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End Semester Examination

November 2019

Max. Marks: 60 | Duration: 3Hrs
Class: B.E. | SEMESTER : 7
Course Code: IT 71 | Branch: IT
Name of the Course: Digital Image Processing

Q. 1 a) What do you understand about dynamic range and contrast? (3)

Definition of dynamic range - The dynamic range is the range of values spanned by the grey scale. ..1 mark
Definition of contrast - ..1 mark
Understanding - Image will have high contrast if dynamic range is high and it will be dull washed or greyed out if dynamic range is low. ..1 mark

Q. 1. b) We can not differentiate the change in intensity when the intensity is too high or too low. Justify. (3)

Diagram of webber ratio v/s intensity. ..1 mark
What is webber ratio. ..1 mark
Understanding - When intensity is too low or high webber ratio is high. ..1 mark

Q. 1. c) Define gradient filter. Write its equation. (3)

Gradient filter is forst order derivative. ..1 mark
Gradient of image f(x,y) at (x,y) is defined as the vector with
magnitude delta f = sqrt($G^2_x + G^2_y$) ..1 mark
And angle = $\tan^{-1} (G_y/G_x)$ ..1 mark

Q. 1. d) If all the pixels of an image are shuffled, will there be any change in histogram? Justify your answer. (3)

Any image drawn and histogram drawn - ..1 mark
Other image with shuffled pixels, and its histogram drawn - ..1 mark
Understanding – If all the pixels in an image are shuffled, there will not be any change in the histogram. ..1 mark

Q. 2. a) Explain with diagram fundamental steps in image processing. (6)

Diagram - ..2 marks
Names of all the steps - ..2 marks
Explaination - .. ..2 marks

Fundamental steps in Digital Image Processing :

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.

2. Image Enhancement - Image enhancement is among the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interest in an image, such as changing brightness & contrast etc.

3. Image Restoration - Image restoration is an area that also deals with improving the appearance of an image. However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation.

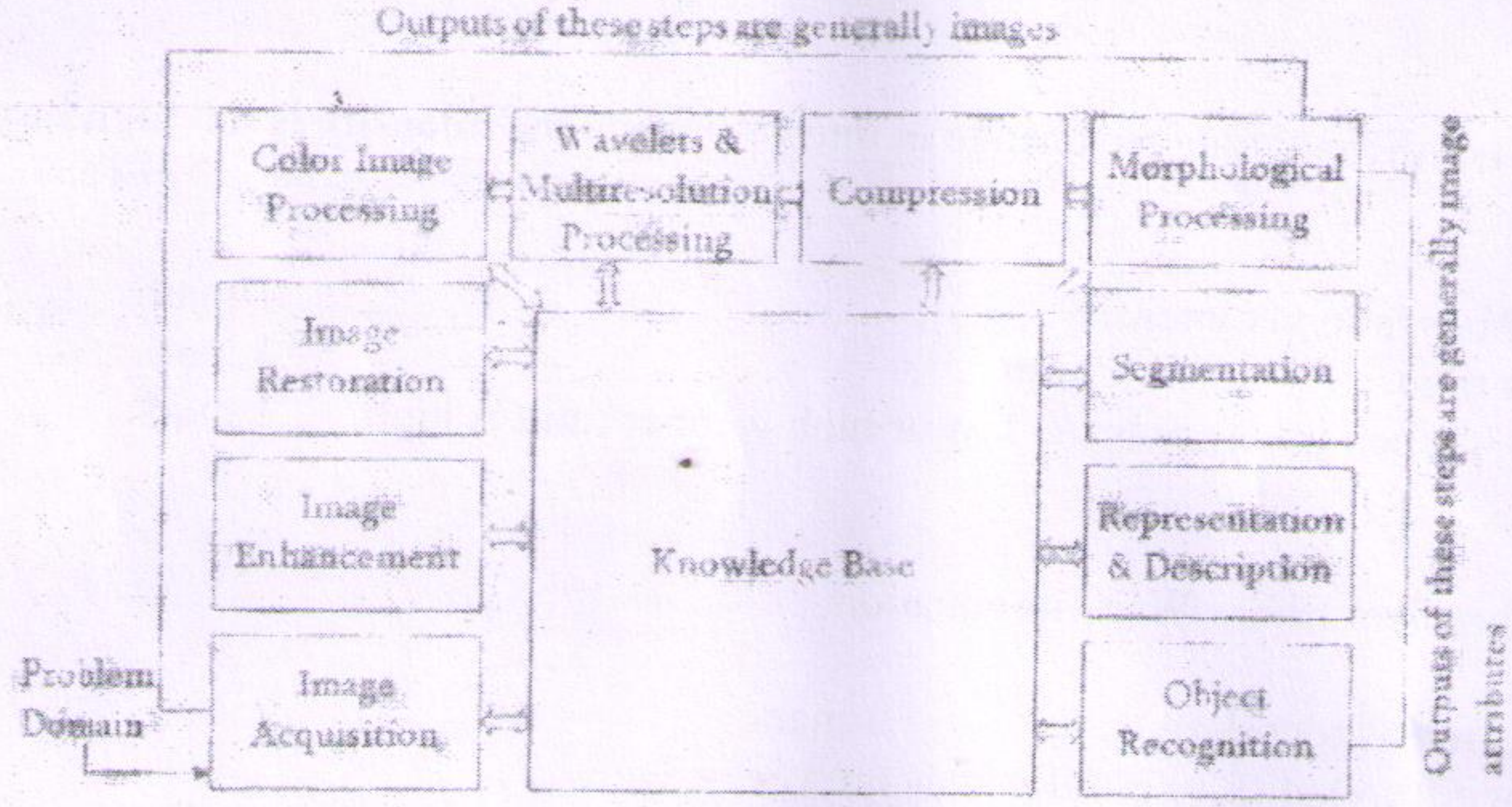


Figure 1

4. Color Image Processing - Color image processing is an area that has been gaining its importance because of the significant increase in the use of digital images over the Internet. This may include color modelling and processing in a digital domain etc.

5. Wavelets and Multi resolution Processing - Wavelets are the foundation for representing images in various degrees of resolution. Images subdivision successively into smaller regions is for data compression and for pyramidal representation.

6. Compression - Compression deals with techniques for reducing the storage required to save an image or the bandwidth to transmit it. Particularly in the uses of internet it is very much necessary to compress data.

7. Morphological Processing - Morphological processing deals with tools for extracting image components that are useful in the representation and description of shape.

8. Segmentation - Segmentation procedures partition an image into its constituent parts or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing.

9. Representation and Description - Representation and description almost always follow the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of a region or all the points in the region itself. Choosing a representation is only part of the solution for transforming raw data into a form suitable for subsequent computer processing. Description deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another.

10. Object recognition - Recognition is the process that assigns a label, such as, "vehicle" to an object based on its descriptors.

11. Knowledge Base - Knowledge may be as simple as detailing regions of an image where the information of interest is known to be located, thus limiting the search that has to be conducted in seeking that information. The knowledge base also can be quite complex, such as an interrelated list of all major possible defects in a materials inspection problem or an image database containing high-resolution satellite images of a region in connection with change-detection applications.

Q. 2. a) Explain briefly neighbours, paths and connectivity with example. (6)

Relationship -	..1 mark
Adjacency and connectivity -	..2 marks
Any Example of each connectivity -	..1 mark each

Relationships between pixels

i) N4, 4-neighbors (also called edge neighbors)
ii) ND, D-neighbors (also called diagonal, or point-neighbors)
iii) N8, 8-neighbors (Together, 4- and D-neighbors)

Adjacency and connectivity

In a binary image, two pixels p and q are 4-adjacent if they have the same value and q is in the set N4(p).
8-adjacent if they have the same value and q is in the set N8(p).
m-adjacent if they have the same value and q is in the set N4(p) OR q is in the set ND(p) AND the set $N4(p) \cap N4(q)$ is empty.
Two pixels (or objects) are 8-, 4-, or m-connected if a 8-, 4-, or m-path can be drawn between them.

Example : Example of each type of connectivity is to be given by the student.

Q. 2. b) Explain various image enhancement techniques in spatial domain. (6)

Three techniques given below – 2 marks each

a) Enhancement by Zero Memory Point Operations

- In zero memory operation, output image pixel value is obtained directly processing the input image pixel value. For every input image pixel value, transformation function gives corresponding output image pixel value and no memory location is required to store intermediate results.
- The various Zero Memory Point operations are:

1. Contrast Stretching Transformation
2. Digital Negative Transformation
3. Logarithmic Transformation
4. Power Law Transformation
5. Intensity Level Slicing Transformation and
6. Bit Level Slicing Transformation.

b) Enhancement by Histogram Processing

Histogram processing involves the modification of input image histogram so as to improve the visual quality of image on display device.

There are three approaches of histogram processing as follow: - Histogram Equalization: It is a process that attempts to spread out the gray levels in an image so that they are evenly distributed over the entire range. The histogram of the output image is almost uniform over the entire range of gray levels. It provides only one type of output. - Histogram Specification: It is a process that attempts to spread out the gray levels in an image as per the specified image histogram. Modifies histogram of the input image closely matches with the histogram of the specified image. - Histogram Stretching: It is a process that attempts to spread out the gray levels in an image linearly as per the required range of output image histogram.

c) Enhancement by Neighborhood Processing: Spatial Filtering

Special filtering involves passing a weighted mask or kernel over the image and replacing the original image pixel value corresponding to the centre of the kernel with the sum of the original pixel values in the region corresponding to the kernel multiplies by the kernel weight.

- Smoothing Linear Filters: Examples of linear filters are Low Pass Averaging Filter, Weighted Average Filter and Trimmed Average Filter.
- Smoothing Non-Linear Filter: Non-linear filters are also called as Ordered Statistic Filters. Examples are Median, Max and Min Filter.
- Sharpening First Order Derivative Filters: Examples are Robert, Prewit, Sobel and Fri-Chen Filter.
- Sharpening Second Order Derivative Filters: Examples are Palladian Filter. High Pass Filter and High Boost Filter.

Q. 3. a) Find 2D DFT of given image using DIF FFT algorithm. (6)

Handwritten Answer

Q. 3. b) Compute the Hadamard transform of the given image. Also generate and compute Walsh transform. (6)

$$F(x,y) = \begin{matrix} 2 & 1 & 1 & 1 \\ 1 & 2 & 3 & 2 \\ 2 & 3 & 4 & 3 \\ 1 & 2 & 3 & 2 \end{matrix}$$

Hadamard matrix ..1 mark
Computation of Hadamard ..1 mark
Walsh matrix ..1 mark
Computation of Walsh ..1 mark
Generation of basis image for Walsh ..2 marks

The given image is 4 x 4.

Transformed image is F = [H(4) . f . H(4)]

$$F = \begin{vmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{vmatrix} \times \begin{vmatrix} 2 & 1 & 2 & 1 \\ 1 & 2 & 3 & 2 \\ 2 & 3 & 4 & 2 \\ 1 & 2 & 3 & 2 \end{vmatrix} \times \begin{vmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{vmatrix}$$

$$F = \begin{vmatrix} 6 & 8 & 12 & 8 \\ 2 & 0 & 0 & 0 \\ 0 & -2 & -2 & -2 \\ 0 & -2 & -2 & -2 \end{vmatrix} \times \begin{vmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{vmatrix}$$

$$F = \begin{matrix} 34 & 0 & -6 & -6 \\ 2 & 2 & 2 & 2 \\ -6 & 2 & 2 & 2 \\ -6 & 2 & 2 & 2 \end{matrix}$$

Walsh Transform - Transformed image is F = T.f.T'

F = [W(4) . f . W(4)']
W(4) is symmetric.

$$F = \begin{vmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{vmatrix} \times \begin{vmatrix} 2 & 1 & 2 & 1 \\ 1 & 2 & 3 & 2 \\ 2 & 3 & 4 & 2 \\ 1 & 2 & 3 & 2 \end{vmatrix} \times \begin{vmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & 1 & -1 & -1 \end{vmatrix}$$

F=

34	-6	-6	2
-6	2	2	2
-6	2	2	2
2	2	2	2

Q. 4. A) Compute the entropy of the image f(m,n). (3)

***Step 1** Probability of occurance of the gray level*

Probability of occurence of gray level 0 is $p(0) = \frac{5}{16}$

Probability of occurence of gray level 1 is $p(1) = \frac{4}{16}$

Probability of occurence of gray level 2 is $p(2) = \frac{5}{16}$

Probability of occurence of gray level 3 is $p(3) = \frac{2}{16}$

***Step 2** Computation of Entropy*

The formula to compute entropy is given by $H = -\sum_{k=0}^{3} p_k \log_2^{p_k}$ bits/pixel

$$H = -\left(\frac{5}{16}\log_2\left[\frac{5}{16}\right] + \frac{1}{4}\log_2\left[\frac{1}{4}\right] + \frac{5}{16}\log_2\left[\frac{5}{16}\right] + \frac{2}{16}\log_2\left[\frac{2}{16}\right]\right) \text{ bits/symbol}$$

$H = 1.924$ bits/symbol

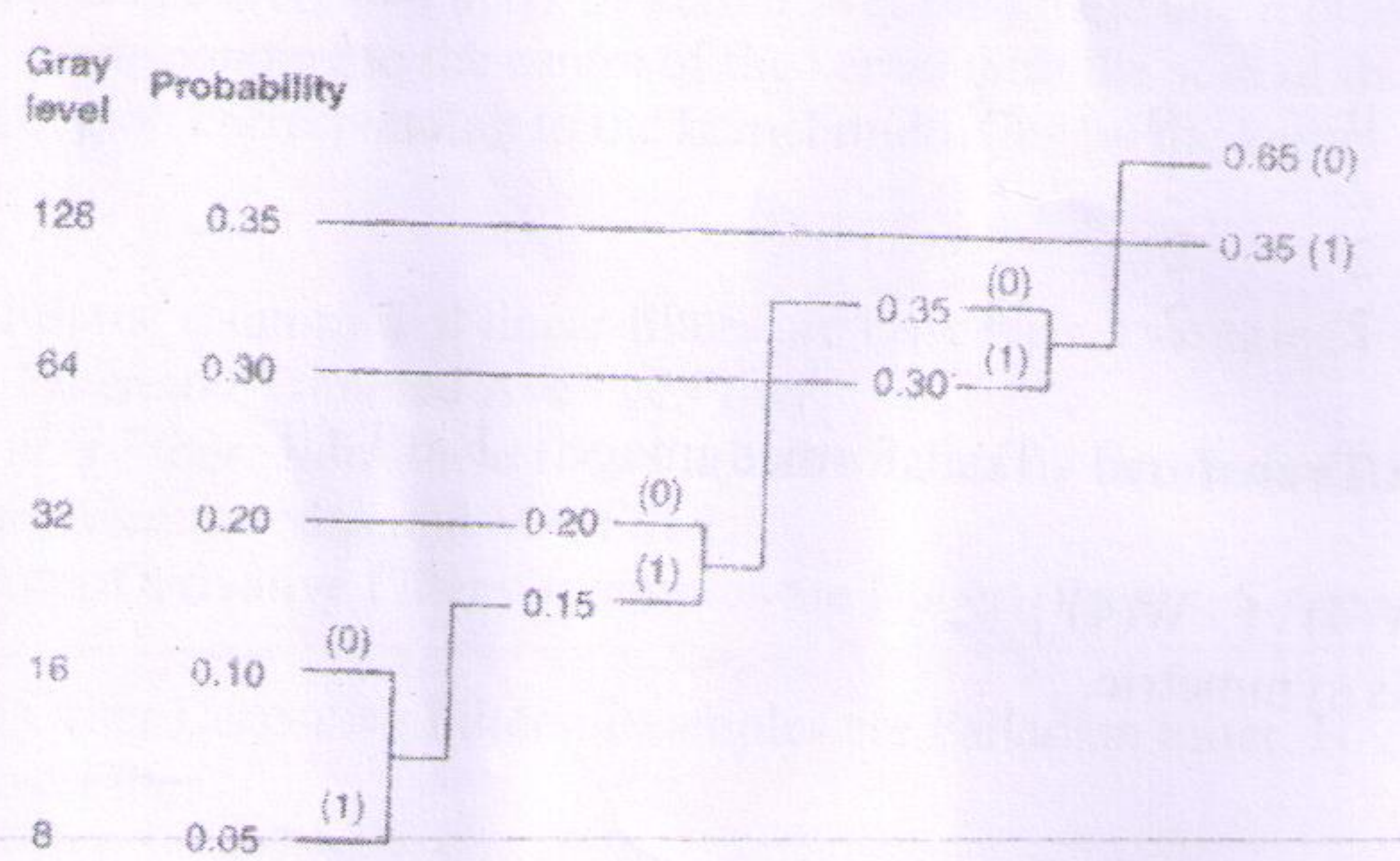
Q. 4. b) For the given data of grey level and count in an image, determine the efficiency if the image is coded using huffman coding. (3)

The entropy of the Huffman code is given by

$$H(s) = -\sum_{k=0}^{N-1} P_k \log_2 P_k$$

$$H(s) = -(0.35\times(-1.52) + 0.3\times(-1.74) + 0.2\times(-2.32) + 0.1\times(-3.32) + 0.05\times(-4.32))$$

$H(s) = 2.06$ bits/symbol



The average length is given by

$$\bar{L} = \sum_{k=0}^{N-1} P_k l_k$$

Huffman code

Gray level	Code
128	1
64	01
32	000
16	0010
8	0011

$$\bar{L} = 0.35\times 1 + 0.30\times 2 + 0.20\times 3 + 0.10\times 4 + 0.05\times 4$$
$$= 2.15 \text{ bits/symbol.}$$

The efficiency of the of the Huffman code is given by

$$\eta = \frac{H(S)}{\bar{L}} = \frac{2.06}{2.15} = 95.81\%$$

Q. 4. c) Compare DPCM-based image compression technique against the transform based image compression technique. (3)

(i) DPCM is simpler than transform-based technique. This is because the linear prediction and differencing operation involved in differential coding are simpler than the 2D transforms involved in transform-based image compression.

(ii) In terms of memory requirement, processing delay DPCM is superior to the transform-based technique. DPCM needs less memory and less processing delay than transform-based compression.

(iii) The design of the DPCM system is sensitive to image-to-image variations, whereas transform-based coding is less sensitive to image statistics.

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(iii) The design of the DPCM system is sensitive to image-to-image variations, whereas transform-based coding is less sensitive to image statistics.

Q. 4. d) What is fundamental principle of fractal image compression. (3)

Fractal image compression exploits similarities within images. The image is divided into range block and domain block. The smaller partition is called range, and the larger ones are called domains. The domain blocks are transformed to match a given range block as closely as possible.

In fractal image compression, the image is represented by means of a 'fractal' rather than by pixel. Each fractal is the fixed point of an iterated function system. That is, the image is represented by an iterated function system (IFS) of which the fixed point is close to that image. This fixed point is called fractal. Each IFS is then coded as a contractive transformation with coefficients. The coefficients of the transformations are saved as the compressed file.

Q. 4 d) What are different types of redundancies exploited in image compression. (3)

Redundancy types - .. 1 mark each

Types of Redundancies :

1) Coding Redundancy
2) Interpixel Redundancy
3) Psychovisual Redundancy

1. Coding Redundancy :
We developed this technique for image enhancement by histogram processing on the assumption that the grey levels of an image are random quantities. Here the grey level histogram of the image also can provide a great deal of insight in the construction of codes to reduce the amount of data used to represent it.

2. Interpixel Redundancy :
Inorder to reduce the interpixel redundancy in an image, the 2-D pixel array normally used for human viewing and interpretation must be transformed in to more efficient form.

3. Psychovisual Redundancy:
Certain information simply has less relative importance than other information in the normal visual processing. This information is called Psycovisual Redundant.

Q. 5. a) Compare the characteristics of first and second order derivative filters. (3)

Q. 5. b) Explain morphological image processing. (3)

Erosion – Formula and example - .. 1 mark
Dilation – Formula and example - .. 1 mark
Opening/Closing Formula and example - ..1 mark

With A and B as two sets in Z2 (2D integer space), the dilation of A and B is defined as

A(+)B={Z|(B^)Z∩A ≠ ϕ}

In the above example, A is the image while B is called a structuring element.

In the equation,(B^)Z simply means taking the reflections of B about its origin and shifting it by Z. Hence dilation of A with

B is a set of all displacements, Z, such that (B^)Z and A overlap by atleast one element. Flipping of B about the origin and then moving it past image A is analogous to the convolution process. In practice flipping of B is not done always.

Dilation adds pixels to the boundaries of object in an image. The number of pixels added depends on the size and shape of the structuring element. Based on this definition, dilation can be defined as

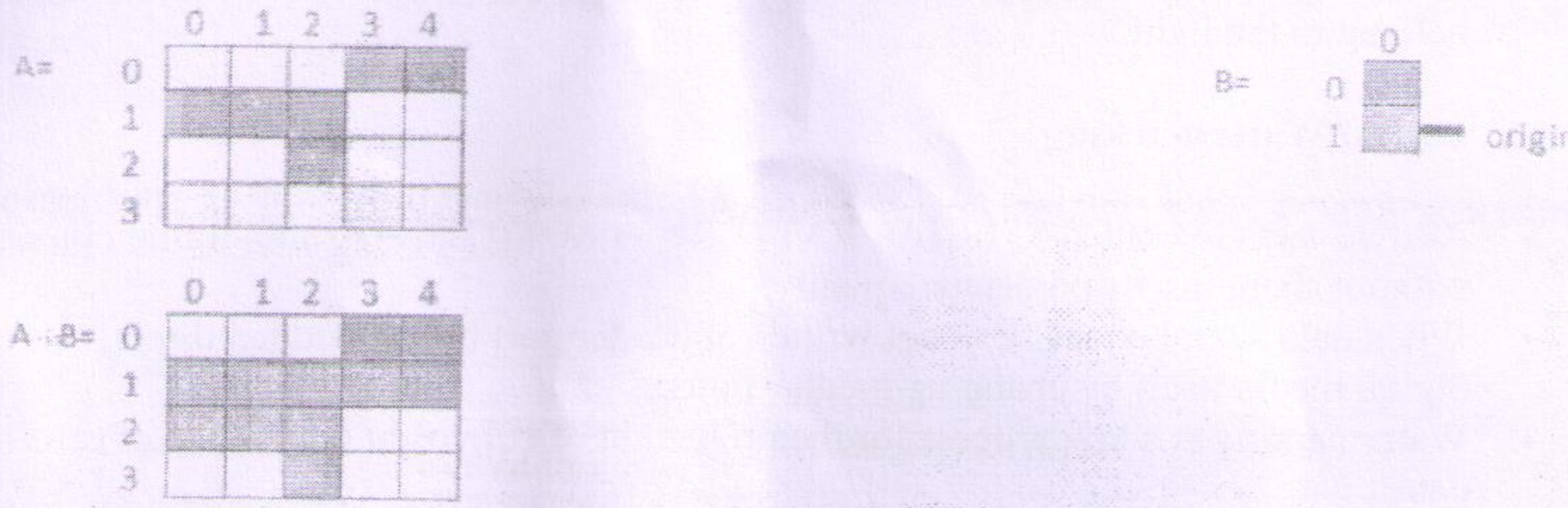
A(+)B={{Z|(B^)Z∩A} ϵ A}

Example:

A={(1,0),(1,1),(1,2),(2,2),(0,3),(0,4)}

B={(0,0),(1,0)}

Then, A B={(1,0),(1,1),(1,2),(2,2),(0,3),(0,4),(2,0),(2,1),(2,2),(3,2),(1,3),(1,4)}



For Image A and structuring element B as in Z2 (2D integer space), Erosion is defined as

$A \ominus B=\{Z|(B)_Z \in A\}$

This equation indicates that erosion of A by B is the set of all points Z such that B, translated (Shifted by Z), is a subset of A i.e., B is entirely contained within A . Erosion reduces the number of pixels from the object boundary. The number of pixels removed depends on the size of the structuring element.

Example:

A={(1,0),(1,1),(1,2),(0,3),(1,3),(2,3),(3,3),(1,4)}

B={(0,0),(1,0)}

Then, A B={(0,3),(1,3),(2,3)}

Q. 5. c) Write short note of Digital Watermarking.

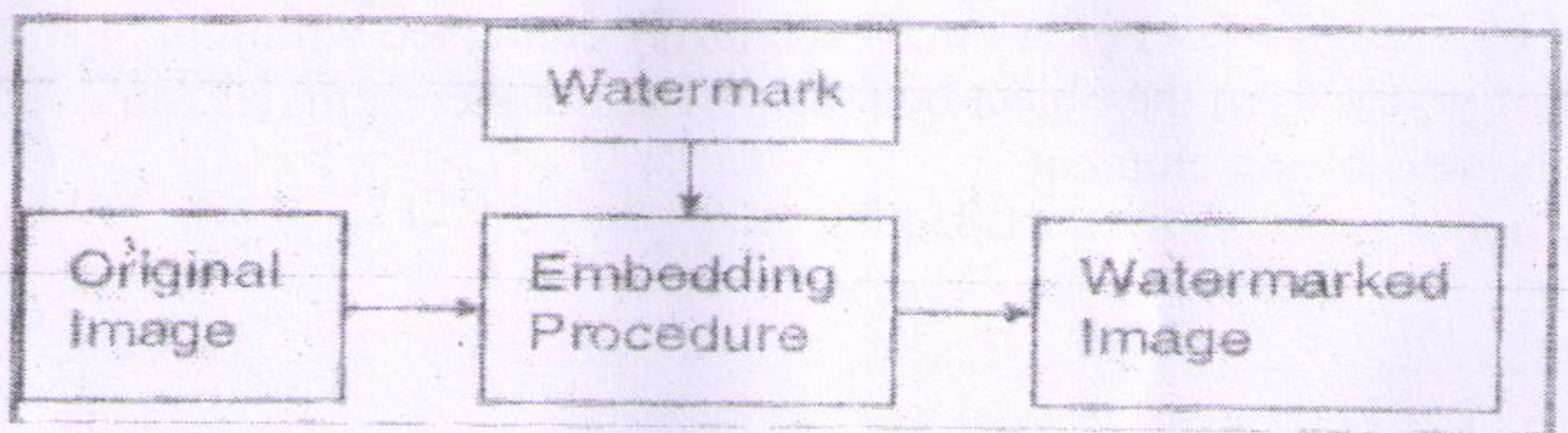
About watermark -	..2 marks
Life cycle phases -	.. 2 marks
Types of watermarks -	..2 marks

- A watermark is a form, image or text that is impressed onto paper, which provides evidence of its authenticity.
- A distinguishing mark impressed on paper during manufacture; visible when paper is held up to the light

Digital Watermarking

- Allows users to embed SPECIAL PATTERN or SOME DATA into digital contents without changing its perceptual quality.
- When data is embedded, it is not written at header part but embedded directly into digital media itself by changing media contents data
- Watermarking is a key process for the protection of copyright ownership of electronic data.
- Digital watermarking is the process of embedding information into a digital signal in a way that is difficult to remove.
- The signal may be audio, pictures or video, for example. If the signal is copied, then the information is also carried in the copy. A signal may carry several different watermarks at the same time.

General Procedure for Digital Watermarking:



Cryptography v/s Watermarking

- cryptography is the most common method of protecting digital content and is one of the best developed science.
- However, encryption cannot help the seller monitor how a legitimate customer handles the content after decryption.
- Digital watermarking can protect content even after it is decrypted.

Visible Watermarking - Visible watermark is a translucent overlaid into an image and is visible to the viewer. Visible watermarking is used to indicate ownership and for copyright protection.

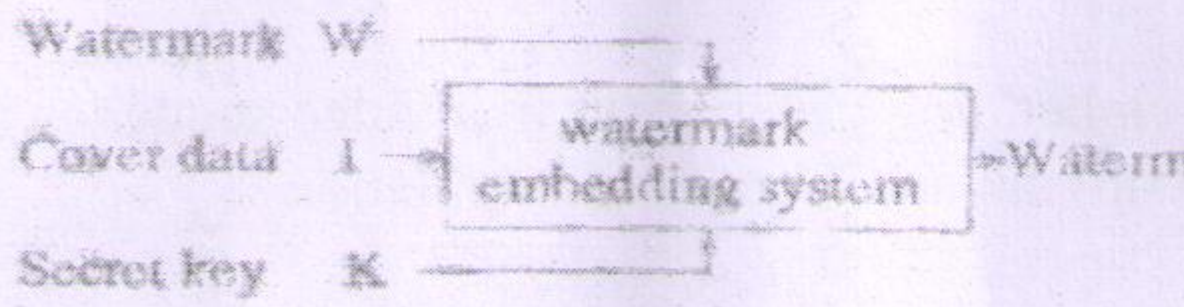
Invisible Watermarking - Invisible watermark is embedded into the data in such a way that the changes made to the pixel values are perceptually not noticed. Invisible watermark is used as evidence of ownership and to detect misappropriated images.

Dual watermarking - Dual watermark is the combination of visible and invisible watermark. An invisible watermark is used as a backup for the visible watermark.

Digital watermarking life cycle phases

A Watermarking system is usually divided into three distinct steps.
- Embedding
- Attack
- Detection

Embedding -In embedding, an algorithm accepts the host and the data to be embedded, and produces a watermarked signal.



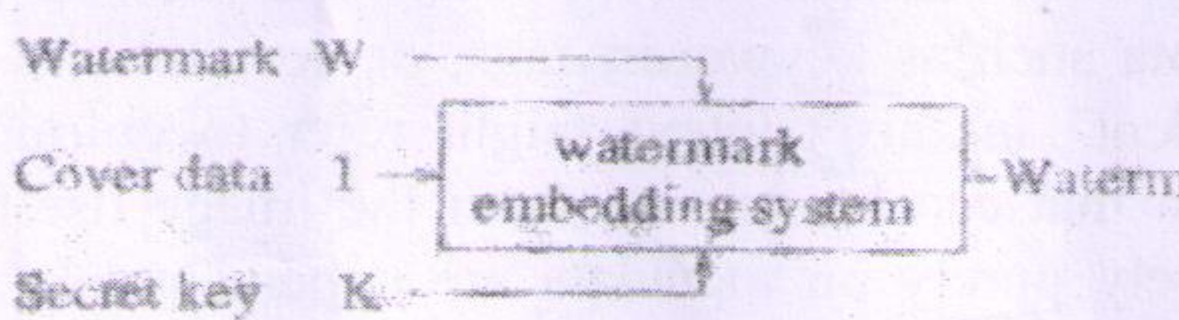
- Inputs to the scheme are the watermark, the cover data and an optional public or secret key. The output are watermarked data. The key is used to enforce security.

Attacks - The watermarked digital signal is transmitted or stored, usually transmitted to another person. If this person makes a modification, this is called an attack. **Few possible attacks:**

1. **Robustness attacks:** Which are intended to remove the watermark such as JPEG compression, cropping, etc.
2. **Presentation attacks:** Under watermark detection failure they come into play. Geometric transformation, rotation, scaling, translation, change aspect ratio, affine transformation etc.
3. **Counterfeiting attacks:** Rendering the original image, generate fake original.

Extraction/Detection

- Detection (often called extraction) is an algorithm which is applied to the attacked signal to attempt to extract the watermark from it.. if the signal was unmodified during transmission, then the watermark still is present and it may be extracted.



- Inputs to the scheme are the watermarked data, the secret or public key and depending on the method, the original data and/or the original watermark. The output is the recovered watermarked W or some kind of confidence measure indication how likely it is for the given watermark at the input to be present in the data under inspection.

Fragile/Semi fragile/Robust

- A watermark is called fragile if it fails to be detected after the slightest modification.

- A watermark is called semi-fragile if it resists beginning transformations but fails detection after malignant transformations.
- A watermark is called robust if it resists a designated class of transformations.

Text/Image/Audio watermarking - Text/Image/Audio watermarking refers to embedding watermarks in an text/image/audio in order to protect the image from illegal copying and identify manipulation.

Video watermarking

- Video watermarking refers to embedding watermarks in a video sequence in order to protect the video from illegal copying and identify manipulation

1. Algorithm for video watermarking : 1. DFT 2. DCT 3. DWT

Types of watermark

1. **Robust watermarking:** A robust watermark is a watermark that is difficult to remove from the object in which it is embedded.
2. **Fragile watermark:** A fragile watermark is destroyed if anybody attempts to tamper with the object in which it is embedded.
3. **Visible watermarking:** A visible watermark is immediately perceptible and clearly identifies the cover object as copyright-protected material, much like the copyright symbols
4. **Invisible watermarking:** An invisible watermark is not normally perceptible, but can still be used by the rightful owner as evidence of data authenticity in a court of law.

Q. 5 c) Write short note Content Based Image Retrieval.

Content-based image retrieval, also known as query by image content (QBIC) and content-based visual information retrieval (CBVIR), is the application of computer vision techniques to the image retrieval problem, that is, the problem of searching for digital images in large databases Content-based image retrieval is opposed to traditional concept-based approaches. Content-based" means that the search analyzes the contents of the image rather than the metadata such as keywords, tags, or descriptions associated with the image. The term "content" in this context might refer to colours, shapes, textures, or any other information that can be derived from the image itself. CBIR is desirable because searches that rely purely on metadata are dependent on annotation quality and completeness.

Having humans manually annotate images by entering keywords or metadata in a large database can be time consuming and may not capture the keywords desired to describe the image. The evaluation of the effectiveness of keyword image search is subjective and is not been well-defined. In the same regard, CBIR systems have similar challenges in defining success. Keywords also limit the scope of queries to the set of predetermined criteria.

Potential uses for CBIR include: Architectural and engineering design ,Art collections, Crime prevention, Geographical information and remote sensing systems, Intellectual property, Medical diagnosis, Military, Photograph archives, Retail catalogues etc.

Q.5 a) compare the characteristics of first & second order derivative filters.

I. First Order Derivative

i) First order derivative shows non-zero response on the onset of grey level step / ramp.

ii) It is non-zero along ramp.

iii) The response is zero in the area of constant grey level.

II. Second Order Derivative

i) Response of 2^{nd} order derivative is zero in flat areas

ii) Response is non-zero at the onset of grey level step or ramp.

iii) Response is zero along ramp of constant step.

The intermediate image is

$$\begin{bmatrix} 2 & -1+j & 0 & -1+j \\ 3 & 1-2j & -1 & 1+2j \\ 3 & j & 1 & -j \\ 3 & 1 & 3 & 1 \end{bmatrix}$$

Now get DFT of each column of this matrix to get 2D DFT.

Use same butterfly diagram for calculating DFT. ~~of~~ of $\begin{bmatrix} 2 & 3 & 3 & 3 \end{bmatrix}$ ← first column.

$\quad f(0) \; f(1) \; f(2) \; f(3)$

$g(0) = f(0) + f(2) = 2 + 3 = 5$

$g(1) = f(1) + f(3) = 3 + 3 = 6$

$h(0) = f(0) - f(2) = 2 - 3 = -1$

$h(1) = f(1) - f(3) = 3 - 3 = 0$

$\cancel{F(0)} =$

$F(0) = g(0) + g(1) = 5 + 6 = 11$

$F(2) = g(0) - g(1) = 5 - 6 = -1$

$F(1) = \cancel{g}h(0) + h(1) = -1 + 0 = -1$

$F(3) = h(0) - h(1) = -1 - 0 = -1$

∴ DFT of first column is $[11, -1, -1, -1]$

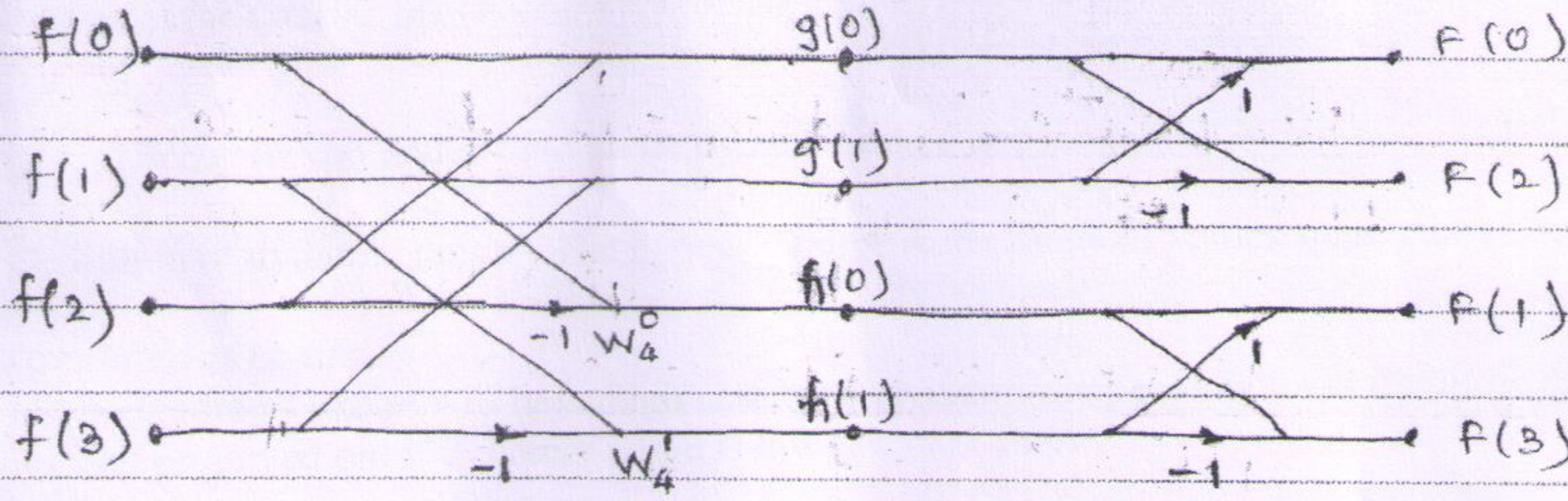
Similarly get DFT of all other columns of intermediate image & final 2D DFT of given image using DIF-FFT is as given below.

$$\begin{bmatrix} 11 & 1 & 3 & 1 \\ -1 & -3 & -1+4j & 1 \\ -1 & -3+4j & -1 & -3-4j \\ -1 & 1 & -1-4j & -3 \end{bmatrix}$$

a]. Find 2D DFT of given image using DIF-FFT algorithm. (6)

$$f(x,y) = \begin{bmatrix} 0 & 0 & 1 & 1 \\ 1 & 2 & 0 & 0 \\ \cancel{8}1 & 0 & 1 & 1 \\ 2 & 0 & 1 & 0 \end{bmatrix}$$

Draw 4-point butterfly diagram using DIF-FFT.



From the diagram, For the first row, calculate DFT.

First row $= \begin{array}{cccc} [0 & 0 & 1 & 1] \\ f(0) & f(1) & f(2) & f(3) \end{array}$.

$g(0) = f(0) + f(2) = 0 + 1 = 1$

$g(1) = f(1) + f(3) = 0 + 1 = 1$

~~g(2)~~

$h(0) = f(0) - f(2) = 0 - 1 = -1$

$h(1) = [f(1) - f(3)](-j) = (0-1)-j = j$

$F(0) = g(0) + g(1) = 1 + 1 = 2$

$F(2) = g(0) - g(1) = 1 - 1 = 0$

$F(1) = h(0) + h(1) = -1 + j$

$F(3) = h(0) - h(1) = -1 - j$

DFT of first row is $[2 \quad -1+j \quad 0 \quad -1-j]$

Similarly get DFT of all the other rows to get intermediate image.