بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

Image Processing

Course Teacher: **Md Mahbub E Noor**

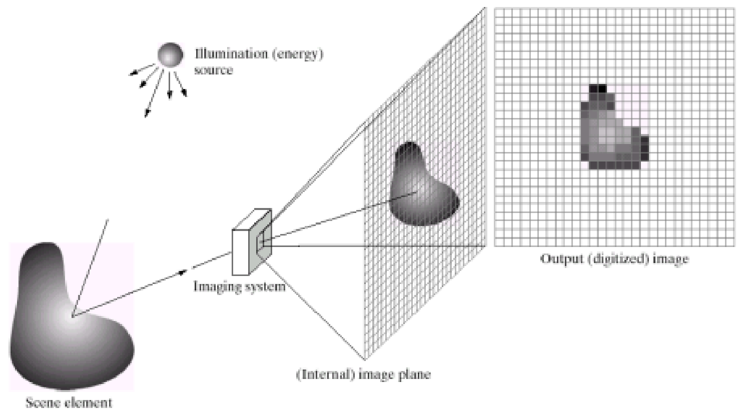
Previous Course Teacher: **Sohely Jahan Ma’am.** তাই আমাদের মিডের প্রশ্ন টা সল্ভ করা আছে শুধু। বাকি সব স্লাইড দিয়ে পড়**.**

6th batch Mid & Some Extra Ques from Slide 1

1. What is digital image and what its processing? Explain shortly

From Slide

- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels



- Digital Image Processing refers to processing digital images by means of a digital computer.
- Digital Image is comprised of a finite number of elements, each of which has a particular location and value. These elements are called picture elements, image elements, pels and pixels.

or,

Digital Image Processing (DIP)

- It is the manipulation of the digital data with the help of computer hardware and software to produce digital maps in which the specific information has been extracted and highlighted.

For Extra see:

Characteristics of Digital Image Processing

- It uses software, and some are free of cost.
- It provides clear images.
- Digital Image Processing do image enhancement to recollect the data through images.
- It is used widely everywhere in many fields.
- It reduces the complexity of digital image processing.
- It is used to support a better experience of life.

Advantages of Digital Image Processing

- Image reconstruction (CT, MRI, SPECT, PET)
- Image reformatting (Multi-plane, multi-view reconstructions)
- Fast image storage and retrieval
- Fast and high-quality image distribution.
- Controlled viewing (windowing, zooming)

Disadvantages of Digital Image Processing

- It is very much time-consuming.
- It is very much costly depending on the particular system.
- Qualified persons can be used.

Applications of Digital Image Processing

- **Image sharpening and restoration:** The common applications of Image sharpening and restoration are zooming, blurring, sharpening, grayscale conversion, edges detecting, Image recognition, and Image retrieval, etc.

- **Medical field:** The common applications of medical field are Gamma-ray imaging, PET scan, X-Ray Imaging, Medical CT, UV imaging, etc.
- **Remote sensing:** It is the process of scanning the earth by the use of satellite and acknowledges all activities of space.
- **Machine/Robot vision:** It works on the vision of robots so that they can see things, identify them, etc.
- **Pattern recognition:** It involves the study of image processing; it is also combined with artificial intelligence such that computer-aided diagnosis, handwriting recognition and images recognition can be easily implemented. Now a day, image processing is used for pattern recognition.
- **Video processing:** It is also one of the applications of digital image processing. A collection of frames or pictures are arranged in such a way that it makes the fast movement of pictures. It involves frame rate conversion, motion detection, reduction of noise and cooler space conversion etc.

History of digital image processing:

1. **Early 1920s**: One of the first uses of digital imaging was in the newspaper industry with the Bartlane cable picture transmission service, sending images between London and New York via submarine cable.
2. **Mid to Late 1920s**: The Bartlane system improved, allowing higher quality images with more tones, thanks to new photographic reproduction processes.
3. **1960s**: Advances in computing and the space race boosted digital image processing. In 1964, computers enhanced moon images from the Ranger 7 probe, and similar techniques were used in other space missions, including Apollo.
4. **1970s**: Digital image processing entered the medical field, and in 1979, the Nobel Prize was awarded for the invention of tomography, leading to CAT scans.
5. **1980s - Today**: Digital image processing has expanded into many fields, including image enhancement, artistic effects, medical visualization, industrial inspection, law enforcement, and human-computer interaction.

2. Explain the differences among different image processing levels (low, mid, high). Segmentation is from the which level of image processing and why?

Sol:

From slide,

- Types of image processing processes:
  - Low-Level
  - Mid-Level
  - High-Level

Low-level :- A low level process is characterized by the fact that both its I/P and O/P are images e.g. reduction in noise, contrast enhancement and image sharpening.

Mid-Level:- It involves tasks such as segmentation (partitioning of image into regions or objects), description of those objects to reduce them to a form suitable for computer processing and classification of individual objects. I/P is image, O/P are attributes extracted from those images.(e.g. edges, contours etc.)

- High-Level:- It makes sense of an ensemble of recognized objects, as in image analysis, and at the far end of the continuum, performing the cognitive functions normally associated with the vision.

Or,

Low-Level: Processes where both input and output are images, like noise reduction, contrast enhancement, and sharpening.
Mid-Level: Involves segmentation, object description, and classification. The input is an image, and the output is features like edges or contours.

High-Level: Focuses on interpreting recognized objects for image analysis and mimics cognitive vision functions.

Here's a table showing the differences among low, mid, and high levels of image processing:

Level	Input	Output	Purpose	Examples
Low-Level	Image	Image	Basic image enhancement or correction	Noise reduction, contrast enhancement, sharpening
Mid-Level	Image	Features or attributes	Extract meaningful image features	Segmentation, edge detection, contour extraction
High-Level	Recognized objects	Interpretation/Understanding	Cognitive analysis and decision-making	Object recognition, image analysis, scene understanding

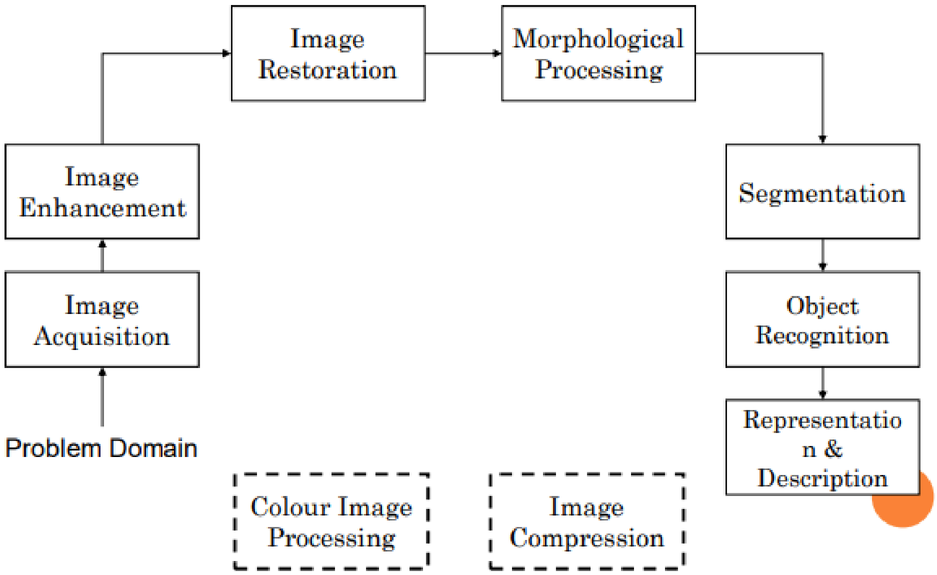
Segmentation is considered a mid-level image processing technique because it operates on a level of detail that goes beyond basic pixel manipulation (low-level) but is not yet performing high-level object recognition or scene understanding, instead focusing on identifying and separating distinct regions within an image based on features like color, intensity, or texture; essentially dividing an image into meaningful segments.

Or,

Segmentation is part of **mid-level** image processing because it involves dividing an image into meaningful regions or objects and extracting features like edges or boundaries, which can then be used for further analysis. The output is not an image but information about the objects within the image.

3. Write all the key stages of digital image processing.

KEY STAGES IN DIGITAL IMAGE PROCESSING



4. What is image sampling and quantization? Please explain shortly.

Sampling with relation to digital images

The concept of sampling is directly related to zooming. The more samples you take, the more pixels, you get. Oversampling can also be called as zooming. This has been discussed under sampling and zooming tutorial.

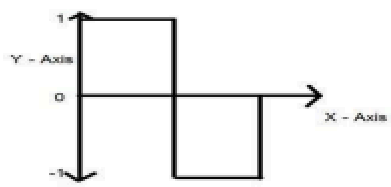
But the story of digitizing a signal does not end at sampling too, there is another step involved which is known as Quantization.

What is quantization?

Quantization is opposite to sampling. It is done on y axis. When you are quantizing an image, you are actually dividing a signal into quanta(partitions).

On the x axis of the signal, are the co-ordinate values, and on the y axis, we have amplitudes. So digitizing the amplitudes is known as Quantization.

Here how it is done



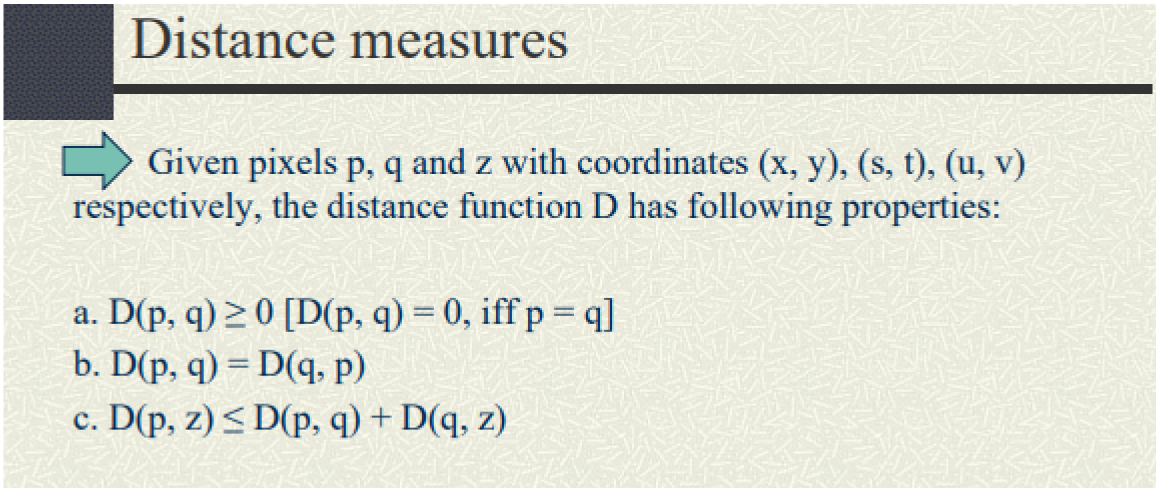
Or,

In digital image processing, signals captured from the physical world need to be translated into digital form through the "Digitization" process. To become suitable for digital processing, an image function f(x,y) must be digitized both spatially and in amplitude. This digitization process involves two main processes called

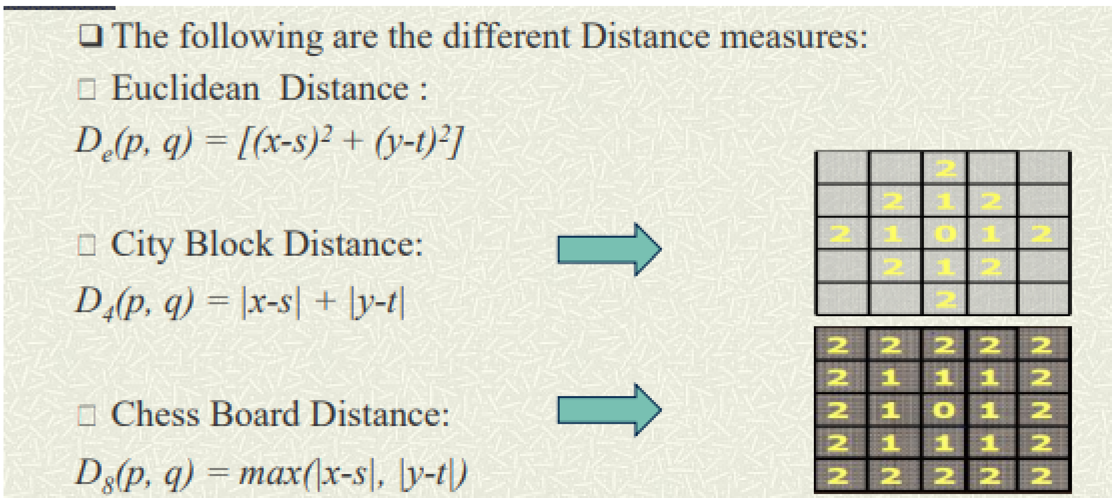
1. **Sampling:** Digitizing the co-ordinate value is called sampling.
2. **Quantization:** Digitizing the amplitude value is called quantization

5. Name different distance measurement techniques. Explain Euclidean distance shortly.

Distance Measures Between Pixels With Examples



.



Euclidean Distance

The Euclidean distance is defined as the distance between two points.

Let us assume two points, such as (x, y) and (s, t) in the two-dimensional coordinate plane.

Thus, the Euclidean distance formula is given by:

d =√[(x – s)2 + (y – t)2]

Where,

"d" is the Euclidean distance

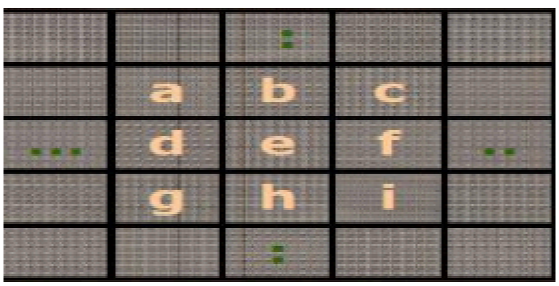
(x1, y1) is the coordinate of the first point

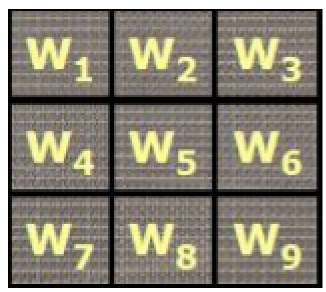
(x2, y2) is the coordinate of the second point.

6. Give an example and briefly explain the procedure to assign a pixel value by neighbourhood-based arithmetic/Logic operation.

Neighborhood based arithmetic/Logic

Value assigned to a pixel at position ‘e’ is a function of its neighbors and a set of window functions.





$$p = (w_1 a + w_2 b + w_3 c + w_4 d + w_5 e + w_6 f + w_7 g + w_8 h + w_9 i)$$
$$= \sum w_i f_i$$

Arithmetic/Logic Operations:

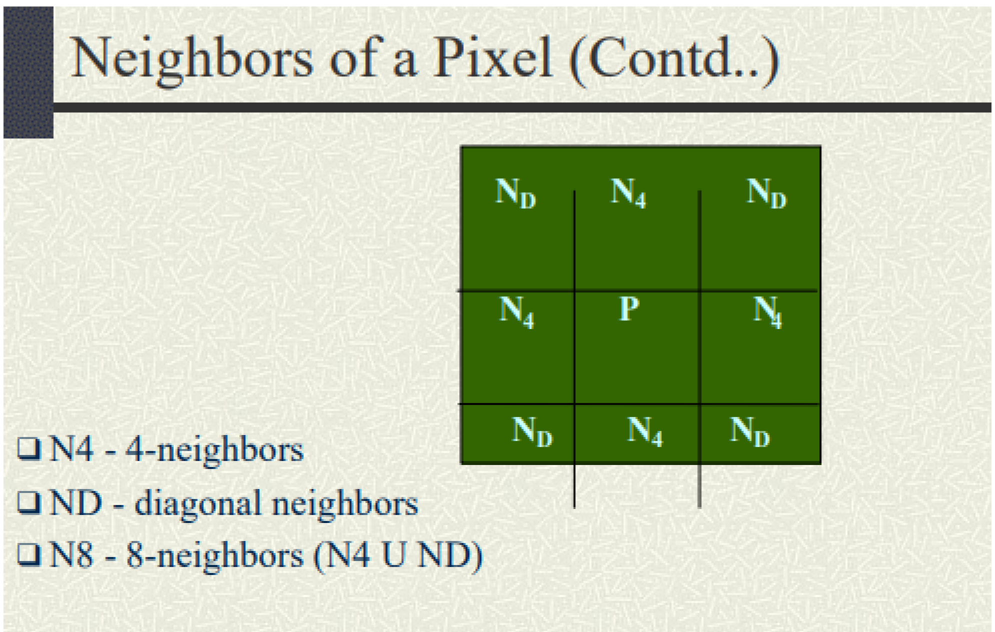
Tasks done using neighborhood processing:

- Smoothing / averaging.
- Noise removal / filtering.
- Edge detection.
- Contrast enhancement

Extra Ques:

1.

Relationship between pixels Neighborhood and Adjacency of Pixels



Relationship between Pixels, Neighbourhood and Adjacency of Pixels

1) Neighbourhood of Pixels

Any image can be represented as the following:

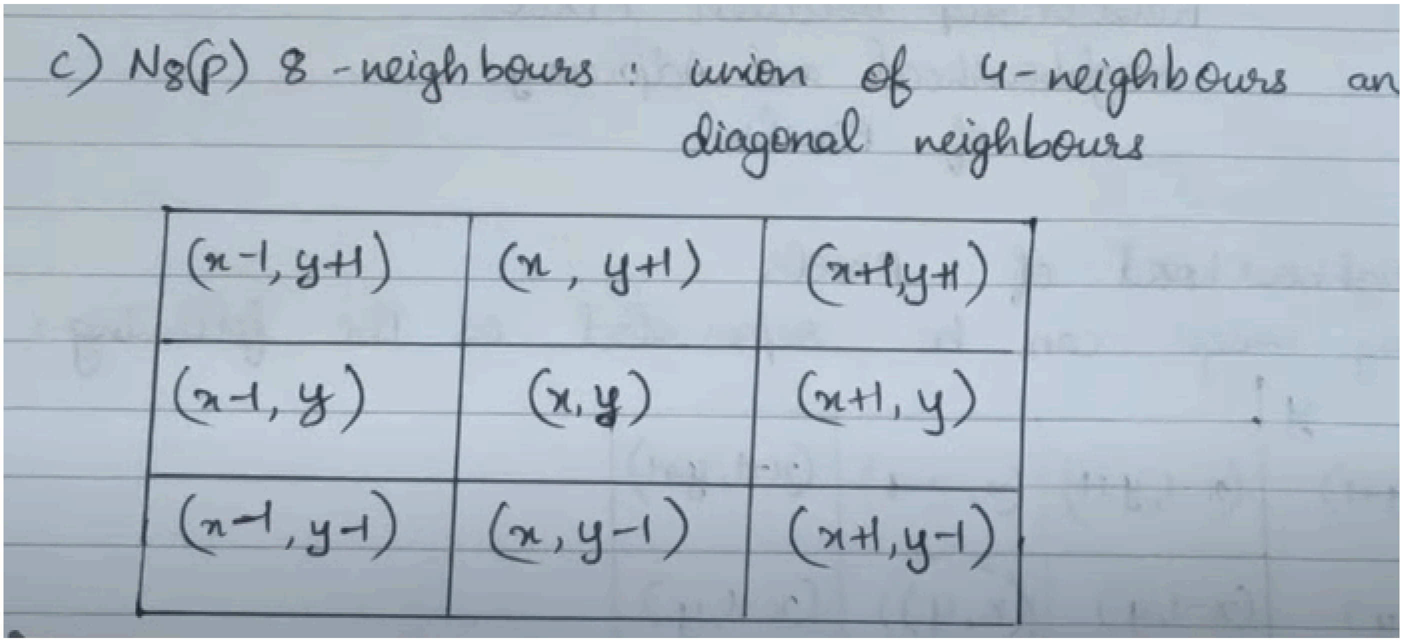
y ↑			
(y+1)	(x-1, y+1)	(x, y+1)	(x+1, y+1)
(y)	(x-1, y)	(x, y)	(x+1, y)
(y-1)	(x-1, y-1)	(x, y-1)	(x+1, y-1)
	(x-1)	(x)	(x+1) → x

a) $N_4(p)$ 4-neighbours : the set of horizontal and vertical neighbours

	(x, y+1)	
(x-1, y)	(x, y)	(x+1, y)
	(x, y-1)	

b) $N_D(p)$ diagonal neighbours : the set of 4 diagonal neighbours.

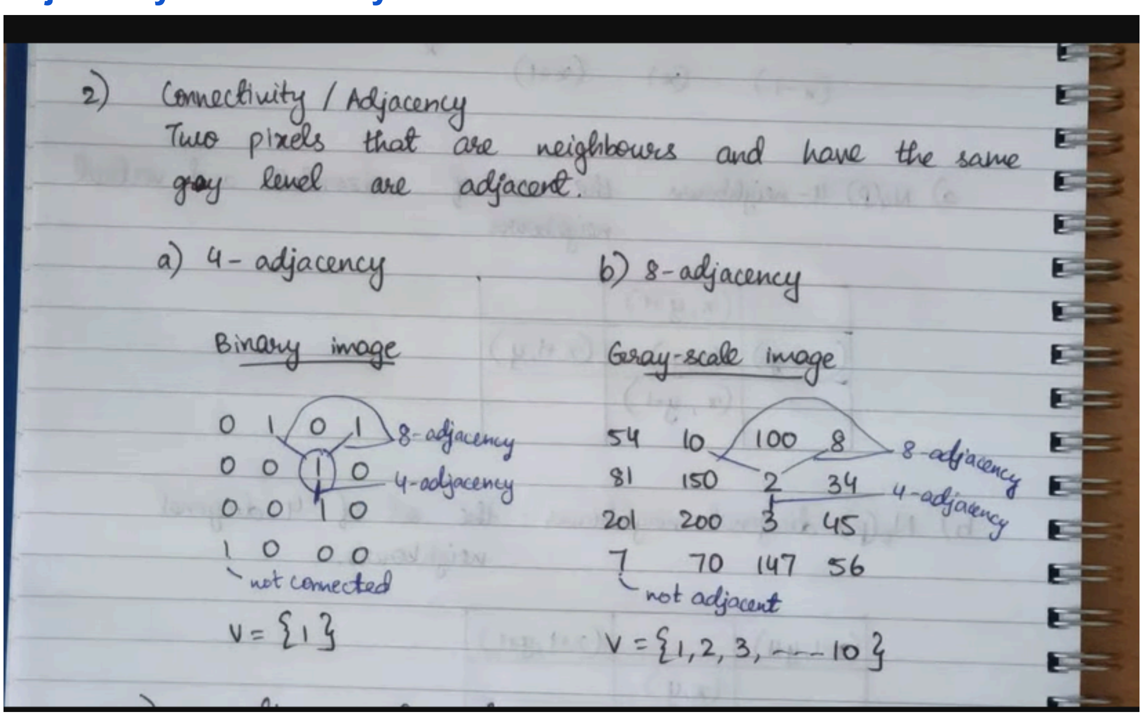
(x-1, y+1)		(x+1, y+1)
	(x, y)	
(x-1, y-1)		(x+1, y-1)



c) $N_8(p)$ 8-neighbours : union of 4-neighbours an
diagonal neighbours

(x-1, y+1)	(x, y+1)	(x+1, y+1)
(x-1, y)	(x, y)	(x+1, y)
(x-1, y-1)	(x, y-1)	(x+1, y-1)

2.
Adjacency/Connectivity



2) Connectivity / Adjacency
Two pixels that are neighbours and have the same gray level are adjacent.

a) 4-adjacency

Binary image

0	1	0	1
0	0	1	0
0	0	1	0
1	0	0	0

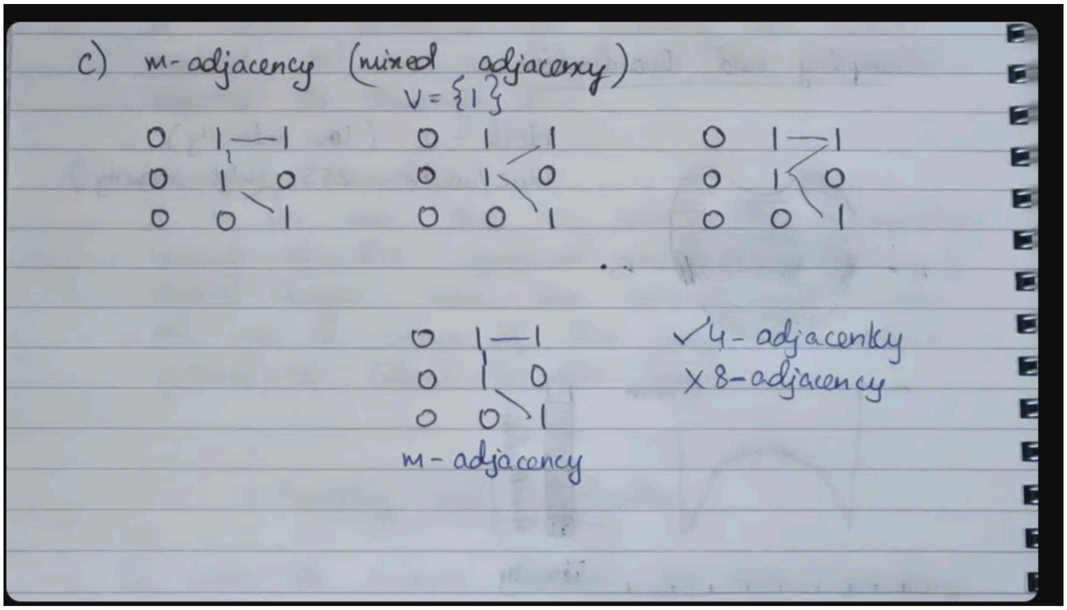
V = {1}

b) 8-adjacency

Gray-scale image

54	10	100	8
81	150	2	34
201	200	3	45
7	70	147	56

V = {1, 2, 3, ---- 10}

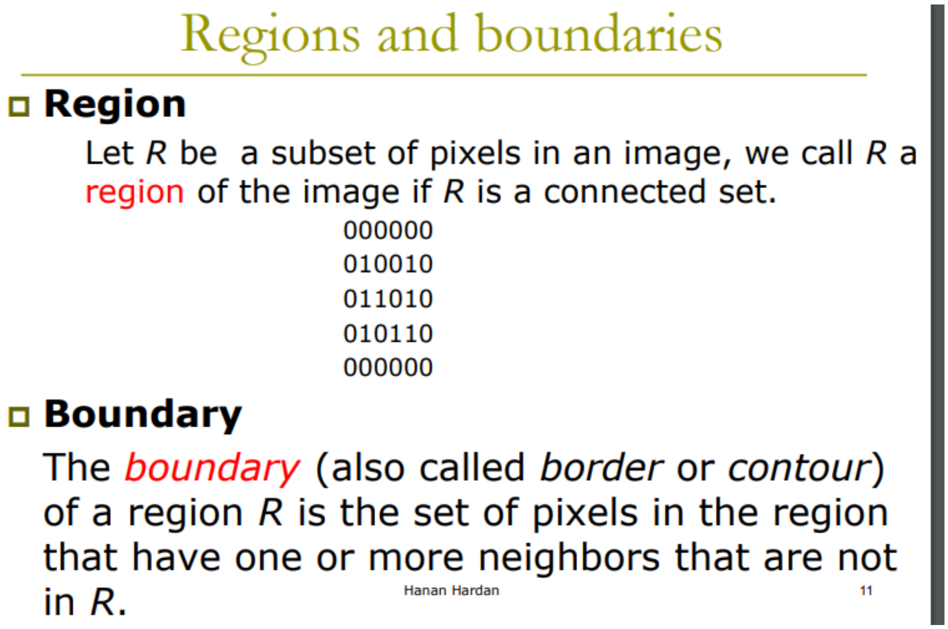


3

Regions and Boundaries

- A subset R of pixels in an image is called a Region of the image if R is a connected set.
- The boundary of the region R is the set of pixels in the region that have one or more neighbors that are not in R.

Or,



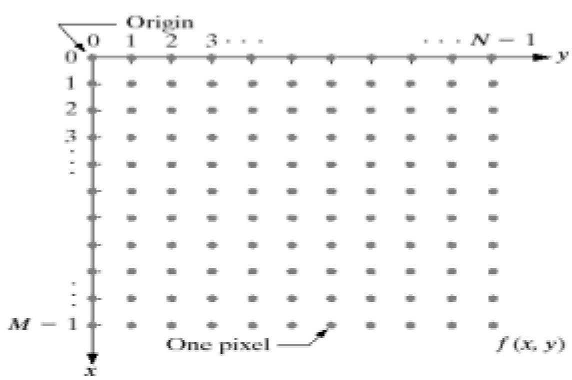
or,

A region is a connected set of pixels in an image, and a boundary is the set of pixels in an area with neighbors outside the region. Boundaries are also known as contours or borders

4.

Image Representation

Before we discuss image acquisition recall that a digital image is composed of M rows and N columns of pixels each storing value Pixel values are most often grey levels in the range 0-255(black-white) We will see later on that image can easily be represented as matrices.



Coordinate convention used to represent digital images. Because coordinate values are integers, there is a one-to-one correspondence between x and y and the rows (r) and columns (c) of a matrix.

5.

Spatial Resolution

- The spatial resolution of an image is determined by how sampling was carried out
- Spatial resolution simply refers to the smallest discern able detail in an image
  - Vision specialists will often talk about pixel size

Intensity Level Resolution

- Intensity level resolution refers to the number of intensity levels used to represent the image
  - The more intensity levels used, the finer the level of detail discern able in an image
  - Intensity level resolution is usually given in terms of the number of bits used to store each intensity level

Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

the number of pixels per square inch, which determines the clarity or sharpness of an image

:

6

1. Image Acquisition

- This is the first step or process of the fundamental steps of digital image processing. Image acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves preprocessing, such as scaling etc.
- This is the first stage of digital image processing.
- The image Acquisition stage involves preprocessing, such as scaling, etc.

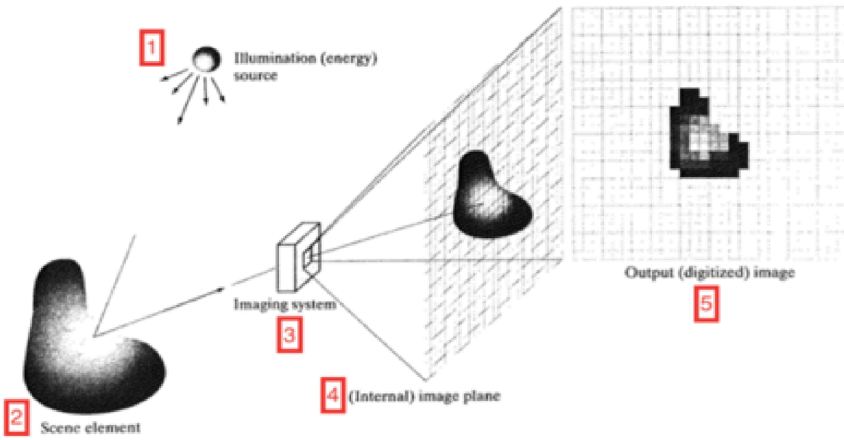


Fig.3. An Example of Steps of Digital Image Acquisition

7.

Analog Image Processing vs. Digital Image Processing

Analog Image Processing	Digital Image Processing
The analog image processing is applied on analog signals and it processes only two-dimensional signals.	The digital image processing is applied to digital signals that work on analyzing and manipulating the images.
Analog signal is time-varying signals so the images formed under analog image processing get varied.	It improves the digital quality of the image and intensity distribution is perfect in it.
Analog image processing is a slower and costlier process.	Digital image processing is a cheaper and fast image storage and retrieval process.
Analog signal is a real-world but not good quality of images.	It uses good image compression techniques that reduce the amount of data required and produce good quality of images

Difference between the Analog signals and Digital signals

Analog signals	Digital signals
Analog signals are difficult to get analysed at first.	Digital signals are easy to analyse.
Analog signals are more accurate than digital signals.	Digital signals are less accurate.
Analog signals take time to be stored. It has infinite memory.	Digital signals can be easily stored.
To record an analog signal, the technique used, preserves the original signals.	In recording digital signal, the sample signals are taken and preserved.
There is a continuous representation of signals in analog signals.	There is a discontinuous representation of signals in digital signals.
Analog signals produce too much noise.	Digital signals do not produce noise.
Examples of analog signals are Human voice, Thermometer, Analog phones etc.	Examples of digital signals are Computers, Digital Phones, Digital pens, etc.

Saturation & Noise

Image Saturation

- saturation is the purity of a color.
- Saturation is a very important aspect in photography, perhaps as important as contrast.
- In addition to our eyes being naturally attracted to vibrant tones, colors have their own unique way of telling a story that plays a crucial part in making a photograph.

Image Noise

- Image noise is random variation of brightness or color information in images.
- it is usually an aspect of electronic noise.
- It can be produced by the image sensor and circuitry of a scanner or digital camera.

#Applications of digital image processing:

- **Space**: Used to improve and analyze images taken from space.
- **Medical (CAT Scans)**: Helps doctors see inside the body by creating 3D images using X-rays. This technology won a Nobel Prize.
- **Image Improvement**: Makes medical and industrial images clearer and easier to understand by enhancing contrast or adding color.
- **Geography**: Helps study pollution patterns using satellite images.
- **Image Repair**: Fixes old or blurry images, making them clearer.
- **Science**: Used in experiments and research in physics, biology, and astronomy to enhance images for better understanding.

Or,

various applications of image processing:

1. **Image Enhancement:** Improves image quality by removing noise or enhancing details.
2. **Hubble Telescope**: Fixed blurry space images from the Hubble Telescope using image processing techniques.
3. **Artistic Effect**s: Adds special effects to make images look more visually appealing or create artistic composites.

4. **Medicine:**
    - MRI scans are used to view detailed slices of body tissues.
    - Techniques like edge detection highlight tissue boundaries for better diagnosis.
5. **PCB Inspection:** Checks printed circuit boards for component placement and solder joint quality using imaging and x-rays.
6. **Human-Computer Interfaces (HCI):**
    - Improves interactions through face and gesture recognition.
    - Makes computer interfaces more natural and intuitive.
7. **Gamma Ray Imaging:**
    - Used in nuclear medicine and astronomy to see inside the body or study cosmic phenomena.
    - Detects gamma rays emitted from radioactive materials.
8. **X-Ray Imaging:**
    - Includes standard chest X-rays and advanced techniques like angiography for viewing blood vessels.
    - Digital X-ray systems either digitize films or use light-sensitive detectors.
9. Ultraviolet Imaging:
    - Used in fluorescence microscopy to study materials that emit light when exposed to UV.
10. **Visible and Infrared Imaging:**
    - Includes light microscopy and imaging in the visible and infrared spectra for various applications.
11. **Geographic Information Systems (GIS):**
    - Processes satellite images for terrain classification and studying phenomena like hurricanes.
12. **Industrial Inspection:**
    - Automated systems check for flaws in manufacturing, such as missing parts or defects in products.
13. **Law Enforcement:**
    - Techniques for number plate recognition, fingerprint analysis, and improving CCTV images.
14. **Microwave Band:**
    - Radar imaging collects data regardless of weather conditions, using microwave energy reflected back to the radar.
15. **Radio Band:**
    - Used in MRI to create detailed images of body tissues using radio waves and a strong magnetic field.
16. **Sound Waves:**
    - Ultrasound Imaging: Uses high-frequency sound waves to create images of internal body structures.
    - Geological Exploration: Uses sound waves to locate minerals and oil.
17. **Electron Microscopes:**

- Provides high magnification for detailed industrial inspections and scientific research using electron beams instead of light.

#Componets of Image processing system

COMPONENTS OF A GENERAL PURPOSE IMAGE PROCESSING SYSTEM

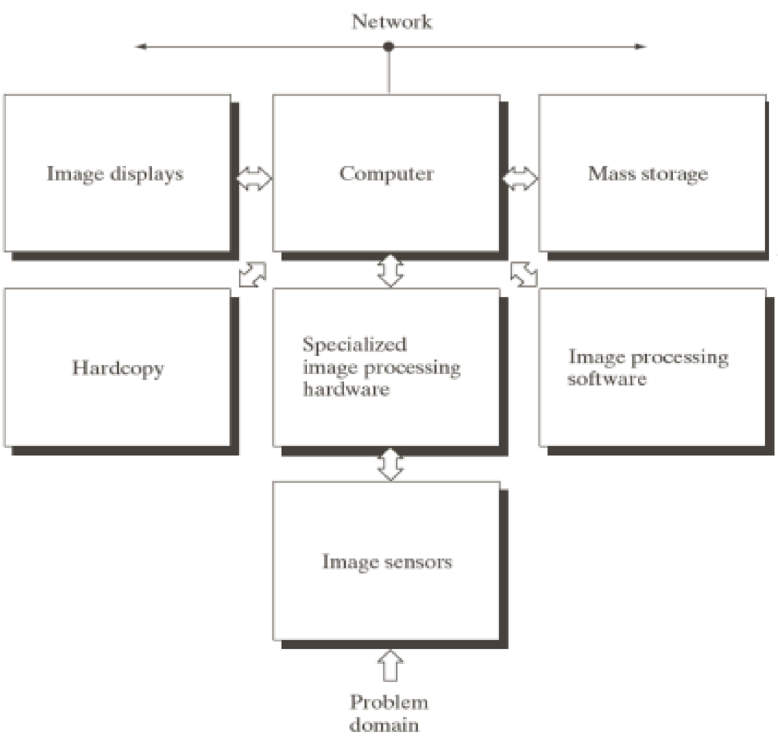


FIGURE 1.24 Components of a general-purpose image processing system.