Lect. 1

Digital Image Processing

Introduction :

Image processing is a subclass of signal processing concerned specifically with pictures.

- * Principal Application Areas :
  - Improve image quality (pictorial information) for human perception and interpretation.
  - Improve image quality for computer interpretation (Processing for image data for storage, transmission and representation for autonomous machine perception).

* Image processing Fields :

1. Computer Graphics : the creation of images
2. Image processing : enhancement or other manipulation of the image.
3. Computer Vision : analysis of the image content.

Input/output	Image	Description
Image	Image Processing	Computer Vision
Description	Computer Graphics	AI

* Some times Image processing defined as a discipline in which both the input and output of a process are Images (in this classification, trivial tasks of computing the average intensity of an Image would not be considered an image processing operations.

* Computerized processes Types :

1. Low - Level processes :

- Input, output are images.
- Premetive operations such as image preprocessing to reduce noise, contrast enhancement and Image sharpening.

2. Mid - Level processes :

- Inputs generally are images, outputs are attributes extracted from those images (edges, contours, ...)
- tasks : a- Segmentation (partitioning an image into regions or objects),
  b- Description of those objects to reduce them to a form suitable for computer processing.
  c- Classification (recognition) of objects.

3. High - Level processes :

Image analysis.

Digital Image Definition :

An image may be defined as a two- dimensional unction $f(x, y)$.

x, y : spatial coordinate, f - the amplitude of any pair of coordinate x, y is called the intensity or gray level of the image at that point.

Digital image : x, y and f are all finite, discrete quantities,

Digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are called picture elements, image elements and pixels.

Image Generation (Sources)

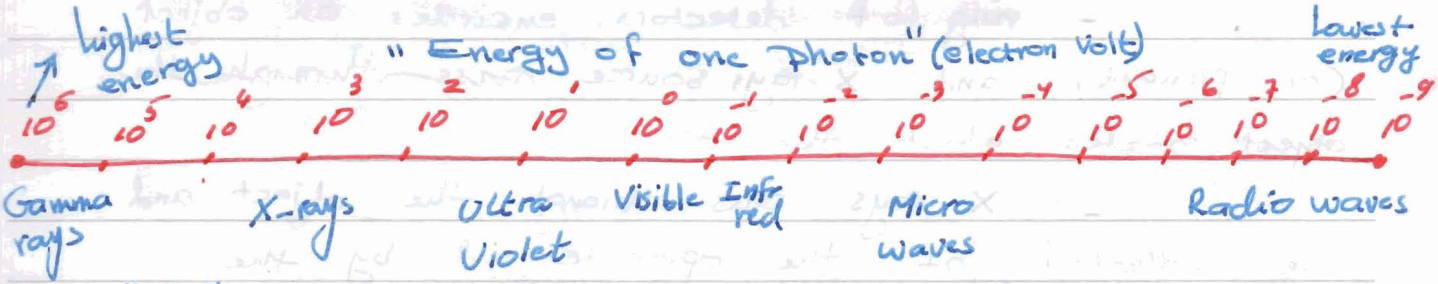
Image sources classification: (by energy)

- Radiation from the Electromagnetic spectrum (EM)
- Acoustic
- Ultrasonic
- Electronic (in the form of electron beams used in electron microscopy)
- Computer (synthetic images used for modelling and Visualization)

* Humans are limited to the visual band of the electromagnetic (EM) spectrum,
Imaging machines cover almost the entire EM spectrum from gamma to radio waves.

I Radiation from EM Spectrum:

Images based on EM spectrum are the most familiar, espcially in X-ray and Visual band.



" The electromagnetic spectrum arranged according to energy per photon"

EM-Waves: a stream of massless (~~Photon~~ Proton) particles, each traveling in a wavelike pattern and moving at the speed of light.

Spectral bands are grouped by energy per photon:
Gamma Rays, X-Rays, Ultra Violet, Visible, Infrared, Microwaves, Radiowaves.

1. Gamma Rays Imaging:

Gamma Ray imaging used in ~~nuclear~~ nuclear Medicine and Astronomy.

- Nuclear Medicine :

. Radioactive isotope injected to emmit gamma rays, while decaying → gamma ray detectors collect the emissions and produce the image. (ex. bone scans).

. positron emission tomography (PET) scans.

as X-ray tomography, ∴ instead of using an external source of X-ray energy, the patient is given a radioactive isotope that emits positons as it decays, These are detected and tomographic image is created.

- Astronomy : Cygnus Loop , nuclear reactor (natural radiation).

2- X-ray Imaging :

▲A. CAT : Computerized axial tomography. or CT scans for short.

CT scans is a process in which :

- ring of detectors encircles an object (or patient), and X-rays source ~~pass through the object~~ rotates about the object.

- X rays pass through the object and are collected at the opposite end by the corresponding detectors in the ring.

- Tomography consists of algorithms that use the sensed data to construct an image that represent a "slice" through the object.

- Motion of the object in a direction perpendicular to the ring of detectors produces a set of slices (3-D image).

* X-rays for medical and industrial imaging are generated using X-ray tube, which is a vacuum tube, with Cathode and anode.

The cathode is heated, causing free electron to be released. when electron meets nucleus, energy is released in the form of X-ray.

using of X-rays :

- Medical diagnostics
  - Chest X-ray
  - Aortic angiogram
  - head CT
- Industrial imaging
  - Circuit board
- Astronomy : Cygnus Loop.

4.6. Angiography : X-ray contrast medium injected with catheter through blood vessels, angiography is a major area of digital image processing where image subtraction is used to enhance further the blood vessels being studied.

3. Imaging in the UltraViolet Band.

Application of UltraViolet "light" are varied :

- Industrial inspection
- Microscop (fluorescence)
- lasers
- biological Imaging
- astronomical observations.

4. Imaging in Visible and Infrared Bands:

Application of visible & infrared bands :

- Astronomy
- light microscopy
- remote sensing : To monitoring environmental Conditions on the planet.
- Industry
- Law enforcement.

Table : Thematic bands in NASA's LANDSAT satellite:

Band No	Name	Wavelength (μm)
1	Visible blue	0.45 – 0.52
2	Visible green	0.52 – 0.60
3	Visible Red	0.63 – 0.69
4	Near Infrared	0.76 – 0.90
5	Middle infrared	1.55 – 1.75
6	Thermal infrared	10.4 – 12.5
7	Middle infrared	2.08 – 2.35

The primary function of LANDSAT is to obtain and transmit images of the Earth from space for purposes of monitoring enviromental condition on the planet.

5. Imaging in Microwave band.

- Imaging radar : the only way to explore inaccessible regions of the earth's surface Note the clarity and detail of the image Unencumbered by clouds or other atmospheric Conditions that normally interfere with images in visual band.

6. Imaging in the Radio Band

- Medicine : Magnetic Resonance Image (MRI) This technique plases a patient in a powerful magnet and passes radio waves through body in short pulses. Each pulse causes a responding pulse of radio waves to be emitted by the patient's tissues. these locations determined by computer which produces a 2-D Image.
- Astronomy.

II - Acoustic Imaging :

- Geological application : use sound in the low end of the sound spectrum (hundred of Hz).
  - Mineral & oil exploration
  - Cross-sectional image of a seismic model.

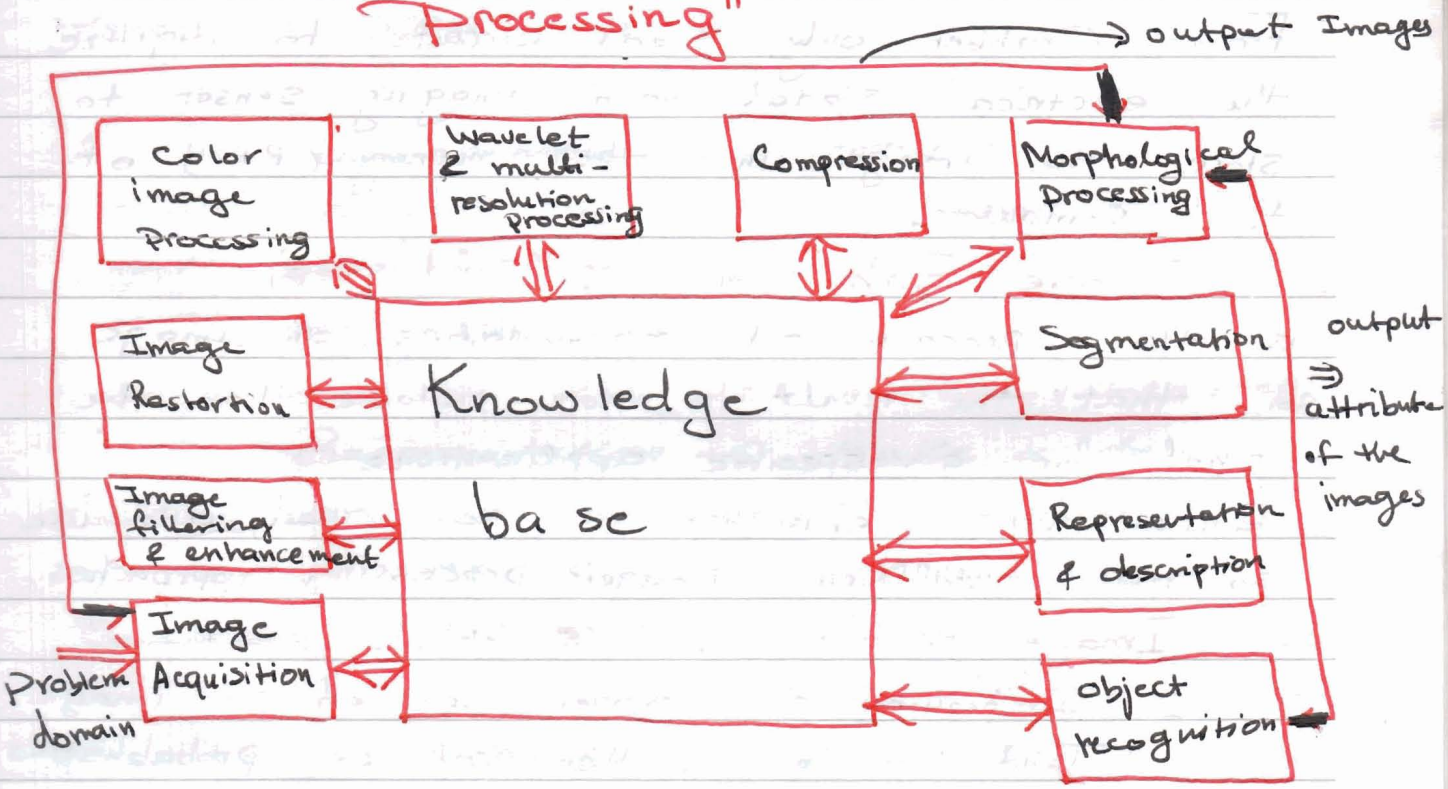
III Ultra Sound Imaging :

- Manufacturing
- Medicine : baby, Mucle Layers showing lesion.

IV Generated Image by Computer:

- fractals : an iterative reproduction of a basic pattern according to some mathematical rules.
- 3-D Computer Modeling.

"Fundamental Steps in Digital Image Processing"



1. Image Acquistion : (first step)

An Image is captured by a sensor (such as a monochrome or color TV camera) and digitized if the output of the camara or sensor is not already in digital form - an analog-to-digital convertor digitizes it.

Camera :

Camera Consits of 2 Parts :

- A lens that Collects the appropriate type of radiation emitted from the object of interest and that forms an image of the real object.
- Semiconductor device - so called Charged Coupled device or CCD which converts the irradiance at the image plan into an electrical signal.

Frame Grabber :

Frame Grabber only needs circuits to digitize the electrical signal from imaging sensor to store the image in the memory (RAM) of the Computer.

2. Image Enhancement : (2-nd step)

is the process of manipulating an image so that the result is more suitable than the original for a specific applications.

Enhancement techniques are so varied, and use so many different image processing approaches.

3. Image Restoration : (3-d step)

- Improving the appearance of an image
- Tend to be mathematical or probablistics models of Image degradation.

4. Color and Image Processing (4-th step).
Use the color of the image to extract features of interest in an image.

5. Wavelets: (5-th step): used in image data compression and Pyramedal representation.

6. Compression: (6-th step):
Techniques for reducing the storage required to save an image or the bandwidth required to transmit it ("JPEG standard").

7. Morphological Processing: (7-th step)
Tools for extracting image components that are useful in the representation and description of shape.

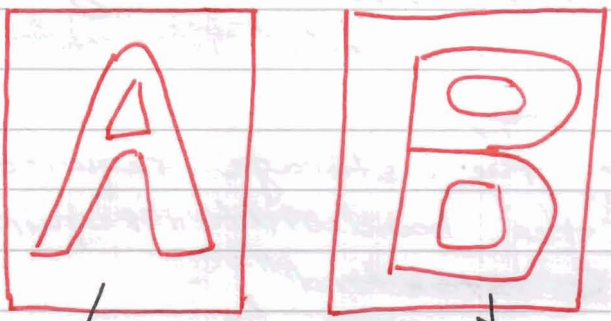
8. Image Segmentation: (8-th step)
- Computer tries to separate objects from the image background.
- it is one of the most difficult tasks in DIP.

: Segmentation Kinds:

- autonomous segmentation
- rugged segmentation (Long Process to get successful solution.
- eratic segmentation.

9. Representation & Description: (9-th step)
. Representation → Make a ~~decision~~ decision whether the data should be represented as a boundary or as a Complete region:
- Boundary Representation → focus on external shape characteristics, such as corners & inflections.

- Region Representation → focus on internal properties, such as texture or skeleton shape.



1 Connected component + 1 hole

1 Connected component + 2 holes

Representation & Description

⇓

transform raw Data

⇓

a form suitable for the Recognition processing.

10. Recognition & Interpretation : (10-th step).

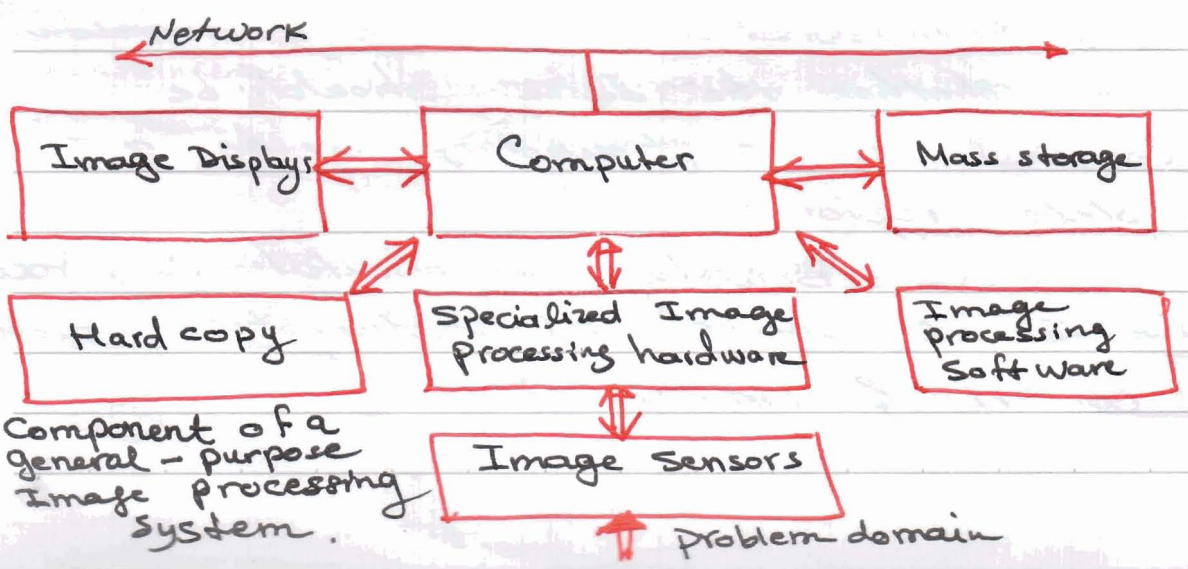
Recognition → the process that assigns label to an object based on the information provided by its descriptors.

11. Knowledge base : (11-th step).

The knowledge base also controls the interaction between modules.

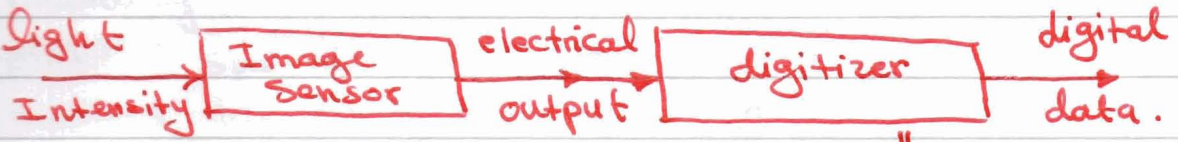
The knowledge about a problem domain is Coded into an image processing system in the form of a knowledge database.

" Components of an Image processing System "



1. **Image Sensors:**

- Physical device that is sensitive to the energy radiated by the object.
- digitizer: Convert the output of the physical sensing device into digital form.



" digital Video Camera."

2. **Specialized Image processing hardware:**
Usually consists of the digitizer, and hardware that performs other primitive operations, such as arithmetic logic Unit (ALU):
Speed: the most important parameter (30 frames/s)

3. **Computer:** (image processing system: from pc to a supercomputer)

4. **Software:** specialized modules that perform specific tasks.

5. **Mass storage Capability:** is a must in image processing applications. (image size of 1024 x 1024 pixels, with intensity for each pixel: 8 bits, requires one Megabyte for saving)

Mass storage categories:
- short-term storage for use during processing
- On-line storage for relatively fast operations
- Archival storage: infrequent access.

6. **Image displays:** flat screen TV monitors,

7. **Hard copy:** devices for recording images: Laser printers, film cameras, CD-ROM disk, others.

8. **Networking:** the key parameter is the bandwidth.