UNIT-I

1. Define image? Explain digital and analog image? Explain digital image processing?

Image is a 2d representation of a 3d world. It is a 2 dimensional function f(x,y) where x and y are the spatial coordinates and f is the function that represents the intensity of grey level of that coordinate.

There are 2 types of images :

Digital image and analog image

Analog image are the continuous images or infinite images

Analog images are represented as a continuous range of values representing position and intensity

Digital image are also called as discrete or finite images

Digital images are composed of picture element known as pixels.Pixels are the smallest sample of an image.A pixel represents the brightness at one point.

Image processing is basically the use of computer technology to process an image.

Input(f(x,y)) → Processing → output(g(x,y))

Raw image enhanced image

Where both f(x,y) and g(x,y) are images.

Adv of dip : flexibility and adaptability 2. Data storage and transmission

Disadv of dip : memory and processing speed capabilities of computers.

2. Briefly describe fundamental steps in image processing.

- Image acquisition is the process of capturing pictures from the real world using devices such as cameras, scanners, or sensors
- image enhancement is the process in which the original image is modified so that the resultant image is better than the original image for specific application i.e image is enhanced
- Image restoration, in simple terms, is like using digital tools to fix or improve a damaged or degraded image.
- Color image processing, involves working with images that have color information to enhance, analyze, or manipulate them
- Wavelets and multiresolution processing,involve tools and techniques for analyzing images at different levels of resolution
- Compression,is the process of reducing the size of a file or data to save space and make it easier to store, transmit, or process
- Morphological processing that involves the manipulation and analysis of the structure and shape of objects within an image
- segmentation is like dividing a larger picture into smaller, more manageable pieces based on certain characteristics
- representation and description are like explaining and summarizing what's in a picture in a way that a computer can understand
- object recognition is like teaching a computer to identify and understand what's in a picture

3. Write down advantages and disadvantages of digital image.

4. List various image file formats. Explain any one in details?
5. What are the applications of digital image processing?
6. How image is formed in Human eye?
7. Write a short note on Sampling and Quantization.
8. Explain the different types of connectivity of pixels with suitable example.
9. What are different fields where image processing is used?
10. List and explain elements of image processing system?
11. Explain 2D unit impulse sequence.

    A 2D unit impulse sequence refers to a discrete signal or sequence in two dimensions, often denoted as δ[n,m], where n and m are integers representing the indices in the two dimensions. This sequence is also commonly known as a 2D Kronecker delta function.

    The 2D unit impulse sequence can be used as a building block for constructing more complex signals in two dimensions. It is often used in signal processing and image processing applications

    types:

- Unit Impulse $\delta(n_1, n_2) = \begin{cases} 1 & n_1 = n_2 = 0 \\ 0 & \text{otherwise} \end{cases}$

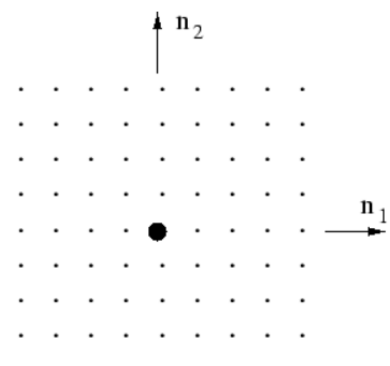


Figure 2: 2-D Unit impulse

2-D unit impulse is separable since $\delta(n_1, n_2) = \delta(n_1)\delta(n_2)$.

- Line Impulses

  Vertical line impulse: $x(n_1, n_2) = \delta(n_1)$ is separable since $x(n_1, n_2) = \delta(n_1) \times 1$

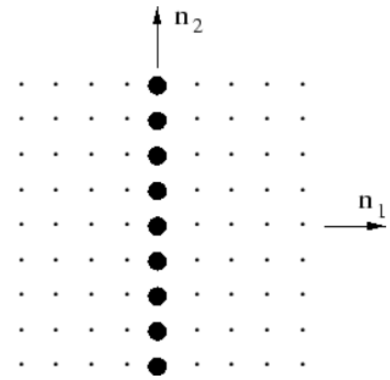


Figure 3: 2-D vertical line impulse

Horizontal line impulse: $x(n_1, n_2) = \delta(n_2)$ is separable since $x(n_1, n_2) = 1 \times \delta(n_2)$

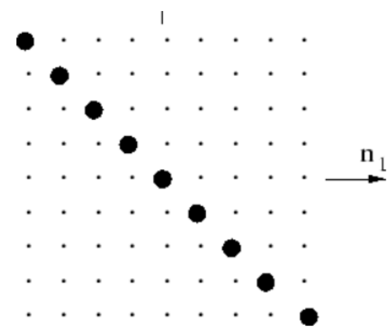


Figure 5: Diagonal line impulse:
$\delta(n_1 + n_2)$

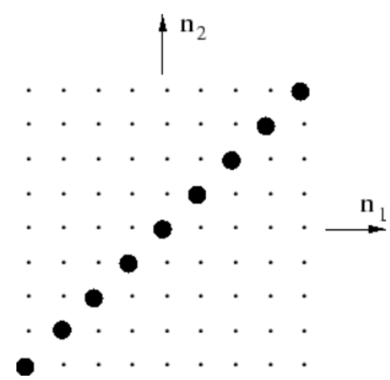


Figure 6: diagonal line impulse:
$\delta(n_1 - n_2)$

A general diagonal line impulse can be written as: $\delta(Pn_1 + Qn_2)$ where P and Q are integers. The slope of the impulses is $-\frac{P}{Q}$.

- Unit step sequence:

$$u(n_1, n_2) = \begin{cases} 1 & n_1 \geq 0 \text{ and } n_2 \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

The unit step function is separable since $u(n_1, n_2) = u(n_1)u(n_2)$.

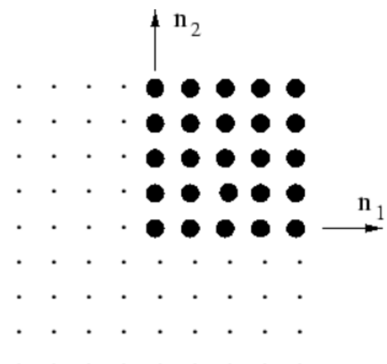


Figure 7: 2-D unit step

12. Write a note on separable and periodic sequence.

Sure, let's discuss separable and periodic sequences in the context of digital image processing:

Separable Sequences:

In the context of digital image processing, a 2D sequence is said to be separable if it can be represented as the outer product of two 1D sequences. Mathematically, if f[n, m] is a separable sequence, it can be expressed as the product of two sequences g[n] and h[m]:

f[n, m] = g[n]. h[m]

This property has significant implications for image processing algorithms because it simplifies the computation. Separable sequences allow for more efficient processing by reducing a 2D convolution operation into two 1D convolutions. This is particularly useful in scenarios where computational efficiency is crucial, such as real-time image processing.

Periodic Sequences:

Periodic sequences in digital image processing refer to sequences that repeat themselves after a certain interval. In the context of 2D images, periodicity may apply horizontally, vertically, or in both directions. A periodic sequence f[n, m] is characterized by:

f[n, m] = f[n + P, m + Q]

where P and Q are the periods in the horizontal and vertical directions, respectively.

Periodic sequences are relevant in image processing when dealing with tiling or repeating patterns. Understanding the periodic nature of certain sequences helps in designing algorithms that can take advantage of these repetitions. Fourier analysis, for example, is a powerful tool in image processing that exploits the periodicity of certain functions to transform them into a combination of sinusoidal functions.

Both separable and periodic sequences are fundamental concepts in digital image processing, and their understanding contributes to the development of efficient algorithms for tasks such as filtering, convolution, and feature extraction in images.

13. Write a note on classification of 2D systems.
14. Find linear convolution of following casual signals. x(n)={1,2,0,1,23,1,1,2,1,0,3} and h(n)={2,2,1}
15. Find the linear convolution of the following casual signal. x(n)={3,4,2,1,2,2,1,1} and h(n)={1,1}.
16. Define convolution and correlation in details?

UNIT-II

1. Apply the following image enhancement techniques for the given 3 bits per pixel image segment.
   Digital Negative
   Thresholding T=5

2	1	2	1	0
7	1	4	3	2
2	4	1	3	7
1	3	4	6	3
1	4	1	3	4

1. Define image enhancement. Explain gray level slicing.
2. Explain the term (a) Thresholding (b) Log Transformation (c) Negative Transformation
3. Explain the following (a) Contrast stretching (b) Grey level slicing.
4. Write a short note on Bit Plane Slicing technique with example.
5. Write a short note on DFT

   Discrete Fourier Transform (DFT):

   The Discrete Fourier Transform (DFT) is a mathematical technique used in signal processing and image analysis to transform a discrete signal or image from its spatial domain representation to its frequency domain representation. It is a fundamental tool for analyzing the frequency content of discrete signals and is widely used in various applications, including image processing, audio signal analysis, and telecommunications.

Key Concepts:

1. **Definition:**
   - The DFT of a sequence x(n) is given by the formula:

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j(2\pi/N)kn}$$

   - Here, X(k) represents the frequency component at index k, and x(n) is the input sequence of length N.

2. **Complex Numbers:**
   - The DFT produces complex numbers, where the real part represents the amplitude, and the imaginary part represents the phase of each frequency component.

3. **Frequency Bins:**
   - The DFT output consists of N frequency components or bins, where each bin corresponds to a specific frequency in the signal. The frequency resolution is determined by the length of the input sequence (N).

4. **Applications:**
   - **Signal Analysis:** DFT is widely used for analyzing the frequency content of signals, enabling the identification of important features and patterns.
   - **Image Processing:** In image analysis, DFT is used for tasks such as image enhancement, compression, and filtering in the frequency domain.
   - **Telecommunications:** DFT plays a crucial role in modulating and demodulating signals in communication systems.

6. State the properties of Discrete Cosine Transform.
7. Explain any two properties of 2D DFT.
8. Explain the terms: (a)Smoothing (b) Sharpening
9. Explain Low pass averaging filter with example?
10. Write a note on image enhancement using spatial filters.
11. What are high boost filters? How are they used? Explain.
12. Explain various image enhancement techniques in frequency domain.

Image enhancement in the frequency domain involves manipulating the frequency components of an image to improve its visual quality or extract specific features. Here are some common techniques:

1. **Fourier Transform:**

   - The first step in frequency domain image processing is to convert the image from spatial domain to frequency domain using Fourier Transform.
   - The Fourier Transform represents the image in terms of its frequency components, decomposing it into sinusoidal waves.

2. **Low-Pass Filtering:**
   - Low-pass filtering is used to enhance the low-frequency components of an image while suppressing the high-frequency details. This is useful for smoothing and noise reduction.
   - Applying a low-pass filter in the frequency domain attenuates high-frequency noise.

3. **High-Pass Filtering:**
   - High-pass filtering emphasizes the high-frequency components of an image, enhancing fine details and edges while suppressing low-frequency components.
   - Useful for sharpening images and extracting fine details.

4. **Bandpass Filtering:**
   - Bandpass filtering allows a specific range of frequencies to pass through while suppressing both low and high frequencies. It is useful for isolating certain features or frequency bands in an image.

5. **Notch Filtering:**
   - Notch filters are used to suppress specific frequencies or remove unwanted periodic noise from an image.
   - They are particularly useful for eliminating interference patterns or periodic artifacts.

6. **Homomorphic Filtering:**
   - Homomorphic filtering is a technique used for enhancing the contrast of an image by separating the illumination and reflectance components.
   - It is effective for images with varying illumination conditions.

7. **Histogram Equalization in Frequency Domain:**
   - While histogram equalization is typically performed in the spatial domain, it can also be applied in the frequency domain for certain applications.

8. **Wiener Filtering:**
   - Wiener filtering is a technique used for image deblurring and noise reduction. It aims to restore the original image from a degraded version by estimating the noise characteristics and enhancing the signal.

9. **Phase Congruency:**

- Phase congruency is a method that focuses on enhancing image features based on the local phase information. It is robust to changes in illumination and contrast.

10. **Radon Transform:**
   - The Radon transform is used for line detection in images. It transforms the image into a set of projections, making it easier to identify linear structures.

These techniques are often used in combination, depending on the specific requirements of the image enhancement task. Choosing the right technique depends on the characteristics of the image and the desired outcome.

13. Explain Fourier Transform and 2D Fourier Series with its equation and frequency response?
14. What are sharpening filters? Give examples. Explain any one in detail.
15. What is histogram of an image? Compare between histogram equalization and histogram matching.
16. Perform Histogram Equalization on Gray level distribution shown in the table. Draw the histograms of the original and equalized images.

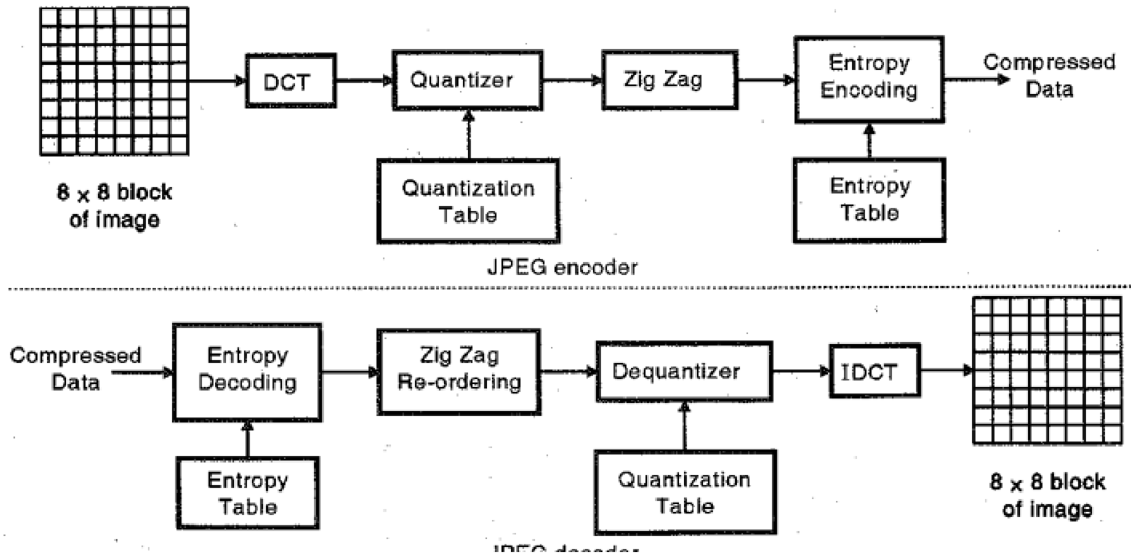
Gray Levels	0	1	2	3	4	5	6	7
No. of Pixels	100	250	100	300	150	0	0	0

17. Perform histogram equalization and plot the histograms before and after equalization.

Gray level	0	1	2	3	4	5	6	7
No:of pixels	128	75	280	416	635	1058	820	684

UNIT-III

1. Draw and explain block diagram of JPEG encoder and decoder.



Encoding :
Block Division:
Divide the image into 8x8 pixel blocks.
Each block represents a unit for processing.

Discrete Cosine Transform (DCT):
Apply DCT to each 8x8 block separately.
Transform spatial domain information to frequency domain.

Quantization:
Quantize the DCT coefficients to reduce the precision of less important information.
This helps in compression.

Entropy Coding (Huffman Coding):
Perform Zigzag scanning to convert the quantized coefficients into a 1D array.
Encode the resulting array using Huffman coding to achieve compression.

Decoding :
Huffman Decoding:
Decode the Huffman-coded bitstream to retrieve the quantized DCT coefficients.

Dequantization:
Reverse the quantization process to restore the precision of DCT coefficients.

Inverse DCT:
Apply the inverse DCT to convert frequency domain information back to the spatial domain.

2. Compare arithmetic coding and Huffman coding.

Arithmetic coding	**Huffman coding.**
• Arithmetic coding is not a statistical method.	• Huffman coding is a statistical method.
• It yields an optimum result	• It does not yields an optimum result
• There is no one to one correspondence between source symbol and code word	• There is one to one correspondence between source symbol and code word
• For eg. If a,b,c are messages then only one unique code to entire message.	• For eg. If a,b,c are messages then separate symbols are assigned.

Arithmetic Coding	Huffman Coding
Does not need the probability distribution	Need a probability distribution
No need to keep and send codeword table	Need to store the codeword table
Decompression speed is slow	Decompression speed is Fast
Compression Speed is low	Compression speed is Fast
Compression ratio is very good	Compression ratio is poor

3. Generate the Huffman code for the word „COMMITTEE‟

4. Explain run length coding with suitable example.

→ RLE

→ It is the simplest dictionary based data compression.

→ Image files frequently contain the same character repeated many times in a row.

→ Each row of such images can have long runs of the same grey value. In, such cases, one can store a code specifying the value of the greylevel, followed by the length of the run.

→ consider the first row of an image which has the following grey value

2 2 2 5 5 5 5 5 5 5 5 6 6 6 6

2 3 5 8 6 4

RLE → 2 3 5 8 6 4

value

RLE eliminat Inter-pixel redundancy.

When there is no Inter pixel redundancy it doubles the size of the file.

5. Compare lossy and lossless image compression.

Lossless Compression:

- Reduces file size without losing any image data.
- Achieves moderate compression ratios.
- Preserves original image quality completely.
- Commonly used in professional photography, medical imaging, and graphic design.
- Suitable for images with critical pixel accuracy, like line drawings or text.
- Fully reversible; original image can be reconstructed exactly.

Lossy Compression:

- Reduces file size by discarding some image data.
- Achieves higher compression ratios, resulting in smaller file sizes.
- Results in a loss of some details and image quality.
- Widely used in web graphics, streaming media, and mobile devices.
- More suitable for natural images, photographs, and detailed images.
- Irreversible; discarded data cannot be perfectly recovered.

6. Write down steps of Shannon-Fano coding.

(2) Shanon fano ~~code~~ encoding.
→ Lossless coding technique

→ Steps
(1) The probability of the symbols are arranged in the descending order.
(2) The probs are partitioned into 2 groups such as the sum of the probs in the 2 groups are nearly equal.
(3) The upper group is given a code 0 and the lower group is given a code 1
(4) Step 2 and 3 are repeated till we have only one prop.

7. Explain Huffman Coding with example?

(1) Huffman encoding → loss-less statistical method finds a variable length code with minimum redundancy.

→ In huffman coding, characters that occur most often, are assigned as few as one or 2 bits while characters whose occurance is rare are assigned more bits.
⇒ It is done by forming a huffman ~~code~~ tree.
Steps for forming huffman tree.
(1) For a given list of characters (symbols), develop a corresponding list of probabilities or frequency count.
(2) Sort the list of characters according to their frequency of occurence i.e place the probabilities in the descending order.
(3) Add the last 2 probabilities (The smallest two).
(4) Taking the new sum from step 3, once again arrange the prob in descending order.
(5) Step 3 and step 4 again and again

1. Explain Dilation and Erosion and explain how opening and closing are related with them.
2. What is Structuring Element? What is the use of it in morphological operation?

the structuring element. One-dimensional and Two-dimensional structuring elements consist of a matrix of 0's and 1's and its size is much smaller than the image. The center pixel of the structuring element is called the origin and it identifies the pixel which is being processed. Depending on the shape present in the input image, we need to define the structuring element. Some common shapes of structuring elements are lines, squares, diamonds, disks, balls etc.

It plays a crucial role in determining how the morphological operations, such as dilation and erosion, are applied to an image.
In dilation, the structuring element is used to expand or thicken the shapes in the image.
In erosion, the structuring element is used to shrink or thin the shapes in the image.
The structuring element acts as a filter that is reflected on the image and shifted across the image during the morphological operation, influencing the outcome at each pixel.

3. What is dilation and erosion of an image? State its applications.

Noise Reduction : Erosion is effective in reducing noise and small disturbances in images
Image Smoothing : It smoothens the inside object contour,break narrow strips and eliminate thin portions of the image.
Shape Matching : match shape of objects in image into predefined templates.pattern matching
Medical Imaging: tasks such as xrays,mri tumour detection n all
Document Image Processing: Dilation and erosion are applied in document image processing to enhance text and remove noise, making it easier to perform optical character recognition (OCR).

4. Explain the morphological image operations on an image.

Dilation is a process in which the binary image is expanded from its original shape. The way the binary image is expanded is determined by the structuring element. This structuring element is smaller in size compared to the image itself, and normally the size used for the structuring element is 3 × 3. The dilation process is similar to the convolution process, that is, the structuring element is reflected and shifted from left to right and from top to bottom, at each shift; the process will look for any overlapping similar pixels between the structuring

Let us define X as the reference image and B as the structuring element. The dilation operation is defined by Eq. (10.7)

$$X \oplus B = \left\{ z \left| \left(\hat{B} \right)_z \cap X \right| \subseteq X \right\} \tag{10.7}$$

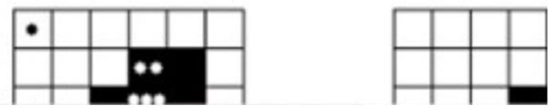
where $\hat{B}$ is the image B rotated about the origin. Equation 10.7 states that when the image X is dilated by the structuring element B, the outcome element z would be that there will be at least one element in B that intersects with an element in X. If this is the case, the position where the structuring element is being centred on

Erosion is the counter-process of dilation. If dilation enlarges an image then erosion shrinks the
The way the image is shrunk is determined by the structuring element. The structuring element is no
smaller than the image with a 3 × 3 size. This will ensure faster computation time when compared to
structuring-element size. Almost similar to the dilation process, the erosion process will move the stru
element from left to right and top to bottom. At the centre position, indicated by the centre of the stru

Let us define X as the reference binary image and B as the structuring element. Erosion is defined
equation

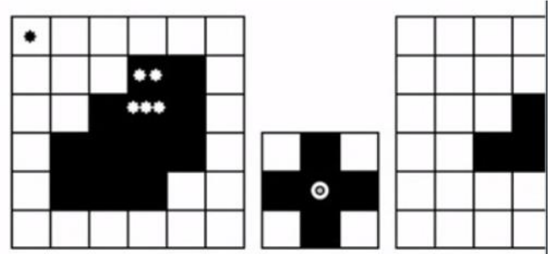
$$X \ominus B = \left\{ z \middle| (B)_z \subseteq X \right\}$$

Equation (10.8) states that the outcome element z is considered only when the structuring element is a subset or equal to the binary image X. This process



Equation (10.8) states that the outcome element z is considered only when the structuring element is a subset or equal to the binary image X. This process is depicted in Fig. 10.15. Again, the white square indicates 0 and the black square indicates 1.

The erosion process starts at position *. Here, there is no complete overlapping, and so the pixel at the position * will remain white. The structuring element is then shifted to the right and the same condition is



10.9.1 Opening

Opening is based on the morphological operations, erosion and dilation. Opening smoothes the insid
object contour, breaks narrow strips and eliminates thin portions of the image. It is done by first ap
erosion and then dilation operations on the image.

The opening operation is used to remove noise and CCD defects in the images. The opening filters and simplifies images by rounding corners from inside the object where the kernel uses fits.
The opening process can be mathematically represented as

$$X \circ B = (X \ominus B) \oplus B$$

where X is an input image and B is a structuring element.

The closing operation is the opposite of the opening operation. It is a dilation operation followed by an erosion operation. The closing operation fills the small holes and gaps in a single-pixel object. It has the same effect of an opening operation, in that it smoothes contours and maintains shapes and sizes of objects.
The closing process can be mathematically represented as

$$X \bullet B = (X \oplus B) \ominus B \tag{10.10}$$

where X is an input image and B is the structuring element. Closing protects coarse structures, closes small gaps and rounds off concave corners.

5. Explain various techniques of image arithmetic.

and plants. In image processing, morphology is about regions and shapes. It is used as a tool for extracting image components that are useful in representing regions and shapes. Unlike the traditional image processing techniques,

There are two different types of operations that are widely used in image processing especially in image morphology.

10.2.1 Arithmetic Operations

Arithmetic operations between two pixels a and b are denoted as follows :

(1) Addition : a + b

Image addition is used in image averaging to reduce noise. This kind of operation was performed in image enhancement.

(2) Subtracting : a – b

Image subtraction is widely used in medical imaging. A very common example is the Digital Subtraction Angiography (DSA).

Image Subtraction is basically used to get rid of background information.

(3) Image multiplication : a × b

(4) Image division : a / b

Both, Image Multiplication and Image Division are used to correct grey level shading that result from non uniformities in illumination or in the sensor used.

Logical operations commonly used are as follows :

(1)	AND	:	a AND b
(2)	OR	:	a OR b
(3)	COMPLEMENT	:	NOT a

The AND operator gives out 1 only when both 'a' and 'b' are equal to 1.

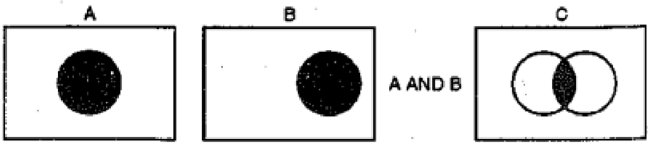


Fig. 10.2.1

The OR operator gives out 1 if either 'a' or 'b' or both are equal to 1.

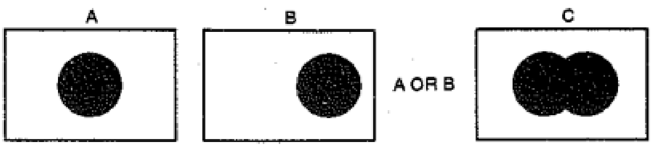


Fig. 10.2.2

The COMPLEMENT (NOT) operator gives out 1 when a = 0

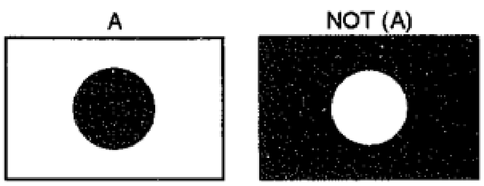


Fig. 10.2.3

6. Given the 7 X 7 Image segment, perform dilation using the structuring element shown.

Structuring element:

1	0
0	1

a.

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

7. What do you mean by Image Segmentation?

Segmentation, as the name suggests, subdivides (segments) an image into its constituent regions or objects. Unlike image enhancement, were our primary concern was to improve the subjective quality of images for display, in segmentation, we address some aspects of analyzing the content of an image. This simply means we endeavour to find out what is in the picture. Segmentation forms a section of computer vision i.e., we use segmentation, when we want the computer to make decisions. Segmentation is used when we need to automate a particular activity. The ultimate aim

Let us take two simple examples where image segmentation is used.

(1) Automated blood cell counting : We all know blood

(2) Finger print matching in forensic studies :

Image segmentation algorithms are generally based on one of the two basic properties i.e. image segmentation can be achieved in any one of the two ways viz.

(1) Segmentation based on discontinuities in intensity.

(2) Segmentation based on similarities in intensity.

8. Explain the classification of image segmentation techniques.

Based on discontinuity in intesity :

Line detection

Point detection

Edge detection

→ Application

1. Automated blood cell counting.
2. Fingerprint matching in forensic studies

→ Methods of segmentation

1. Segmentation based on discontinuities in intensity
2. Segmentation based on similarities in intensity

→ In the first method, the approach is to partition an image based on abrupt changes in intensity such as edges.

→ In the second method, we partition an image into regions that are similar according to a set of predefined criteria.

→ Point detection

→ The easiest to find this discontinuity we need masks which are basically high pass

→ Point detection

→ Points, lines and edges are all high frequency and hence we need high pass mask filter

→ The characteristics of high filter mask is sum of the co-efficients of the mask has to be equal to 0 in all three cases.

→ To detect the points we use the following mask

$$\begin{matrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{matrix}$$

→ $|R| \geq T$

→ where R is derived from the standar convolution.

→ Line detection

$$\begin{matrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{matrix} \qquad \begin{matrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{matrix} \qquad \begin{matrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{matrix} \qquad \begin{matrix} -1 & -1 & 2 \\ -1 & 2 & -1 \\ 2 & -1 & -1 \end{matrix}$$

[−45°] Horizontal

In an image, lines can be in any direction and detecting these lines would need different masks

Based on similarity in intensity :

Region based segmentation

Region splitting is a segmentation technique that involves dividing an image into regions by recursively splitting larger regions into smaller ones until certain criteria are met. The basic idea is to start with the entire image as one region and iteratively divide it into smaller regions based on certain homogeneity or similarity criteria. This method is often paired with a merging step to refine the segmentation.

Region merging is a segmentation technique that involves merging neighboring regions based on certain criteria to create larger, more homogeneous regions. The main idea is to start with an initial over-segmentation of the image, where each pixel or group of pixels forms a separate region, and then iteratively merge adjacent regions that meet specific homogeneity or similarity criteria. Region merging is often employed in combination with region splitting to achieve more accurate and meaningful segmentation results.

Region Growing: Starts with seed points and grows regions by adding adjacent pixels that satisfy certain criteria (e.g., intensity similarity).

Region Merging: Begins with the whole image as a single region and iteratively merges adjacent regions based on predefined criteria.

Threshold segmentation

Thresholding-Based Techniques:

Global Thresholding: Involves selecting a single intensity threshold to separate objects from the background based on pixel intensity values.

Local Thresholding: Adapts the threshold for each pixel based on its local neighborhood.

9. Explain clustering technique used for image segmentation.

Clustering techniques are commonly used for image segmentation to group similar pixels or regions based on certain features, such as color, intensity, or texture. The goal is to partition an image into distinct segments that share similar characteristics. Here are some clustering techniques used for image segmentation:

K-Means Clustering :

Pixels in the image are treated as data points in a feature space

assigns each pixel to the cluster whose centroid is nearest and updates the centroids based on the assigned pixels

Results in K clusters

Fuzzy C-Means (FCM) Clustering

Similar to K-means but extends it to allow data points to belong to multiple clusters

The pixels have varying degrees of membership

Mean Shift Clustering

A non-parametric technique that does not require specifying the number of clusters (K) in advance.
Well-suited for segmenting regions with varying shapes and sizes

DBSCAN (Density-Based Spatial Clustering of Applications with Noise)
Well-suited for segmenting regions with irregular shapes and handling noise

Hierarchical Clustering:
Thresholding the hierarchy tree at different levels provides different segmentations, allowing for multi-scale analysis

10. How is thresholding used in image segmentation?

    Thresholding is a simple yet effective technique used in image segmentation to separate objects or regions of interest from the background based on pixel intensity values.

    two fundamental groups :

    those with intensities above the threshold (foreground)

    those below or equal to the threshold (background)

    working of thresholding in image segmentation

    - Separate objects or regions of interest from the background in an image.
    - Choose a threshold value based on characteristics of the image or using automated methods like Otsu's method.
    - Classify pixels into two groups: above threshold (foreground) and below or equal to threshold (background).
    - Obtain a binary image where objects of interest are highlighted against a background.

11. Explain various edges detected in segmentation process.

    An edge can be defined as a set of connected pixels that form a boundary between two disjoint regions.

    A typical example of an edge is shown in Fig. 7.2.2.

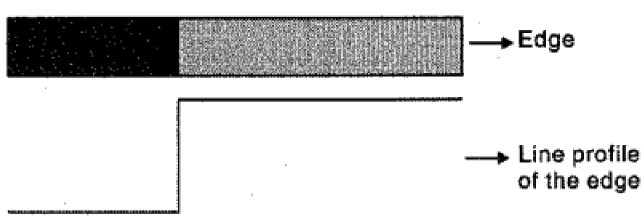


Fig. 7.2.2

Here the set of pixels that separate the black region from the grey region is called an *edge*. The line profile of such an edge is shown along with edge.

The image shown has a step edge. Such step edges

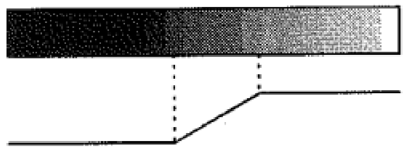


Fig. 7.2.4

Here the slope of the ramp is inversely proportional to the degree of blurring.

Given below are some of the two dimensional, discrete domain edge models.

a	a	a	a	a	b	b	b	b	b
a	a	a	a	a	b	b	b	b	b
a	a	a	a	a	b	b	b	b	b
a	a	a	a	a	b	b	b	b	b
a	a	a	a	a	b	b	b	b	b

Vertical step edge

a	a	a	b	b	b	b	b	b	b
a	a	a	a	b	b	b	b	b	b
a	a	a	a	a	b	b	b	b	b
a	a	a	a	a	a	b	b	b	b
a	a	a	a	a	a	a	b	b	b

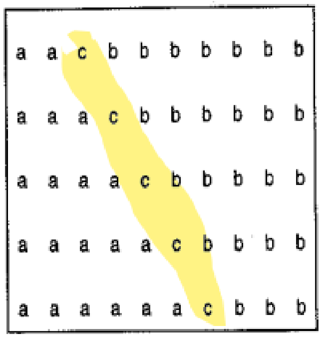
Diagonal step edge

a	a	a	a	a	a	a	a	a	a
a	a	a	a	a	a	a	a	a	a
a	a	a	a	a	b	b	b	b	b
a	a	a	a	a	b	b	b	b	b
a	a	a	a	a	b	b	b	b	b

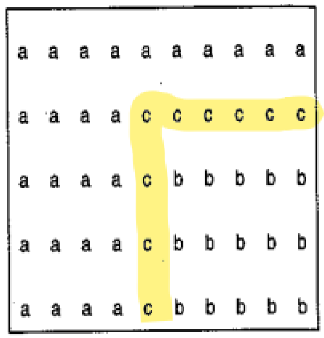
Corner step edge

a	a	a	a	c	b	b	b	b	b
a	a	a	a	c	b	b	b	b	b
a	a	a	a	c	b	b	b	b	b
a	a	a	a	c	b	b	b	b	b
a	a	a	a	c	b	b	b	b	b

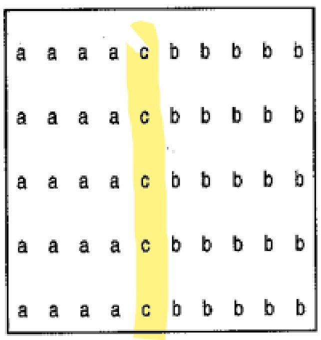
Vertical ramp edge



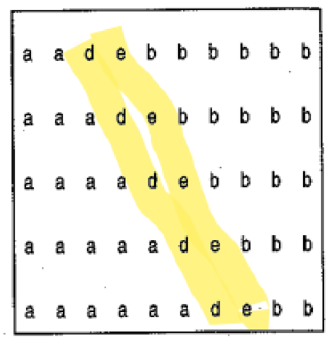
Diagonal ramp edge
Single pixel transition



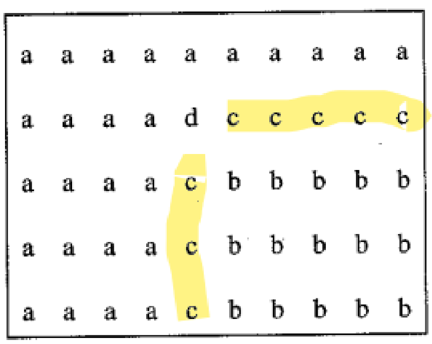
Corner ramp edge



Vertical ramp edge



Diagonal ramp edge
Smoothed transition



Corner ramp edge

12. What is block processing? Explain in detail.
13. Define segmentation. State different methods based on similarity. Explain any one method with example.

    Segmentation definition

    Region based segmentation

    Region growing

    Region merging

    Region splitting

    Region split and merge

    ➔ Region growing :

1. Start with seed points and iteratively grow regions by adding adjacent pixels that satisfy certain homogeneity criteria.
2. Pixels are added to the region if they are similar to the seed pixel in terms of intensity, color, or other feature values
3. Capable of handling irregular-shaped regions.

   Example of region growing

unique label. Now a new seed pixel is chosen and the same procedure is repeated. We continue doing this until all the pixels are assigned to some region or the other.

Let us take an example.

Ex. 7.10.1

Consider an 8×8 image, the grey levels range from 0 to 7. Segment this image using the region growing technique.

Soln. :

Before starting the region growing process, we need to define two things

5	6	6	6	7	7	6	6
6	7	6	7	5	5	4	7
6	6	4	4	3	2	5	6
5	4	5	4	2	3	4	6
0	3	2	3	3	2	4	7
0	0	0	0	2	2	5	6
1	1	0	1	0	3	4	4
1	0	1	0	2	3	5	4

(1) What is the predicate ?

(2) Which do we take as the seed pixel ?

Both these conditions are fed in by the user. Let the predicate be

$$\max\{g(x, y)\} - \min\{g(x, y)\} < th$$

where th is the threshold.

In this case let the threshold be ≤ 3.

$$\therefore P(R_i) = \max_{(x,\, y \in R)}\{g(x, y)\} - \min_{(x,\, y \in R)}\{g(x, y)\} \leq 3$$

We assume 4-connectivity. Let us start with the seed pixel 6 (encircled).

We use the above equation to get the image shown →

5	6	6	6	7	7	6	6
6	7	6	7	5	5	4	7
6	6	4	4	3	2	5	6
5	4	5	4	2	3	4	6
0	3	2	3	3	2	4	7
0	0	0	0	2	2	5	6
1	1	0	1	0	3	4	4
1	0	1	0	2	3	5	4

The shaded portion gets labelled as a (say). Is segmentation complete ? The answer is NO. For segmentation, to be complete, all the pixels have to be assigned to some region. We now select 0 (encircled) as the seed pixel and label the new area as b.

We hence have →

a	a	a	a	a	a	a	a
a	a	a	a	a	a	a	a
a	a	a	a	b	b	a	a
a	a	a	a	b	b	a	a
b	b	b	b	b	b	a	a
b	b	b	b	b	b	a	a
b	b	b	b	b	b	a	a

We arrived at the above segmented image by using 6 and 0 as the seed pixels.

Note : In each of the two regions, the predicate $\max\{g(x,y)\} - \min\{g(x,y)\} \leq 3$ in satisfied. The problem in this case is that if we change the seed pixel, the segmented image would look completely different.

Let us take the seed pixel as 3. Let the predicate be the same i.e, th ≤ 3

Thus this image is segmented into 3 different regions by using a different seed point.

In this method, at a time only one pixel is assigned as a member of the current region because of which it is very

14. Explain the method of edge linking using Hough transform.
15. Write a short note on region splitting and merging.

Split and merge is an image segmentation technique that combines region splitting and merging to achieve a more refined segmentation of an image. This approach aims to balance the trade-off between over-segmentation and under-segmentation by iteratively splitting and merging regions based on certain homogeneity criteria

(a) Split any region into four quadrants if the uniformity predicate is not true or not satisfied.

(b) Continue this subdivision for all new sub-images until the stopping criteria is reached (usually single pixels)

(c) Merge any adjacent regions for which the uniformity condition is true.

(d) Stop when no further merging is possible.

Example :

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

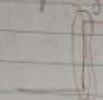
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	1	1	1	1
0	0	0	0	1	1	1	1
0	0	0	1	1	1	1	1
0	0	1	1	1	1	1	1
0	0	1	1	1	1	0	0
0	0	1	1	1	0	0	0

16. Explain edge detection.

→ Edge detection

→ An edge can be defined as a set of conn. pixels that form a boundary between two disjoint regions.

Line profile of the edge



→ Here the set of pixels that seperate the black region from the grey region is called an edge.

→ The image show is a step edge

→ To deetect an edge we use derivative approach.

• In this method we use ~~for~~ first order derivative for 1D function and 2nd order derivative for 2D.

Case 1 : Output is a function of one variable (**Example :** 1-dimensional signal) $y = f(x)$.

We know that the derivative of y w.r.t. x is

$$\frac{dy}{dx} = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h} = f'(x)$$

The slope is $\frac{dy}{dx}$

Case 2 : Output is a function of two variables (2-dimensional example), $f(x, y)$. In the two variable case, x and y are the variables. Both these variables change to say $x + h$ and $y + k$. To find the gradient, we work with each separately i.e., we take partial derivatives.

Let us first keep y fixed and alter only x.

$$\frac{\partial f}{\partial x} = \lim_{h \to 0} \frac{f(x+h, y) - f(x, y)}{h}$$

Similarly, keeping x fixed and changing y, we get

$$\frac{\partial f}{\partial y} = \lim_{k \to 0} \frac{f(x, y + k) - f(x, y)}{k}$$

$\frac{\partial f}{\partial y}$ is the rate of change of f w.r.t. y keeping x constant.

Hence the final gradient is

$$\nabla F = \hat{i}\frac{\partial f}{\partial x} + \hat{j}\frac{\partial f}{\partial y} \qquad ...(7.3.1)$$