma rays are given off by **stars**, and by some **radioactive substances**.
- They are extremely high frequency waves, and carry a large amount of energy.
- They pass through most materials, and are quite difficult to stop - you need lead or concrete in order to block them out.
- Because Gamma rays can kill living cells, they are used to **kill cancer cells** without having to resort to difficult surgery.
- This is called "**Radiotherapy**", and works because cancer cells can't repair themselves like healthy cells can when damaged by gamma rays. Getting the dose right is very important!

Gamma Rays

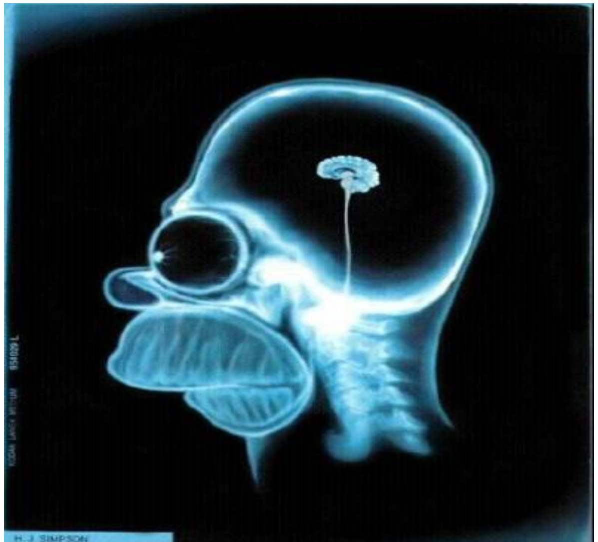
- Tracers:
- Doctors can put slightly **radioactive substances into a patient's body**, then **scan the patient** to detect the gamma rays and build up a picture of what's going on inside the patient. This is very useful because they can see the body processes actually working, rather than just looking at still pictures.

- Example: the picture below is a "Scintigram" and shows an asthmatic person's lungs. The patient was given a slightly radioactive gas to breathe, and the picture was taken using a gamma camera to detect the radiation. The colors show the air flow in the lungs.



X-Rays

- X-rays are very high frequency waves, and carry a lot of energy. They will pass through most substances, and this makes them useful in medicine and industry to see inside things.
- X-rays are given off by **stars**, and strongly by some types of nebula.
- An **X-ray machine** works by firing a beam of electrons at a "target". If we fire the electrons with enough energy, X-rays will be produced.



Uses of X-Rays

- X-rays are used by doctors to **see inside people**. They pass easily through soft tissues, but not so easily through bones.

- X-Rays are also used in **airport security** checks, to see inside your luggage.

- They are also used by **astronomers** - many objects in the universe emit X-rays, which we can detect using suitable radio telescopes.

Ultra-Violet Rays

- **Ultraviolet** (**UV**) light is electromagnetic radiation with a wavelength shorter than that of visible light, but longer than X-rays, in the range 10 nm to 400 nm.

- It is named because the spectrum consists of electromagnetic waves with frequencies higher than those that humans identify as the color violet.

- These frequencies are invisible to humans, but visible to a number of insects and birds.

- They are also indirectly visible, by causing fluorescent materials to glow with visible light.

Uses of UV rays

- Uses for UV light include getting a **sun tan** , **detecting forged bank notes** in shops, and hardening some types of dental filling.

- You also see UV lamps in clubs, where they make your clothes glow. This happens because of substance "fluoresce“ (also found in washing powder) when UV light strikes them - they absorb the UV and then re-radiate the energy at a longer wavelength.

- Hospitals use UV lamps to sterilize surgical equipment and the air in operating theatres. Food and drug companies also use UV lamps to **sterilize** their products.

- Suitable doses of Ultraviolet rays **cause the body to produce vitamin D**, and this is used by doctors to treat vitamin D deficiency and some skin disorders.

Visible Light

- Our eyes can detect only a **tiny** part of the electromagnetic spectrum, called **visible light**.
- This means that there's a great deal happening around us that we're simply not aware of, unless we have instruments to detect it.
- Light waves are given off by **anything that's hot enough to glow**.
- This is how light bulbs work - an electric current heats the lamp filament to around 3,000 degrees, and it glows white-hot.
- The surface of the Sun is around 5,600 degrees, and it gives off a great deal of light.

Infrared Light

- Infra red waves are just below visible red light in the electromagnetic spectrum ("Infra" means "below").
- You probably think of Infra-red waves as heat, because they're given off by **hot objects**, and you can feel them as warmth on your skin.
- Infra Red waves are also given off by **stars**, **lamps**, **flames**

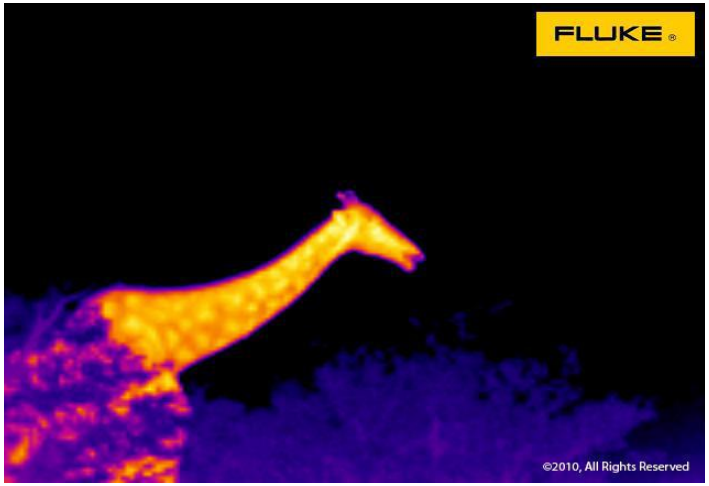
Uses of Infrared

- Infra-red waves are **called "IR" for short**.
- They are used for many tasks, for example, **remote controls for TVs** and video recorders
- IR is also used for short-range communications, for example between mobile phones
- Because every object gives off IR waves, we can use them to "see in the dark“
- **Night sights** for weapons sometimes use a sensitive IR detector.

Uses of Infrared

- Apart from remote controls, one of the most common modern uses for IR is in the field of security. "Passive Infra-Red" **(PIR) detectors** are used in burglar **alarm systems**, and to control the security lighting that many people have fitted outside their houses. These detect the Infra-Red emitted by people and animals.

- You've probably seen TV programs in which **police helicopters** track criminals at night, using "**thermal imaging**" cameras which can see in the dark. These cameras use Infra-Red waves instead of "ordinary" light, which is why people look bright in these pictures. Similar cameras are also used by fire crews and other **rescue workers**, to find people trapped in rubble.



Microwaves

- Microwaves are basically extremely high frequency radio waves, and are made by various types of **transmitter**.
- In a mobile phone, they're made by a transmitter chip.
- Stars also give off microwaves.
- Microwaves cause water and fat molecules to vibrate, which makes the substances hot. So we can use microwaves to **cook** many types of food.

Uses of Microwaves

- **Mobile phones** use microwaves
- Microwaves are also used by fixed traffic **speed cameras**, and for **radar**, which is used by aircraft, ships and weather forecasters.
- The most common type of radar works by sending out bursts of microwaves, detecting the "echoes" coming back from the objects they hit, and using the time it takes for the echoes to come back to work out how far away the object is.

Dangers of Microwaves

- Prolonged exposure to microwaves is known to cause "**cataracts**" in your eyes, which is a clouding of the lens, preventing you from seeing clearly (if at all!) So don't make a habit of pressing your face against the microwave oven door to see if your food's ready!

- Recent research indicates that microwaves from mobile phones can **affect parts of your brain** - after all, you're holding the transmitter right by your head.

Radio Waves

- Radio waves are made by various types of **transmitter**, depending on the wavelength.

- They are also given off by stars, sparks and lightning, which is why you hear interference on your radio in a thunderstorm.

- Radio waves are the lowest frequencies in the electromagnetic spectrum, and are used mainly for **communications**.

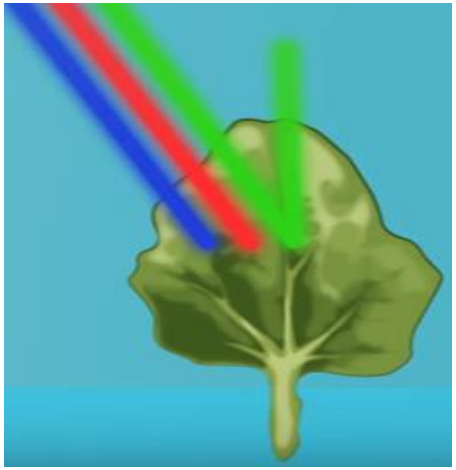
Medical Imaging

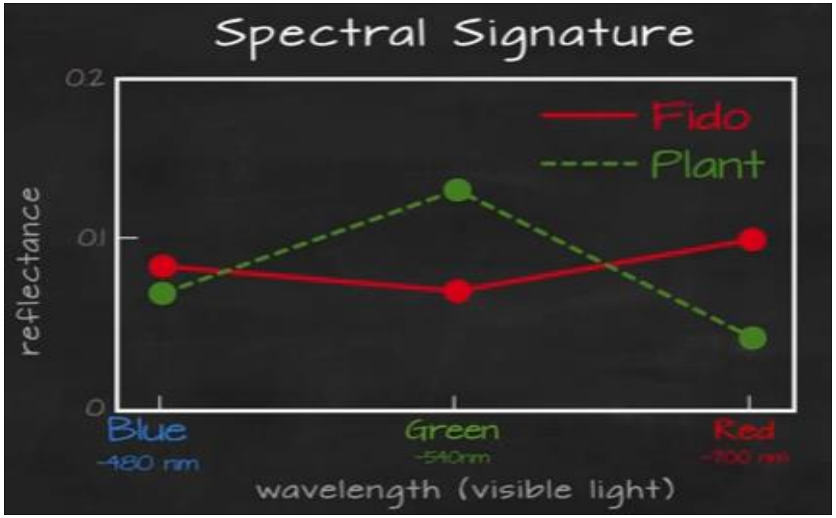
- Image processing has been widely used in the field of medical
  - Applications of Image processing in medical are:
    - Tumor Detection
    - Cancer Detection
    - Ultrasound and many more……….

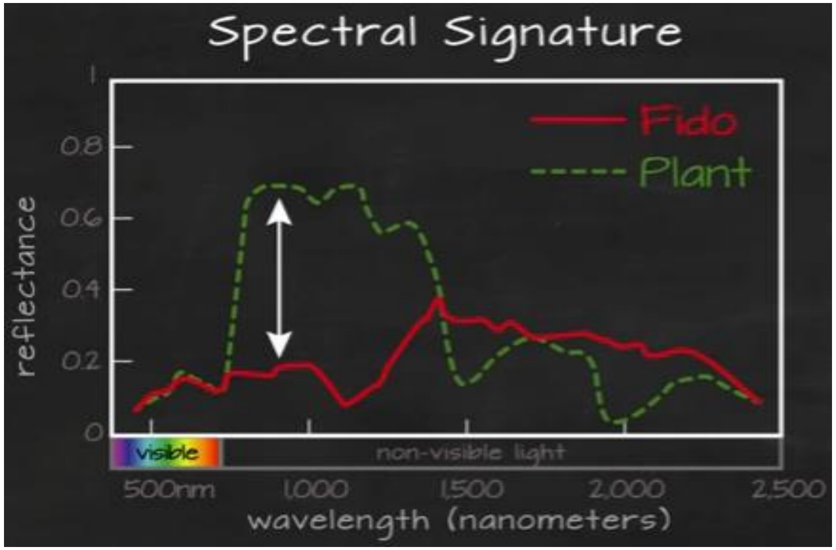
Remote Sensing

- Remote sensing can be defined as any process whereby information is gathered about an object, area or phenomenon without being in contact with it.
- We can use remote sensing images from satellites or air crafts to identify different features without being there.
- To do this we need to know how different objects reflect and absorb light. The absorption characteristics are called spectral signatures and are recorded as Digital Numbers (DN).
- Spectral signatures are plots of the reflected radiation of different objects collected using different wavelength filters of the satellite sensor. Spectral signatures can be used to identify, distinguish and monitor various land cover features.
- The higher the DN value the higher the reflectance and therefore brighter the image. The lower the DN value the lower the reflectance therefore darker (black) the image.

Spectral Signature

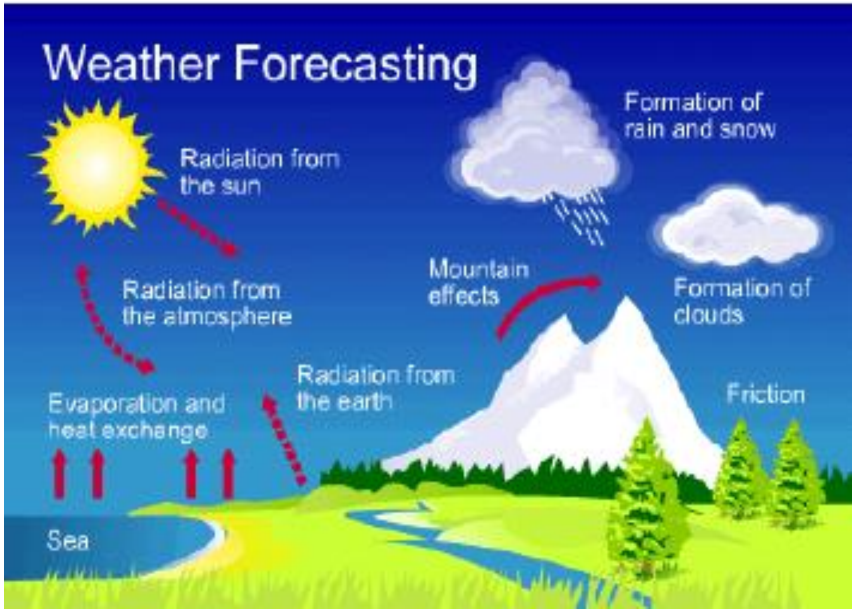






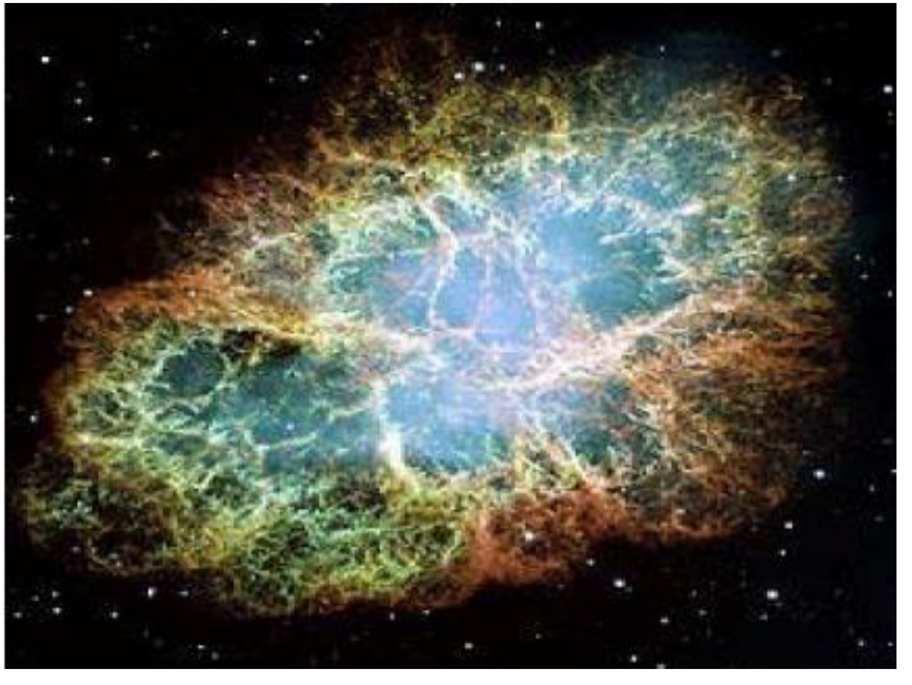
Weather Forecasting

- Image processing techniques have been used extensively for weather forecasting
- Techniques like Image Enhancement and Restoration are used significantly to obtain better quality images free from noise or any degradation
- Techniques like Image Segmentation uses to extract specific parts like the clouds from the image
- Image Recognition has been applied to classify various weather phenomena's e.g to classify the clouds from the hurricane



Astronomy

- Image processing techniques have been used extensively for Astronomical Observations
- Astronomy is a natural science that deals with the study of celestial objects (such as stars, planets, comets, nebulae, star clusters and galaxies) and phenomena that originate outside the Earth's atmosphere

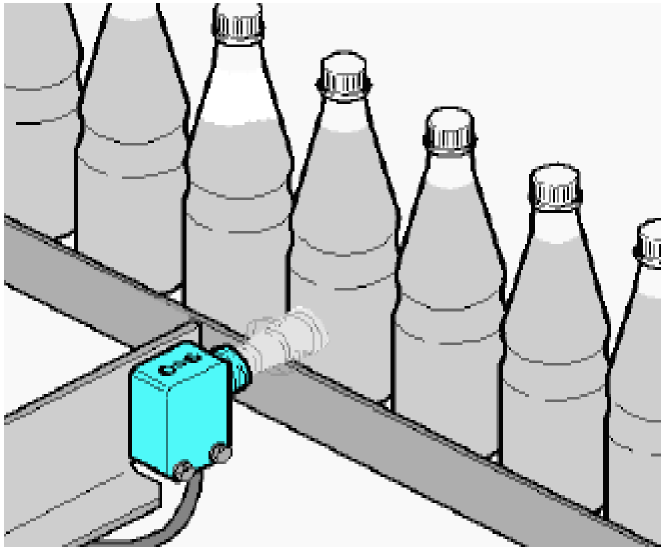


Machine Vision Applications

- Here the interest is on the procedures for extraction of image information suitable for computer processing
- Typical applications are:
  - Industrial Machine Vision for Product Assembly and Inspection
  - Automated Target Detection and Tracking
  - Finger Print Recognition
  - Iris Recognition
  - Face Detection, Tracking and Recognition e.t.c

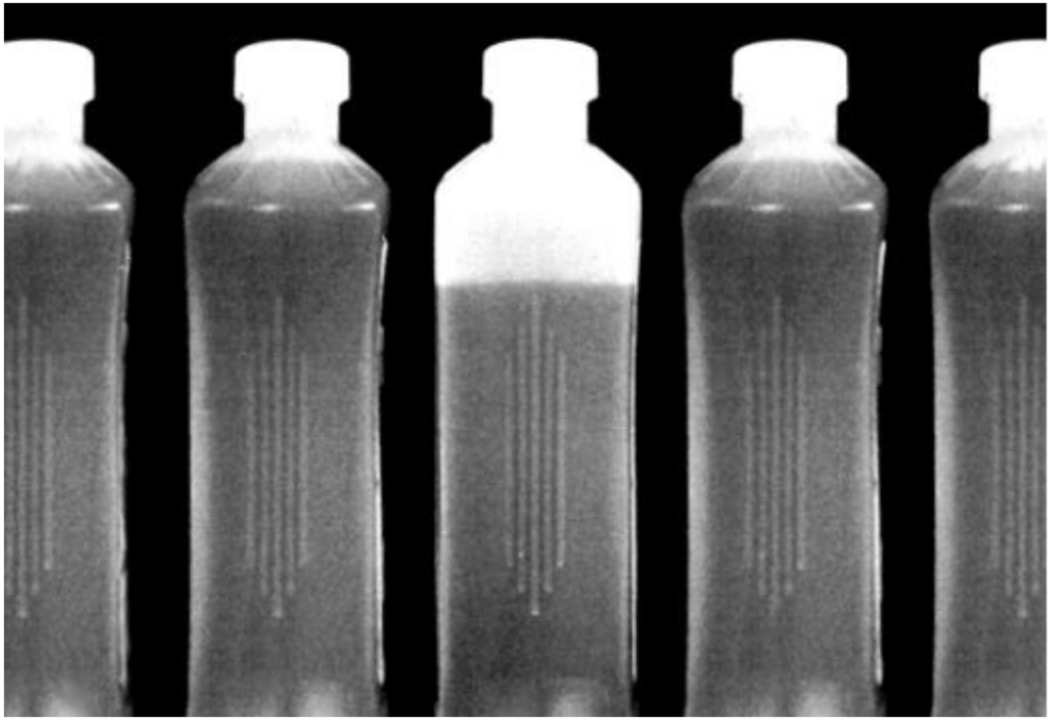
Automated Product Inspection

- Image Processing techniques have great utilization in the industry for various product inspections
- Some of them can be:
  - Automated Inspection of Bottling Plant Automation
  - Automated Inspection of IC Manufacturing
  - Automated Inspection of Computer Components etc.



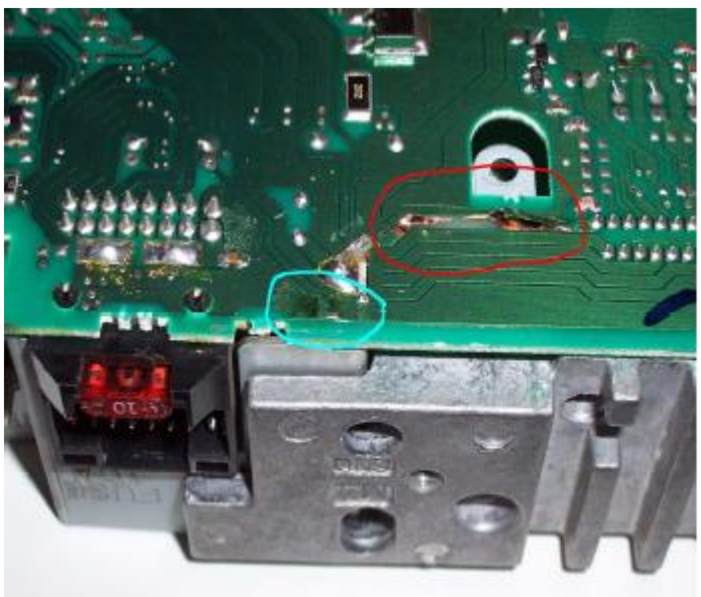
Automated Inspection of Bottling Plant Automation

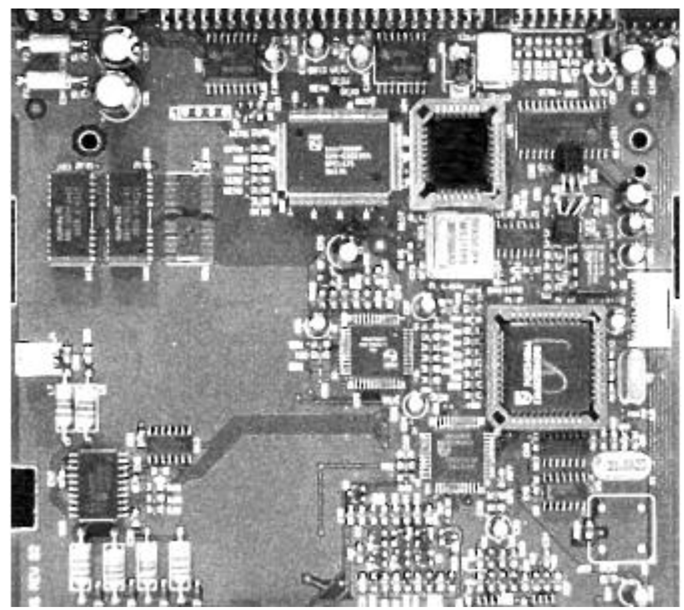
- Image processing techniques can be used to inspect the bottles of soft drinks to check whether any bottle is empty or partially filled so to avoid any such product delivered to the customer which can effect the goodwill of the company



Automated Inspection of Integrated Circuits & Circuit board/ Motherboard

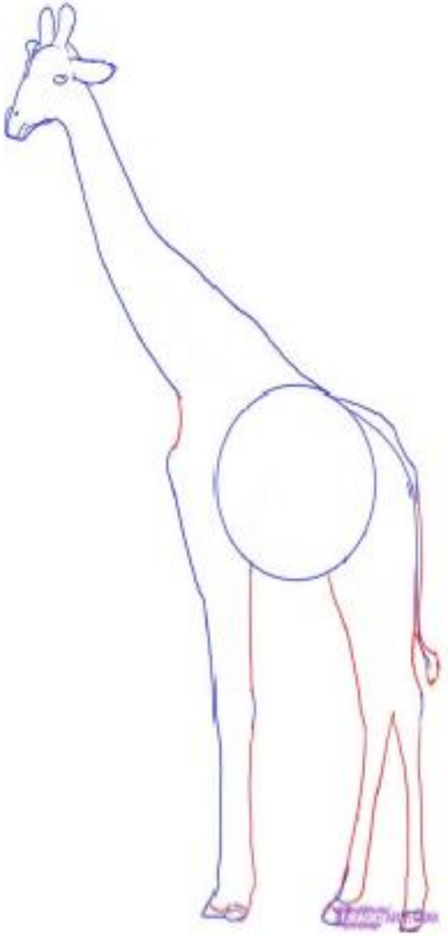
- Image processing techniques can be used to inspect the Integrated Circuits during the manufacturing phase to detect any missing components or any parts that is broken
- E.g. In 1st figure some part is broken while in second figure a component is missing so these problems can be identified through image processing techniques





Boundary Information

- The boundary of an object is very useful to recognize the object



Video Sequence Processing

- The major emphasis of image sequence processing is detection of moving parts

- Typical applications are:
  - 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

Movement Detection and Tracking

- There are huge number of applications in the field of corporate sector, educational institutions, sports industry, e.t.c which involves the detection and tracking of an object to achieve the task
- For example some of the applications can be:
  - The detection and tracking of pedestrians to give information to drivers who drives vehicle on the road to avoid as many accidents as possible
  - The detection and tracking of suspicious person to achieve the security measures
  - The detection and tracking of old persons or babies in the houses to monitor their activities and includes an alarming system to inform the other house members in case of any dangerous situation
  - The detection and movement of instructor in front of the white board in case you are developing a system to extract the information from the white board into handouts from the video lectures e.t.c

Fingerprint Recognition

- **Patterns** The three basic patterns of fingerprint ridges are the arch, loop, and whorl:
  - arch: The ridges enter from one side of the finger, rise in the center forming an arc, and then exit the other side of the finger.
  - loop: The ridges enter from one side of a finger, form a curve, and then exit on that same side.
  - whorl: Ridges form circularly around a central point on the finger.

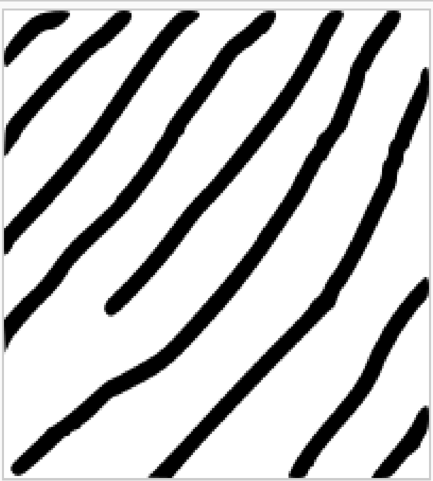
The arch pattern.

The loop pattern.

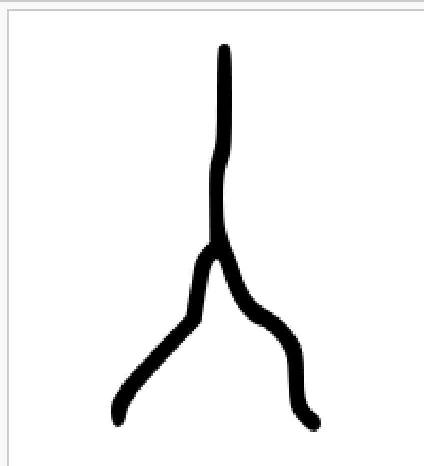
The whorl pattern.

Fingerprint Recognition

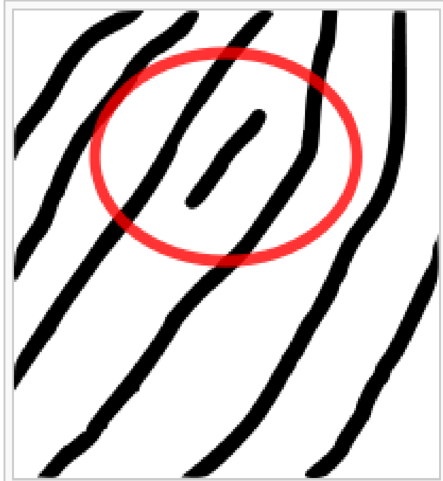
- **Minutia** The major Minutia features of fingerprint ridges are: ridge ending, bifurcation, and short ridge (or dot).
  - The ridge ending is the point at which a ridge terminates.
  - Bifurcations are points at which a single ridge splits into two ridges.
  - Short ridges (or dots) are ridges which are significantly shorter than the average ridge length on the fingerprint.



Ridge ending.

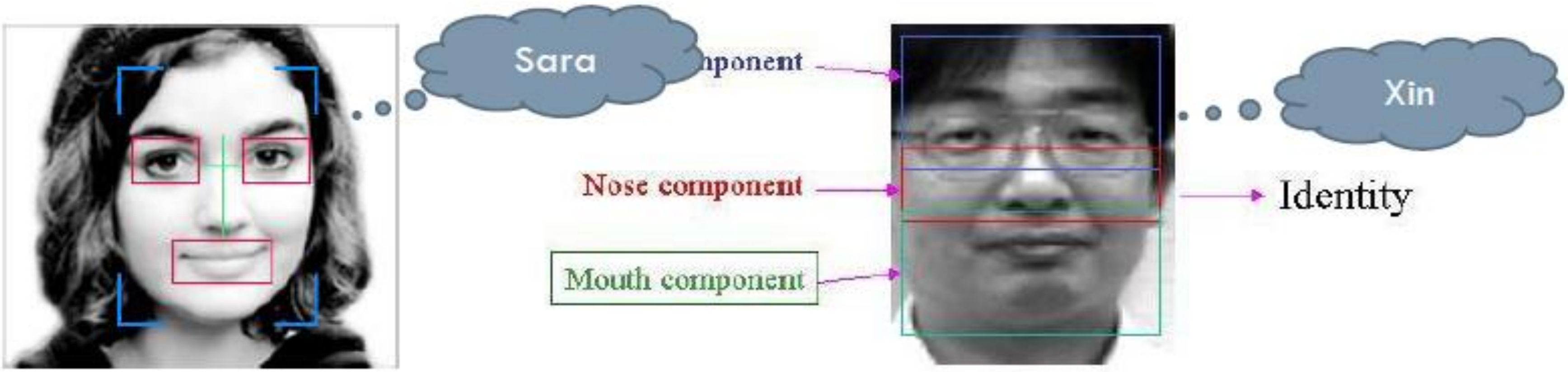


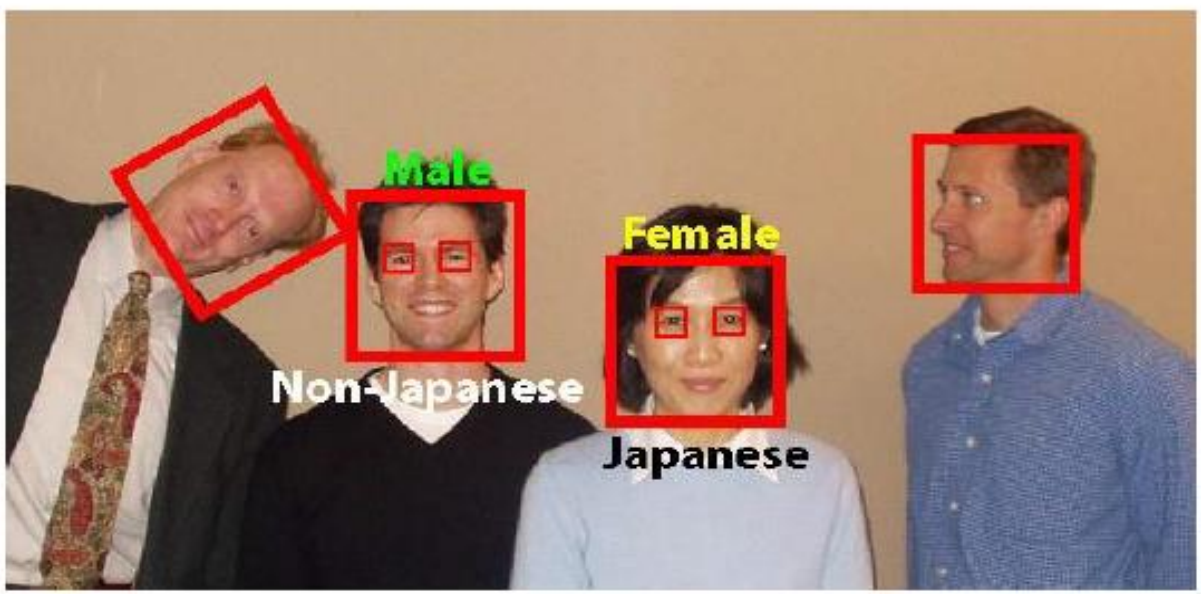
Bifurcation.



Short Ridge (Dot).

Face Recognition

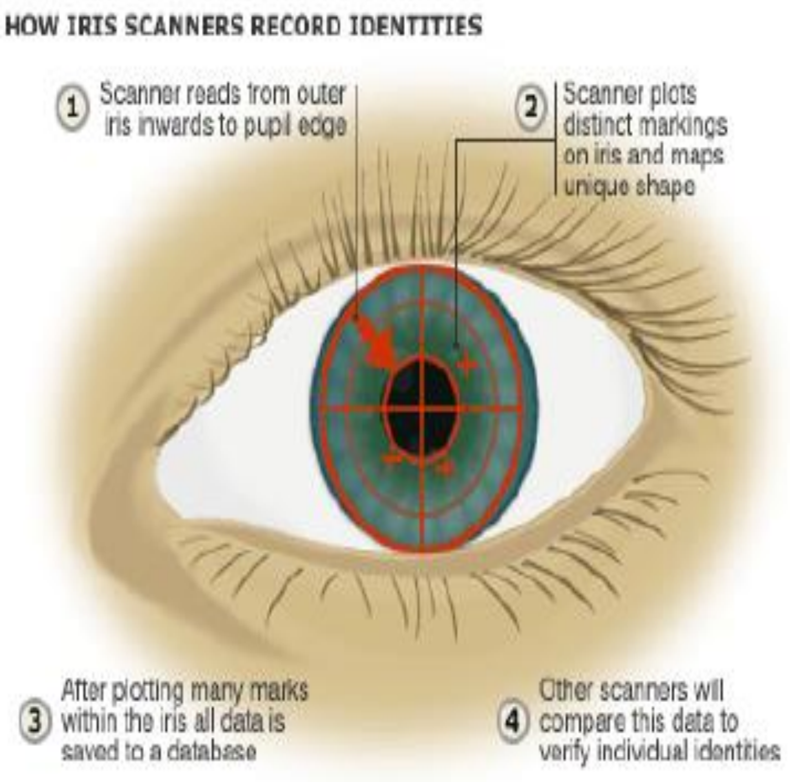




Face Morphing

- Morphing: the smooth transformation of one image into another by computer.

Personal Identification Using Iris Recognition

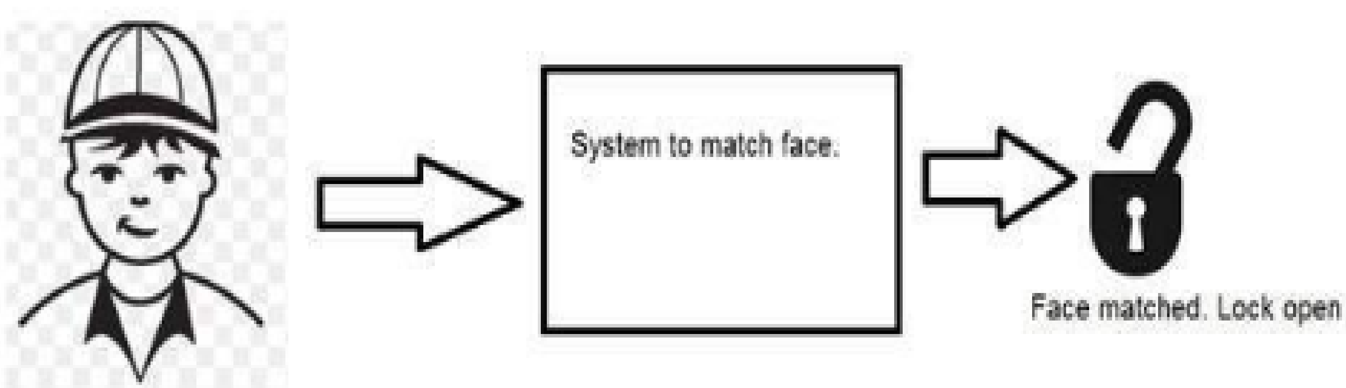


Overlapping fields

- Machine/Computer vision
- Computer Graphics
- Artificial Intelligence
- Signal Processing

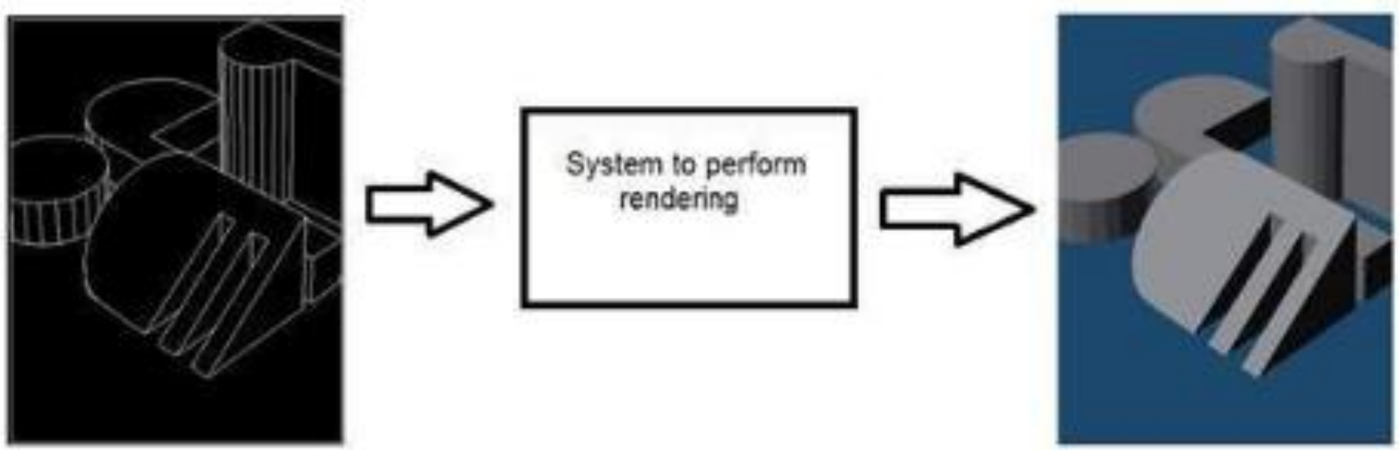
Machine/Computer vision

- Machine vision or computer vision deals with developing a system in which the input is an image and the output is some information.
  - Example: Developing a system that scans human face and opens any kind of lock.



Computer Graphics

- Computer graphics deals with the formation of images from object models, rather then the image is captured by some device.
  - Example: Object rendering. Generating an image from an object model.



Artificial Intelligence

- Artificial intelligence is more or less the study of putting human intelligence into machines.
- Artificial intelligence has many applications in image processing.
  – Example: Developing computer aided diagnosis systems that help doctors in interpreting images of X-ray , MRI e.t.c and then highlighting conspicuous section to be examined by the doctor.

Signal Processing

- Signal processing is an umbrella and image processing lies under it.

- The amount of light reflected by an object in the physical world (3d world) is pass through the lens of the camera and it becomes a 2d signal and hence result in image formation.

- This image is then digitized using methods of signal processing and then this digital image is manipulated in digital image processing.

Why do we need to process Images?

- Extract Information
- Prepare for display or printing
- Improvement of pictorial information for human perception
  - Whatever image you get you want to enhance the quality of the image so that image has a better look.
- Image processing for autonomous machine application
  - Quality control in industrial assembly line products
- Efficient storage and transmission
  - Image need some amount of disc space, transmission of good images on low bandwidth channel

Digital Image Processing & Levels of DIP

- Processing of digital images
- Levels of Digital Image Processing
  - Low Level:
    - Pre-Processing to remove noise
    - Sharpen or Enhance an image
    - Input: Image
    - Output: Image

Low-Level Image Processing

Blurry Image

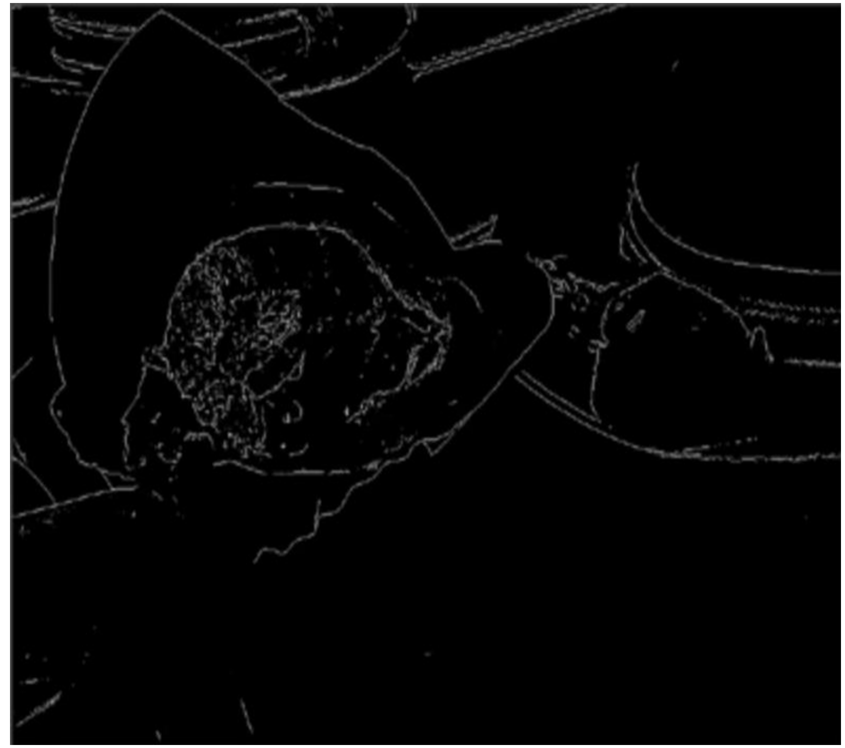
Pre-processed Image:
Sharpened or Enhanced Image

Levels of DIP

- Mid-Level:
- Segmenting an image into regions/objects; describing an image concisely
- Input: Image
- Output: Attributes of Image (Edges, Lines, Regions)

Mid Level Image Processing

Input Image



Segmented Image with highlighted edges

Levels of DIP

- High Level
- Making sense of an Image
- Image understanding, Computer Vision

Major Categories of Digital Image Processing

- Image Acquisition
- Image Manipulation & Enhancement (Subjective Process – Geometric operations, Color operations)
- Image Restoration (Objective Process)
- Image reconstruction
- Image Compression
- Image Segmentation (Edges, Lines, Objects)
- Image Understanding & Computer Vision
- Advanced Topics (E.g. Visual Effects)

- Any Questions?